

THE CHILEAN CASE ON IMPROVING POWER TRANSMISSION WITHIN THE NON-CONVENTIONAL RENEWABLE ENERGIES PARADIGM

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Abstract: Although global discussions about climate change and transitioning to clean energy have focused on the development of non-conventional renewable energy ("NCRE") like solar and wind generation, this new energy paradigm also presents challenges to states' power transmission systems. This article first proposes a theoretical framework for analyzing the regulatory effectiveness of transmission sector regulations in light of challenges posed by growing NCRE generation. Next, it analyzes key regulations of the Chilean electricity sector as a case study—arguably one of the most successful cases of NCRE development in the Americas—and assesses the effectiveness of those regulations on facilitating NCRE development and solving contemporary transmission challenges in Chile. From this analysis, the article distills lessons, including the importance of developing a strong transmission system with the support of a regulatory framework that promotes NCRE development through long-term national energy policies and other forward-looking regulations.

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I. INTRODUCTION

Climate change and the need to drastically reduce carbon emissions together present one of the most serious challenges to the electricity sector.[1] One widely accepted approach to climate change mitigation is to reduce fossil fuel generation use, and in recent years, the global share of renewable electricity generation has grown at an exponential rate.[2] For example, between 2011 and 2021, global solar capacity increased by 27.9%[3] and global wind capacity increased by 14.1%.[4] Given this growth, the electric generation sector is cited globally by scholars as an example of decarbonization success,[5] "and sometimes as the only energy sector for which the future path seems clear."[6]

Yet despite many countries' environmental awareness of the need for decarbonization and the explosive growth of renewable energy internationally, fossil fuel demand is also expected to grow significantly.[7] Global coal use, for example, is projected to increase more than all renewables combined in 2021 and 2022 and to cause "a rise in emissions of almost 5%, or 1500 Mt [metric megatons]"[8] and reverse "80% of the drop in 2020 [emissions], with emissions ending up just 1.2%

1. Valérie Masson-Delmotte et al., SUMMARY FOR POLICY MAKERS: GLOBAL WARMING OF 1.5°C. AN IPCC SPECIAL REPORT ON THE IMPACTS OF GLOBAL WARMING OF 1.5°C ABOVE PRE-INDUSTRIAL LEVELS AND RELATED GLOBAL GREENHOUSE GAS EMISSION PATHWAYS, IN THE CONTEXT OF STRENGTHENING THE GLOBAL RESPONSE TO THE THREAT OF CLIMATE CHANGE, SUSTAINABLE DEVELOPMENT, AND EFFORTS TO ERADICATE POVERTY (2018), https://www.ipcc.ch/site/assets/uploads/sites/2/2022/06/SPM_version_report_LR.pdf.

2. BRITISH PETROLEUM, STATISTICAL REVIEW OF WORLD ENERGY 44 (2022). Among the most remarkable growth rates of renewable energy generation in 2021 are Argentina (32.8%), Chile (30.3%), Saudi Arabia (301.7%), Israel (30.3%), and Vietnam (135.5%), among others. *Id.*

3. *Id.* at 46.

4. *Id.* at 47.

5. Hugh Rudnick & Constantin Velásquez, *Transmission Investment and Renewable Integration*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 417, 417-18 (Mohammad Resa Hesamzadeh et al. eds. 2020).

6. *Id.* at 418; *Cf.* Clemens Gerbaulet et al., *European Electricity Sector Decarbonization under Different Levels of Foresight*, RENEWABLE ENERGY, Oct. 2019, at 973, 981 (providing recent research on the challenges of full decarbonization in the electricity power sector).

7. INT'L ENERGY AGENCY, GLOBAL ENERGY REVIEW 2021: ASSESSING THE EFFECTS OF ECONOMIC RECOVERIES ON GLOBAL ENERGY DEMAND AND CO2 EMISSIONS IN 2021 2-3 (2021), https://iea.blob.core.windows.net/assets/d0031107-401d-4a2f-a48b-9eed19457335/GlobalEnergyReview2021.pdf.

8. *Id.* at 2.

(or 400 Mt) below 2019 emissions levels."[9] Therefore, the challenge, both worldwide and in Chile, is to develop regulatory approaches to sustain the growth of renewable energy and to secure a fast-paced transition toward a clean energy matrix in all economic sectors.[10]

Many regulatory approaches supporting this new non-conventional renewable energy ("NCRE") paradigm[11] focus on electric power generation, often leaving aside the transmission and distribution sectors.[12] It has been argued that new energy challenges must be addressed comprehensively, with regulatory schemes that include all parts of the electricity system, particularly transmission.[13] To achieve decarbonization in the power sector for any country, the whole grid must be modernized, including "uptake, transmission, distribution, off-take, [and] metering,"[14] while taking into account the unique political and geographical considerations of that country.[15] For example, the importance of the power transmission sector to NCRE transition has been the subject of many recent discussions in Europe.[16]

Existing literature evaluates the Chilean NCRE phenomenon from perspectives that do not fully grasp Chile's regulatory approach to transmission.[17] This

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9. *Id. Cf.* Horacio Andres Aguirre-Villegas & Craig H. Benson, *Expectations for Coal Demand in Response to Evolving Carbon Policy and Climate Change Awareness,* ENERGIES*,* May 19, 2022, at 1, 18 (noting that some scholars foresee that "[c]oal's predominance in the energy matrix has reached a peak, and a decline in coal demand is expected after 2024 and will continue in the future. The decline of coal's share will accelerate as China focuses on carbon neutrality goals, the U.S. re-engages in the Paris Agreement and implements new climate legislation, the E.U. progresses towards its emission reduction targets, and India moves to a lower-carbon future. Coal demand should diminish greatly by 2060, when China meets its carbon neutrality goal").

10. David García Howell, POLICY BRIEF ON TRADE AND ENVIRONMENT NO. 13: ARE WE ADVANCING IN THE TRANSITION OF THE ENERGY MATRIX IN LATIN AMERICA? ANALYSIS AND CONSIDERATIONS 3, 13 (2021), www.kas.de/energie-klima-lateinamerika ("The term 'energy matrix' can be defined as the combination of diverse primary energy sources used to satisfy the energy needs in a geographic region.").

11. For the purposes of the analysis presented in this article, NCRE refers to renewable energy generators whose primary energy source is solar radiation, wind power, hydraulic energy, biomass, geothermal energy, and energy generated from the sea, as defined in the Chilean legislation. *See* Law No. 20257, Introduce Modificaciones a la Ley General de Servicios Eléctricos Respecto a la Generación de Energía Eléctrica con Fuentes de Energías Renovables no Convencionales, Marzo 20, 2008, DIARIO OFICIAL [D.O.] (Chile).

12. *See* Thomas Sattich, *Electricity Grids: No Decarbonization without Infrastructure*, *in* DECARBONIZATION IN THE EUROPEAN UNION 70 (Claire Dupont & Sebastian Oberthür eds., 2015) ("discuss[ing] the role of electricity transmission infrastructure for the integration of renewables into the European power system in the context of the EU's decarbonization goals," and the relatively low attention that this issue has been given compared to other renewable energy transition issues).

13. *Id.*

14. *Id.* at 75.

15. *Id.*

16. Eckehard Tröster et al., EUROPEAN GRID STUDY 2030/2050 (2011); Till Kolster et al., *The Contribution of Distributed Flexibility Potentials to Corrective Transmission System Operation for Strongly Renewable Energy Systems*, 279 APPLIED ENERGY 115870 (2020); Rolando A Rodriguez et al., *Transmission Needs across a Fully Renewable European Power System*, 63 RENEWABLE ENERGY J. 467 (2014); Philipp Staudt et al., PREDICTING TRANSMISSION LINE CONGESTION IN ENERGY SYSTEMS WITH A HIGH SHARE OF RENEWABLES (2019).

17. Juan Carlos Osorio-Aravena et al., *The Impact of Renewable Energy and Sector Coupling on the Pathway toward a Sustainable Energy System in Chile*, 151 RENEWABLE AND SUSTAINABLE ENERGY REVS. 111557 (2021).

article fills that gap by assessing the effectiveness of Chilean regulations on promoting and integrating NCRE through transmission development, identifying the most successful regulatory approaches in the Chilean transmission sector that enabled the development of NCRE, and distilling lessons to be considered in other countries' regulatory frameworks.

First, the article frames the transmission discussion by analyzing the challenges of the NCRE energy transition and proposing a framework for reviewing the regulatory effectiveness of transmission regulations. Next, in section III, the article presents Chile as a case study, including its energy matrix and the unique regulatory framework of its NCRE-friendly electricity market. Section III also evaluates the regulatory effectiveness of Chile's transmission regulations, its level of NCRE integration, and its current energy challenges. Finally, in section IV, the article offers some lessons distilled from the Chilean case study to inform the development of a general legal framework that can promote a transmission sector compatible with the NCRE paradigm and the requirements of our global energy transition.

II. A Framework for Analyzing Regulatory Effectiveness: Contemporary Challenges of Electricity Transmission

Transmission systems play a significant role in integrating NCRE development but face numerous challenges to their expansion, from planning complexities or pricing disputes, to outdated regulatory frameworks.[18] This section offers a framework for analyzing the effectiveness of transmission regulations by presenting the challenges encountered by transmission systems around the world to promote NCRE growth and integration and categorizing them for later use in the article.

A. Transmission Planning Challenges

One of the most pressing challenges of expanding electric power transmission is the need for holistic investment planning and coordination.[19] As Professors Hesamzadeh of the KTH Royal Institute of Technology and Vogelsang of Boston University explain, currently, the "operation and investment decisions of the transmission and distribution network have been placed under the control of regulators

18. Rudnick & Velásquez, *supra* note 5, at 418.

19. Notice of Proposed Rulemaking, Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection, 87 Fed. Reg. 26,504 (2022) [hereinafter Notice of Proposed Rulemaking]. See also Barbara Tyran, A Transmission Boom is Needed to Realize the Inflation Reduction Act's Benefits, and It Will Pay for Itself, UtilityDive (Oct. 6, 2022), https://www.utilitydive.com/news/transmission-boom-clean-energy-benefits-inflation-reduction-act/633156/. *See* Modernizing the Electric Grid: State Role and Policy Options, NAT'L CONF. OF STATE LEGISLATURES, https://www.ncsl.org/research/energy/modernizing-the-electric-grid-state-role-and-policy-options.aspx.

and system operators,"[20] which could be public or private actors.[21] The involvement of these actors, among other factors, adds complexity to the goal of efficient generation and transmission investment coordination,[22] or — in other words — the "determination of the optimal capacity, sequence and timing of transmission network investments,"[23] resulting in what is often described as "the transmission planning problem."[24]

Another transmission planning challenge is the intermittency of NCRE sources, which has altered the needs of many countries' grids.[25] In response, transmission expansion planning must adapt by anticipating the changing availability of NCRE along with other factors, including the increasing deployment of energy storage and the continued growth in electricity demand.[26] For example, in New Zealand, the increasing development of dispersed solar and wind generation is challenging the country's "long-accepted institutional structure for electricity production and delivery"[27] by promoting generation decentralization as well as the inclusion of economically feasible storage solutions.[28] Although New Zealand's transmission network is considered to be presenting "signs of stress,"[29] and to be "close to the limit of [its] existing capabilities,"[30] the country is responding by changing its regulations, for instance, to allow the development of "[b]attery storage of energy directly with the grid."[31]

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20. M.R. Hesamzadeh et al., *An Introduction to Transmission Network Investment in the New Market Regime*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 1, 1 (Mohammad Resa Hesamzadeh et al. eds. 2020).

21. REGUL. ASSISTANCE PROJECT, ELECTRICITY REGULATION IN THE US: A GUIDE 9, 10 (2011), https://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-electricityregulationintheus-guide-2011-03.pdf.

22. *Id.*; *see also* Carlos Matamala et al., *The Value of Network Investment Coordination to Reduce Environmental Externalities When Integrating Renewables: Case on the Chilean Transmission Network*, ENERGY POL'Y, 2019, at 251, 253 (2019) (discussing how "the benefits associated with coordination of network investments among new entrants (and also incumbent market participants) in terms of the saving in both investment costs and socio-environmental costs related to new network expansions needed to connect coming renewable generators").

23. Hesamzadeh et al., *supra* note 19, at 1.

24. *Id.*

25. *Id.* at 2.

26. Qingyu Xu & Benjamin F. Hobbs, *Transmission Planning and Co-Optimization with Market-Based Generation and Storage Investment*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 201, 201-2 (Mohammad Resa Hesamzadeh et al. eds. 2020).

27. Lewis Evans, *Practical Experiences with Transmission Investment in the New Zealand Electricity Market*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 523, 554 (Mohammad Resa Hesamzadeh et al. eds. 2020).

28. *Id.*

29. Zhiguo Zhang et al., *Overview of the Development and Application of Wind Energy in New Zealand*, ENERGY AND BUILT ENV'T, 2022, at 1, 10.

30. *Id.*

31. Evans, *supra* note 25, at 554.

Many countries have considered new transmission planning adaptations in response to NCRE intermittency challenges.[32] One transmission adaptation proposal is to optimize the use of national grids by developing dynamic and efficient use of existing transmission capacity limits.[33] For example, NCRE such as solar and wind farms have greater flexibility than traditional power plants and can adjust their size and output due to their modular constructability.[34] In other words, these type of plants have the ability to scale up or down within a broader geographical range because they are composed of many smaller units, meaning that they can be vastly dispersed across a country's territory where needed.[35]

However, widely distributed generation presents its own challenges and requires improved coordination among generation, transmission, and distribution systems.[36] Because NCRE plants must be located where the primary resource (i.e., wind, sun) is technically feasible to collect, transmission infrastructure must effectively respond to new generation demands scattered throughout a country's territory.[37] NCRE investors and transmission planners must consider these new variables and plan further ahead, which adds additional complexity compared to the planning processes of traditional fossil fuel power plants.[38] If done thoughtfully, however, transmission expansion and NCRE growth can be mutually beneficial.[39] For example, Professor Wolak from Stanford has illustrated in an Alberta, Canada case study that "[t]he expected economic benefits associated with Alberta's transmission expansion policy were also found to be significantly larger with a larger share of intermittent wind generation in the system."[40]

In light of these challenges, some countries have recognized the need for holistic transmission planning reform.[41] A recent case of proposed regulatory reform of regional transmission planning in the United States is the Federal Energy Regulatory Commission's (FERC) proposed rule to address planning for long-term transmission investment to address NCRE generation challenges.[42] Among other changes, the proposal specifically envisions more extensive long-term regional transmission planning and improved coordination and transparency for regional

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32. Thomas-Olivier Léautier, *Regulated Expansion of the Power Transmission Grid*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 69 (Mohammad Resa Hesamzadeh et al. eds. 2020).

33. *Id.* at 72-73.

34. Rudnick & Velásquez, *supra* note 5, at 418. *See* Peter Mark Jansson & Richard A. Michelfelder, *Integrating Renewables into the US Grid: Is It Sustainable?*, 21 ELEC. J. 9, 13 (2008).

35. Rudnick & Velásquez, *supra* note 5, at 418.

36. *Id.*

37. *Id.*

38. *Id.* at 418-19.

39. Frank A. Wolak, *Transmission Planning and Operation in the Wholesale Market Regime*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 101, 122 (Mohammad Resa Hesamzadeh et al. eds. 2020). *See generally* Frank A. Wolak, *Measuring the Competitiveness Benefits of a Transmission Investment Policy: The Case of the Alberta Electricity Market*, ENERGY POL'Y, 2015, at 426.

40. *Transmission Planning and Operation in the Wholesale Market Regime*, *supra* note 36, at 122.

41. Notice of Proposed Rulemaking, *supra* note 19.

42. *Id.* at 26,506; *see* Eric L. Christensen, *FERC Proposes Reforms to Transmission Planning and Cost Allocation; Will Interconnection Reform Be Next?*, THE NAT'L L. REV. (May 4, 2022), https://www.natlawreview.com/article/ferc-proposes-reforms-to-transmission-planning-and-cost-allocation-will.

and local transmission planning to address needs driven by the increases of renewable energy in the resource mix and corresponding changes in demand.[43]

In summary, countries must enhance their transmission planning and grid operations to face challenges posed by the new global energy transition toward NCRE. As illustrated by the Chilean case below, this includes novel regulatory approaches that promote effective development of transmission infrastructure and investments in the whole transmission grid, including areas with NCRE potential.[44]

B. The Need for Increased Flexibility

To respond to the variable character of NCRE,[45] countries' power sectors need to develop more flexibility in operation, planning, and regulation.[46] For example, the massive growth of NCRE in electric power systems demands new ways of developing expansion-planning models.[47] These models are generally created by the specific entity in charge of "deciding which equipment should be selected, where it should be installed, and . . . the best time to install it,"[48] in the power generation, transmission and distribution sectors.[49] For example, when considering reliability in its expansion-planning models, regulators or other entities may need to conduct studies to predict power availability during peak load periods, which becomes more difficult with the increase in NCRE deployment.[50]

In the United States, policymakers have taken different steps to address this load prediction issue.[51] One example is the response to the duck curve phenomenon in California and elsewhere, particularly in states that have increasing deployment and operation of solar power plants.[52] This phenomenon demands innovative

43. Notice of Proposed Rulemaking, *supra* note 19, at 26,506.

44. Rudnick & Velásquez, *supra* note 5, at 418.

45. R.P. O'Neill, *Transmission Planning, Investment, and Cost Allocation in US ISO Markets*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 171, 178 (Mohammad Resa Hesamzadeh et al. eds. 2020).

46. *Id. at* 178-79; *see* Marco Nicolosi, *Wind Power Integration and Power System Flexibility–An Empirical Analysis of Extreme Events in Germany under the New Negative Price Regime*, ENERGY POL'Y, 2010, at 7257; *see also* Hannele Holttinen et al., *The Flexibility Workout: Managing Variable Resources and Assessing the Need for Power System Modification*, IEEE POWER AND ENERGY MAG., 2013, at 53.

47. O'Neill, *supra* note 42, at 174.

48. M. Majidi & R. Baldick, *Definition and Theory of Transmission Network Planning*, *in* 79 TRANSMISSION NETWORK INVESTMENT IN LIBERALIZED POWER MARKETS 17, 19 (Mohammad Resa Hesamzadeh et al. eds. 2020).

49. Qixin Chen et al., *Power Generation Expansion Planning Model towards Low-Carbon Economy and Its Application in China*, 25 IEEE TRANSACTIONS ON POWER SYSTEMS 1117, 1117–19 (2010); *see* Alireza Soroudi & Mehdi Ehsan, *A Distribution Network Expansion Planning Model Considering Distributed Generation Options and Techo-Economical Issues*, 35 ENERGY 3364, 3364 (2010).

50. Chen et al., *supra* note 46, at 1117-19.

51. *See* Richard Schmalensee, Competitive Energy Storage and the Duck Curve, ENERGY J., 2022, at 1.

52. *Id.* The "duck curve" refers to the phenomena that "increased penetration of behind-the-meter solar photovoltaic (PV) generation . . . would depress net demand in the middle of the day and increase ramping requirements in the late afternoon." *Id.*

solutions to increase the entire grid's flexibility, including the development of energy storage rules for participation in wholesale markets,[53] which could mitigate power variations and increase grid flexibility.[54] Thus, increased NCRE power generation capacity must be paired with new regulatory approaches to incentivize solutions that ensure grid stability.[55]

If planned for and constructed at the scale needed, increased transmission capacity could serve as a "primary source of flexibility for the power system,"[56] and enable "sharing of the most economic and flexible resources across the power system, key for a secure operation under varying flow patterns."[57] This ability to rely on resources across the system could lead to avoidance of serious curtailments, because additional transmission capacity would be available at critical periods.[58]

C. Challenges in Increasing Transmission Infrastructure Capacity and Extension

In the coming years, the vast majority of transmission expansion projects in many countries will be focused on increasing the transmission grid's capacity to respond to NCRE needs.[59] Because renewable energy generation must be located where the primary energy resource resides, they must be placed in geographic areas which are frequently far from the load centers.[60] Consequently, well-planned transmission line expansion that can serve as common infrastructure for multiple renewable generation projects is economically beneficial for both load centers and NCRE generation hubs.[61] These transmission grid extensions address variability

53. John Kosowatz, *Energy Storage Smooths the Duck Curve*, 140 MECHAL. ENG'G 30, 35 (2018); *see* Paul Dunholm et al., OVERGENERATION FROM SOLAR ENERGY IN CALIFORNIA: A FIELD GUIDE TO THE DUCK CHART 27 (2015); *see also* Alexander J. Headley & David A. Copp, *Energy Storage Sizing for Grid Compatibility of Intermittent Renewable Resources: A California Case Study*, ENERGY J., 2020, at 117310.

54. Said O. Amrouche et al., *Overview of Energy Storage in Renewable Energy Systems*, 41 INT'L J. OF HYDROGEN ENERGY 20914, 20914 (2016).

55. Notice of Intent, Building a Better Grid Initiative to Upgrade and Expand the Nation's Electric Transmission Grid to Support Resiliance, Reliability, and Decarbonization, 87 Fed. Reg. 2769 (2022).

56. Rudnick & Velásquez, *supra* note 5, at 418; *see also* Sattich, *supra* note 12, at 72 (explaining how "the larger, more flexible and diverse a power pool is, the better a network can be stabilized").

57. Rudnick & Velásquez, *supra* note 5, at 418.

58. Kolster et al., *supra* note 16, at 313. *See* Sattich, *supra* note 12, at 72 (explaining how electricity grids must be optimized with interregional power lines providing system operators with the flexibility needed to keep the network stable despite local load changes); *cf.* F.F. Wu et al., *Transmission Investment and Expansion Planning in a Restructured Electricity Market*, 31 ENERGY 954, 961 (2006). However, the difficulty is striking an appropriate balance, because an overbuilding of transmission capacity could also be expensive and economically inefficient. *Id.*

59. Léautier, *supra* note 32, at 75.

60. Rudnick & Velásquez, *supra* note 5, at 418. "Load centers" refer to a particular geographical area where a relevant amount of power is consumed. *Id.*

61. *Id.*

by absorbing additional NCRE generation and meeting changing load requirements.[62] This type of "proactive transmission planning"[63] optimizes major investments "to connect remote areas with high renewable generation potential with load demands."[64]

For example, Brazil has promoted a proactive transmission planning approach.[65] Under the guidance of governmental authorities, private developers of NCRE are in charge of developing plans to interconnect their projects with existing networks.[66] When NCRE developers want to build generation projects, they have to present a technical plan to government authorities that includes the connection demands of their projects and how they intend to cover the associated costs.[67] Placing the responsibility on private developers has ensured that they plan ahead for the interconnection of NCRE in remote areas, and those additional resources allow distribution companies to "ease their capacity burden."[68]

Another useful example is Texas's regulatory approach to promote renewables through improved transmission infrastructure within its state borders.[69] The Competitive Renewable Energy Zone (CREZ) legislation enacted in Texas was a success in facilitating the "access to low-cost wind energy."[70] The 2005 legislative amendments to the Texas Utilities Code imposed a mandate to the Public Utility Commission of Texas to define "competitive renewable energy zones in areas with strong renewable-energy resources and 'develop a plan to construct transmission capacity necessary to deliver to electric customers, in a manner that is most beneficial and cost-effective.'"[71] This policy resulted in "an increase of 11,553 MW of capacity at a cost of over $6.5 billion" over six years.[72] Federal and state governments in the United States continue to consider multiple approaches to increase

62. Tom Brown et al., *Optimising the European Transmission System for 77% Renewable Electricity by 2030*, IET RENEWABLE POWER GENERATION, 2015, at 1, 2; *see* Rodriguez et al., *supra* note 16, at 476 (in the European case, transmission network should be multiple times stronger in capacity to support a fully renewable energies power matrix).

63. Alexandre Moreira et al., *Reliable Renewable Generation and Transmission Expansion Planning: Co-Optimizing System's Resources for Meeting Renewable Targets*, 32 IEEE TRANSACTIONS ON POWER SYSS. 3246, 3247 (2016).

64. *Id.*

65. Marcelino Madrigal & Steven Stoft, TRANSMISSION EXPANSION FOR RENEWABLE ENERGY SCALE-UP: EMERGING LESSONS AND RECOMMENDATIONS xv (2012) available for download at https://openknowledge.worldbank.org/handle/10986/9375.

66. *Id.* at 26.

67. *Id.*

68. *Id.*

69. Madeline Claire Gould, Everything's Bigger in Texas: Evaluating the Success and Outlook of the Competitive Renewable Energy Zone (CREZ) Legislation in Texas v (Aug. 2018) (M.A. thesis, University of Texas at Austin) (on file with Texas ScholarWorks, University of Texas Libraries).

70. *Id.* at 43. *See* R. Ryan Staine, *CREZ II, Coming Soon to a Windy Texas Plain Near You: Encouraging the Texas Renewable Energy Industry through Transmission Investment*, 93 TEX. L. REV. 521, 524, 532 (2014).

71. Staine, *supra* note 70, at 529-28 (quoting Tex. Util. Code Ann. § 39.904(g) (West 2007)).

72. *Id.* at 524. *See* PUB. UTIL. COMM'N OF TEX., COMPETITIVE RENEWABLE ENERGY ZONE PROGRAM OVERSIGHT: CREZ PROGRESS REPORT NO. 14 10 (2014).

transmission expansion, including planning and permitting reforms, partnerships and coordination, and cost allocation initiatives.[73]

In summary, NCRE challenges demand countries to innovate, create new regulatory frameworks, and supply the transmission sector with effective tools to adapt to significant generation mix changes. The following sections analyze the Chilean case, assess the aptitude and efficacy of its energy sector regulations, and distills recommendations and lessons for transmission frameworks elsewhere in the world.

III. THE CHILEAN CASE

This section begins with brief comments on the Latin American perspective on NCRE and delves into the case study of the Chilean electric power transmission sector and regulations, including its existing legal framework and whether its regulations have effectively addressed NCRE challenges. Next, this section identifies continuing challenges to fully ensuring a successful energy transition in the Chilean transmission sector.

A. Why is the Chilean Case Relevant?

Latin America is experiencing a faster increase in carbon dioxide emissions per capita than "the rest of the world."[74] The need to promote and facilitate the construction and operation of NCRE generation is essential to the region, and Latin American countries are responding to the challenge.[75] According to the United Nations Economic Commission for Latin America and the Caribbean, by 2018, Latin America was "a world leader in RE [renewable energy], since it reached almost 28% of total energy consumption, while the world average remained at 18%."[76] Since 2010, the largest increase in NCRE share of the energy matrix within the region has been in "Brazil, Mexico, Chile, and Uruguay."[77]

Chile is a relevant case study because it exemplifies a developing country which has experienced a dramatic change to its power generation matrix in the last decade, despite continuing challenges to NCRE development.[78] The country has moved from a highly polluting and concentrated energy industry, where four companies accounted for 90% of the electricity generation, to being one of the leading

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73. Liza Reed et al., HOW ARE WE GOING TO BUILD ALL THAT CLEAN ENERGY INFRASTRUCTURE? CONSIDERING PRIVATE ENTERPRISE, PUBLIC INITIATIVE, AND HYBRID APPROACHES TO THE CHALLENGE OF ELECTRICITY TRANSMISSION 1, 5–6, NISKANEN CENTER (2021), https://www.niskanencenter.org/wp-content/uploads/2021/08/CleanEnergyInfrastructure_Report_08.19.21.pdf.

74. Christian Washburn & María Pablo-Romero, *Measures to Promote Renewable Energies for Electricity Generation in Latin American Countries*, 128 ENERGY POL'Y 212, 212 (2019).

75. *Id.*

76. *Id.* at 213.

77. *Id.* at 221.

78. Clemente Pérez Errázuriz, Normas y Políticas Públicas Destinadas Al Crecimiento de Las Energías Renovables En Chile, REVISTA DE DERECHO AMBIENTAL, 2020, at 9-11.

NCRE generation countries, with multiple companies undertaking NCRE projects.[79] "Chile has been recognized as a world leader among emerging markets for enabling and using sustainable energy."[80]

According to scholars from the LUT University of Finland, Chile has several characteristics that make it a useful case study for studying NCRE regulations.[81] According to the Chilean national inventory on GHG emissions, by 2018, the energy sector represented 77% of the country's total GHG emissions,[82] and "Chile [was] one of the first countries to . . . announce its commitment to reach carbon neutrality by 2050."[83] The amount of renewable power powering the grid "has exceeded by 3.8 times the mandatory target set by the government."[84] However, there is still a long way to go—despite having among the "best solar and wind . . . resources" worldwide,[85] the country has only used "less than 1% of [its renewable energy] potential for electricity generation."[86]

Chile has adopted multiple regulatory approaches to promote NCRE, such as "net metering, certificate system, and grid access, as well as some fiscal incentives for rural areas in electricity production."[87] Among the most relevant regulations for this case study analysis is the establishment of a renewable energy target through an increasing mandatory quota under Law 20.257/2008, which is the first

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79. *Id.* at 9, 10.

80. Osorio-Aravena et al., *supra* note 17, at 2.

81. *See id.* at 2–3 (explaining some of the relevant criteria in detail).

82. MINISTRY OF ENVIRONMENT OF CHILE, INFORME DEL INVENTARIO NACIONAL DE CHILE 2020: INVENTARIO NACIONAL DE GASES DE EFECTO INVERNADERO Y OTROS CONTAMINANTES CLIMÁTICOS 1990-2018 15–17 (2021), https://unfccc.int/sites/default/files/resource/7305681_Chile-BUR4-1-2020_IIN_CL.pdf.

83. Palma Behnke R., et al., CHILEAN NDC MITIGATION PROPOSAL: METHODOLOGICAL APPROACH AND SUPPORTING AMBITION 13, MITIGATION AND ENERGY WORKING GRP. (2019), https://mma.gob.cl/wp-content/uploads/2020/03/Mitigation_NDC_White_Paper.pdf.

84. Osorio-Aravena et al., *supra* note 17, at 2.

85. *Id.* at 3.

86. *Id.* at 2, 13, 77 (reasserting that an energy system based on a 100% of renewable energies is technically and economically feasible in the Chilean case by 2050). According to these authors, Chile has a great potential, and it has been "found that a fully sustainable energy system for Chile could be achieved by 2050 mainly based on three vital elements (from a technological point of view) and three key enablers (from a cost-optimal point of view)." *Id.* at 13. Specifically, the three elements refer to: "high levels of renewable-based electrification across all sectors;" flexibility, through a "combination of electricity exchanges through the grids and the coupling of the sectors;" and "sustainable fuels production." *Id.* Moreover, "the three key enablers . . . to [maintain] a fully sustainable energy system are: solar PV technology, zonal interconnection and full sectoral integration." *Id. See* Yeliz Simsek et al., *Review and Assessment of Energy Policy Developments in Chile,* ENERGY POL'Y, 2019, at 87, 88; Rodrigo A. Escobar et al., *Estimating the Potential for Solar Energy Utilization in Chile by Satellite-Derived Data and Ground Station Measurements*, SOLAR ENERGY, 2015, at, 139.

87. Simsek et al., *supra* note 86, at 97; *see* Pérez Errázuriz, *supra* note 78, at 28; *see also* IRENA, RENEWABLE ENERGY IN LATIN AMERICA 2015: AN OVERVIEW OF POLICIES 16 (2015), available for download at https://www.irena.org/publications/2015/Jun/Renewable-Energy-in-Latin-America-2015-An-Overview-of-Policies ("Certificate systems are based on the principle of fixing a quota (absolute or relative) of electricity from renewable energy sources that subject parties (e.g. generators, distributors, consumers) must meet. This is achieved by creating a tradable renewable energy certificate system, where renewable energy producers are awarded certificates according to their production. Producers can then sell those certificates to subject parties who redeem them to meet their quota requirements. The specific design elements are particular to each jurisdiction, including items such as eligible technologies, compliance periods, bankability, etc.").

Latin American statute to establish a quota system and requires electricity generation companies to comply with a 10% annual renewable energy production quota.[88] This law deployed multiple regulatory tools to diversify the Chilean energy matrix and promote NCRE by allowing for different ways to fulfill that quota, including buying certificates from another company with an excess amount of NCRE generation.[89] This quota percentage was later increased to a requirement of 20% NCRE generation by 2025,[90] through one and two percent annual increases,[91] serving as an important "supportive system for clean energies."[92] Compliance by the regulated sector was a success because the quotas were met by every major company.[93] Yet some scholars have argued that the quotas were too low to be a real incentive to the development of renewable energy in the country and could have been set higher.[94]

Chile has also established electric market rules that promote NCRE.[95] For example, the country eliminated minimum power selling amounts in energy markets under Law No. 19,940/2014, which opened energy markets to small NCRE and promoted their economic feasibility.[96] The law allowed these smaller generators to sell energy "with a surplus power of less than 20 MW"[97] and exempted them—totally or partially—from paying the power transmission service toll through the main transmission lines of the network under certain generation limits.[98] Chile also established a new power bidding system under Law No. 20,018/2005, which required electric power distribution companies to secure their electric power supply through a more competitive bidding process, including long-term supply contracts with a maximum 15-year duration.[99] These reforms pro-

88. Sophie Von Hatzfeldt, *Renewable Energy in Chile: Barriers and the Role of Public Policy*, COLUM. J. OF INT'L AFF. (2013); Tania Varas et al., *Evaluation of Incentive Mechanism for Distributed Generation in Northern Chile*, 14 IEEE LATIN AMERICA TRANSACTIONS 2719, 2719 (2016); Cristián Flores-Fernández, *The Chilean Energy "Transition": Between Successful Policy and the Assimilation of a Post-Political Energy Condition*, INNOVATION: THE EUR. J. OF SOC. SCI. RES., 2020, at 173, 179.

89. Pérez Errázuriz, *supra* note 78, at 15.

90. Varas et al., *supra* note 88, at 2719.

91. *See* Law No. 20968, Propicia la ampliación de la matriz energética, mediante fuentes renovables no convencionales, Octubre 22, 2013, Diario Oficial [D.O.] (Chile).

92. Miguel Saldivia & Matías Guiloff, *3 Key Policies behind the Development of Solar Energy in Chile*, *in* GREEN BANKING 665, 666 (Jörg Böttcher ed., 2020).

93. Pérez Errázuriz, *supra* note 78, at 17.

94. *Id.*; *see* MINISTRY OF ENERGY, *MINISTRO JOBET ANUNCIA NUEVA META: "LAS ERNC REPRESENTARÁN EL 40% DE LA MATRIZ AL 2030,"* (2021), https://energia.gob.cl/noticias/nacional/ministro-jobet-anuncia-nueva-meta-las-ernc-representaran-el-40-de-la-matriz-al-2030 (explaining that in June 2021, the previous Minister of Energy announced it would present a bill to the Congress to increase the quota to 40% which to this date has not been done).

95. *The Legal Framework for Renewable Energy in Chile*, LEXOLOGY (2019), https://www.lexology.com/library/detail.aspx?g=88f2a68e-4da7-421d-8986-41016e2f6274.

96. Enrique Benítez et al., *Chile – A Clean Energy Powerhouse* (Jan. 14, 2019), https://www.globalenergyblog.com/chile-a-clean-energy-powerhouse/.

97. Von Hatzfeldt, *supra* note 88.

98. *Id.*

99. Miriam Grunstein et al., *Energy and Natural Resources*, 41 INT'L LAW. 491, 504 (2007).

moted NCRE investments by giving generators the chance to sign long-term contracts with more stable prices.[100] This power bidding system law was later amended by Law No. 20,805/2015, which, among other changes, extended the duration of the supply contracts up to 20 years, facilitated financing of NCRE projects, and permitted energy generators to offer NCRE energy during smaller chunks of time, instead of compromising to supply 24 hours of the day, so that solar projects, for example, did not have to supply during the night as well.[101] The amendments were a success and resulted in substantial energy price reductions, increased competition, and diversification of NCRE generation.[102] The two power auctions following the enactment of these amendments resulted in a 40% decrease in energy prices, with an increasing number of energy offers in the following years.[103]

One of the most remarkable characteristics of the Chilean approach toward NCRE is that the country has been able to successfully promote NCRE largely without using fiscal incentives, subsidies, or feed-in tariffs ("FITs").[104] Rather, the Chilean government developed a holistic regulatory approach to promote the transition to NCRE, as further discussed below.[105]

As a result of the government's actions, the NCRE generation percentile in Chile's electrical matrix grew from 5% in 2014 to over 20% by 2020.[106] This positioned Chile as the second most attractive country for energy transition investment in the world in 2021.[107] Even though the country's GHG emissions are expected to peak in 2027,[108] because of Chile's high dependency on external energy sources like natural gas or coal,[109] its power generation companies are on the path

100. Benítez et al., *supra* note 96.

101. Pérez Errázuriz, *supra* note 78, at 19.

102. Saldivia & Guiloff, *supra* note 92, at 656. *See* Hugh Rudnick & Andrés Romero, *Hacia Un Modelo En Competencia: Licitaciones de Suministro Eléctrico*, *in* REVOLUCIÓN ENERGÉTICA EN CHILE 413, 425 (Máximo Pacheco ed., Universidad Diego Portales First ed. 2018).

103. CHILEAN MINISTRY OF ENERGY, NUEVA LEY CHILENA DE LICITACIÓN DE SUMINISTRO ELÉCTRICO PARA CLIENTES REGULADOS: UN CASO DE ÉXITO 80 (2017), https://www.cne.cl/wp-content/uploads/2017/08/Libro-Licitaciones-de-Suministro-El%C3%A9ctrico.pdf.

104. Simsek et al., *supra* note 86, at 97; Pérez Errázuriz, *supra* note 78, at 11; Osorio-Aravena et al., *supra* note 17, at 2; IRENA, RENEWABLE ENERGY POLICY BRIEF: CHILE 3 (2015), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_RE_Latin_America_Policies/IRENA_RE_Latin_America_Policies_2015_Country_Chile.pdf?la=en&hash=304E17839F669D9E62CD40C68391A31364F97892#:~:text=Chile%20has%20a%20target%20to,10%25%20renewable%20electricity%20by%202024.

105. Pérez Errázuriz, supra note 78, at 11.

106. *Id.* at 29; Raúl O'Ryan et al., Renewable Energy Expansion in the Chilean Power Market: A Dynamic General Equilibrium Modeling Approach to Determine CO2 Emission Baselines, 247 J. CLEANER PROD. 119645, 1 (2020); ASOCIACIÓN DE GENERADORAS DE CHILE, REPORTE ANUAL 2020 44 (2021), available for download at http://generadoras.cl/documentos/reportes-anuales/reporte-anual-2020.

107. *Results*, CLIMATESCOPE BY BLOOMBERNEF (2022), https://global-climatescope.org/results/.

108. MINISTRY OF ENVIRONMENT OF CHILE, *supra* note 82, at 12-13; Osorio-Aravena et al., *supra* note 17, at 2-3.

109. Pérez Errázuriz, *supra* note 78, at 13–14; Flores-Fernández, *supra* note 88, at 33. *See* Osorio-Aravena et al., *supra* note 17, at 10 fig. 9; Simsek et al., *supra* note 86, at 90 fig. 3. In fact, in December 2020, the 99.3% of the Chilean electric system had "an installed generation capacity of 26,310 MW, of which 49% corresponds

toward decarbonization, including through committing to early decommissioning and no more new coal plants.[110]

However, challenges remain in Chile's path toward decarbonization. The Chilean energy system structure has been subject to a range of critiques, including allegations of excessive centralization and privatization.[111] There are also socio-political hurdles to overcome.[112] According to Professors Carrasco and Rosner from the University of Chicago, Chilean society remains divided and inconsistent on energy and environmental policy matters, and because of this political problem, the country has not been able to fully satisfy its energy needs from its own vast renewable natural resources.[113] As discussed in the next section, this article dissents from these critiques and presents clear evidence—such as a successful long-term energy policy—proving that both the Chilean government and civil society have reached a virtuous cycle toward the development of NCRE.

Setting aside these hurdles, energy projects in Chile still face multiple institutional and regulatory barriers, which lie beyond the scope of this article.[114] The most pressing hurdles include, for example, long processing times for administrative permits including an environmental impact statement (EIA), difficulties in securing rights to land or water resources (e.g., securing land easement agreements if the land to be occupied is owned by the Chilean state, and local opposition to project development).[115] Indeed, local opposition to a project could delay its EIA and even prevent its approval,[116] although the opposition has typically focused on fossil fuel projects.[117]

B. *The Chilean Electricity Transmission Sector*

This section analyzes the Chilean transmission sector regulatory framework by identifying the most influential statutes and regulations and then evaluating

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to thermoelectric power plants, 25.9% to hydroelectric power plants, 9.6% to wind power plants, 13.6% to solar photovoltaic power plants, and 1.9% to biomass, geothermal and cogeneration power plants." ASOCIACIÓN DE GENERADORAS DE CHILE, *supra* note 106, at 43.

110. Pérez Errázuriz, *supra* note 78, at 13–14.

111. Flores-Fernández, *supra* note 88, at 173; O'Ryan et al., *supra* note 106, at 2; Osorio-Aravena et al., *supra* note 17, at 3.

112. Flores-Fernández, *supra* note 88, at 174.

113. Camila Carrasco & Robert Rosner, *The Chilean Electricity Sector Confronts Climate Change*, BULL. OF THE ATOMIC SCIENTISTS, 2017, at 395, 395.

114. Shahriyar Nasirov et al., *Assessment of Barriers and Opportunities for Renewable Energy Development in Chile*, ENERGY SOURCES, PART B: ECONS., PLANNING, AND POL'Y, 2016, at 150, 154.

115. Shahriyar Nasirov et al., *Investors' Perspectives on Barriers to the Deployment of Renewable Energy Sources in Chile*, 8 ENERGIES 3794, 3805-7 (2015).

116. Sebastián Huneeus et al., *Delayed and Approved: A Quantitative Study of Conflicts and the Environmental Impact Assessments of Energy Projects in Chile 2012–2017*, SUSTAINABILITY, 2021, at 1, 11.

117. Javiera Barandiarán & Sebastián Rubiano-Galvis, *An Empirical Study of EIA Litigation Involving Energy Facilities in Chile and Colombia*, ENV'L IMPACT ASSESSMENT REV., 2019, at 2-3, 8 (2019). One of the most renowned NCRE cases that has suffered strong local opposition is the wind farm 'Parque eólico Chiloé', which would be installed in the south of Chile, and has faced constant opposition for over a decade. *See* Jaime Garrido et al., *Les Respostes Socials a La Instal· Lació de Parcs Eòlics: El Cas Del Conflicte Mar Brava a La Illa Gran de Chiloé (Xile)*, 15 PAPERS 547 (2015).

their effectiveness in integrating NCRE. From there, the next section presents lessons and recommendations from this Chilean case study for transmission regulatory frameworks addressing NCRE growth and integration throughout other parts of the world.

The analysis begins with a few words of caution. This article aims to evaluate the impact of Chilean laws and regulations on its generation mix, but as the Chilean energy lawyer Pérez Errázuriz explains,[118] when measuring a regulatory measure's success on promoting NCRE, it is difficult to isolate the aggregate effect of one measure over another measure or factor, especially in light of cost decreases accelerated by technological innovation.[119] Additionally, this section only identifies the relevant regulations on the Chilean transmission sector from recent decades rather than historically, and limits discussion to those regulations that have played an important role in securing the transition to NCRE.[120]

C. *Regulatory Framework*

According to Professors Rudnick and Velásquez from the Pontifical Catholic University of Chile,[121] the modern regulatory transmission framework in Chile is characterized by several factors: the inclusion of scenario planning processes, by combining "predictive, explorative, and normative" scenarios;[122] development of spare capacity to ensure a robust transmission expansion;[123] flexibility in the transmission sector;[124] simplification of the "transmission cost allocation" methods;[125] the development of new "spatial transmission planning and siting" instruments, with a prominent state role;[126] and "open access to the transmission system" for renewable generation.[127] The success of the framework itself is due in large part to the Ministry of Energy's support of NCRE, the development of Chile's long-term energy policy, and a new transmission law designed to adapt the transmission

118. Pérez Errázuriz, *supra* note 78, at 30.

119. *Id.*

120. Enzo Enrique Sauma Santis, *Políticas de Fomento a Las Energías Renovables No Convencionales (ERNC) En Chile* (2012); Carlos Rodríguez Delgado, *Las Energías Renovables No Convencionales (ERNC) En Chile*23–28 (June 2018) (B.S. final degree project, Universidad de Sevilla); Javiera Soledad Turra Cid, *Energías Renovables No Convencionales: Mecanismos de Incentivo Para Su Inserción En El Mercado Eléctrico* (October 2019) (L.L.M. thesis, Universidad del Desarrollo Facultad de Derecho); Cristóbal Ricardo Muñoz Barañao, *Un Modelo de Expansión de La Red de Transmisión Eléctrica Compatible Con El Crecimiento de Las Energías Renovables No Convencionales En Chile* (July 2011) (M.S. thesis, Pontificia Universidad Católica de Chile); Daniel Alfonso Celis Rioseco, *Conexión de Energías Renovables No Convencionales Al Sistema Eléctrico* (2011) (Diploma in Engineering report, Pontificia Universidad Católica de Chile).

121. Rudnick & Velásquez, *supra* note 5, at 426–42.

122. *Id.* at 426.

123. *Id.* at 428.

124. *Id.* at 428–29.

125. Rudnick & Velásquez, *supra* note 5, at 431-32.

126. *Id.* at 433.

127. *Id.* at 442.

sector to Chile's changing energy matrix.[128] This section briefly discusses each of these three key regulatory pieces and identifies their main characteristics.

1. The Ministry of Energy

The creation of the Ministry of Energy (Ministry) has provided more autonomy to the electric sector within the government, by establishing a specialized authority for the development of innovative and long-term energy policies.[129] The Ministry, created by Law No. 20,402/2009,[130] has the legal mandate to prepare and coordinate plans, policies, and standards for the proper operation and development of the electric sector.[131] From its creation, the Ministry has played a critical role in championing the development of NCRE, and "long-term energy planning in Chile [has] gained momentum and accelerated after [its] establishment."[132]

A recent example of how the Ministry influenced NCRE development is the presentation of its "Just Transition Strategy" in December 2021.[133] This strategy, resulting from extensive participative processes, proposes multiple criteria for the retirement of coal power plants in the country, with the goal of promoting NCRE.[134] Specifically, this strategy delineates a comprehensive approach for the energy transition from fossil fuels to renewable energy, in the electricity, mining, industrial, and transportation sectors, and even in housing.[135]

2. The Ministry's Long-Term Energy Policy

The Ministry's Long Term Energy Policy, developed in three steps, played a decisive role in the integration of NCRE into Chile's generation mix.[136] The first step, called "Energy Agenda: A Country Challenge, Progress for All" (Energy Agenda),[137] recognized that the expansion of the transmission sector is key to the efficient and economic development of NCRE potential in the country.[138] Specifically, the Energy Agenda formally announced the interconnection of the two largest electric subsystems or grids of the country, established an inclusive participation process to decide the regulatory changes to the transmission system, and took

128. Alejandro Vergara Blanco, Regulación Del Procedimiento Concesional Eléctrico. Diagnóstico de Problemas, Actas de Derecho de Energía 401, 401 (2012), Thomas Reuters Legal Publishing. *See also* Law No. 20.402, Crea el Ministerio de Energía, Estableciendo Modificaciones al DL N° 2224, de 1978 y a Otros Cuerpos Legales, Diciembre 3, 2009, DIARIO OFICIAL [D.O.] (Chile).

129. *Id.*

130. Law No. 20.402, *supra* note 129.

131. *See* Law No. 2.224, Crea el Ministerio de Energía y la Comision Nacional De Energía, Mayo 25, 1978, DIARIO OFICIAL [D.O.] (Chile). Modified by Law No. 20.402.

132. Simsek et al., *supra* note 86, at 91.

133. CHILEAN MINISTRY OF ENERGY, ESTRATEGIA DE TRANSICIÓN JUSTA EN EL SECTOR ENERGÍA (2021), https://energia.gob.cl/sites/default/files/documentos/estrategia_transicion_justa_2021.pdf.

134. *Id.* at 7.

135. *Id.*

136. Flores-Fernández, *supra* note 88.

137. CHILEAN MINISTRY OF ENERGY, AGENDA DE ENERGÍA: UN DESAFÍO PAÍS, PROGRESO PARA TODOS (2013), https://energia.gob.cl/sites/default/files/documentos/agenda_de_energia_version_completa_esp.pdf [hereinafter AGENDA DE ENERGÍA].

138. *Id.* at 46.

first steps toward regulatory reforms to adapt the operation of electricity grids for the efficient and safe incorporation of NCRE.[139] The Energy Agenda was the result of extensive dialogue between the Ministry and multiple social, political, parliamentary, municipal, business, NGO, and academic actors, including coordination with universities and other academic entities.[140] After the Energy Agenda was published, the most relevant regulatory reform announced was the development of a bill to pass a new transmission law within one year.[141]

The second step, called "Roadmap 2050: Toward a Sustainable and Inclusive Energy for Chile" (Roadmap),[142] recognized a historical lack of governmental involvement in the long-term strategic planning of energy transmission infrastructure.[143] To address this deficiency, the Roadmap established a 2025 commitment to adapt transmission regulations to eliminate competition barriers in generation, among other guidelines.[144] The Roadmap also emphasized the necessity of improving energy efficiency throughout the whole system to avoid the excessive expansion of transmission infrastructure and its socioenvironmental impacts.[145]

Third, the Ministry presented the "Chilean Energy Policy 2050" (2050 Policy)[146] with the main goal of advancing the country toward sustainable energy, in all its dimensions, based on attributes of reliability, social inclusion, competitiveness, and environmental sustainability.[147] Regarding the transmission sector, the 2050 Policy acknowledges the necessity of a long-term energy plan to guide the adequate and timely development of electricity transmission infrastructure.[148] The 2050 Policy also emphasizes the need to periodically review transmission grid design to respond to the new power system and demand reconfiguration needs driven by NCRE growth.[149] Therefore, besides explicitly addressing the role of NCRE in combatting climate change, the 2050 Policy also recognizes the transmission sector's role in decarbonization and promotes a proactive planning approach to transmission development to support NCRE growth and integration.[150]

139. *Id.* at 61–62.

140. *Id.* at 7.

141. AGENDA DE ENERGÍA, *supra* note 137, at 61.

142. CHILEAN MINISTRY OF ENERGY, HOJA DE RUTA 2050: HACIA UNA ENERGÍA SUSTENTABLE E INCLUSIVA PARA CHILE (2015), https://www.energia.gob.cl/sites/default/files/hoja_de_ruta_cc_e2050.pdf [hereinafter HOJA DE RUTA 2050].

143. *Id.* at 46.

144. *Id.* at 58.

145. *Id.* at 59.

146. CHILEAN MINISTRY OF ENERGY, ENERGÍA 2050: POLÍTICA ENERGÉTICA DE CHILE (2015), https://www.energia.gob.cl/sites/default/files/energia_2050_-_politica_energetica_de_chile.pdf [hereinafter ENERGÍA 2050].

147. *Id.* at 39. *See* Flores-Fernández, *supra* note 88, at 180.

148. ENERGÍA 2050, *supra* note 146, at 65, 104.

149. *Id.* at 97.

150. *Id.* at 71–81.

3. New Electricity Transmission System

As a result of the work in planning and developing the 2050 Policy, and from the participative processes of the Energy Agenda, the Chilean Congress enacted Law No. 20,936/2016 (Electricity Transmission System Law).[151] This new law was designed to adapt the transmission sector to the growth of renewable energy and address other local transmission regulatory problems, such as the intricate process of routing new transmission projects over private land.[152] Notably, it established a new nation-wide transmission system by directing the interconnection of the two largest Chilean electricity systems or grids, as previously envisioned in the Energy Agenda.[153] In doing so, the law led to the establishment of electrical connections between fourteen of the sixteen regions in the country, and has been lauded as "another advantage for attaining a fully sustainable energy system."[154] For example, joining these two grids facilitated the flow of NCRE-generated electricity from the Atacama Desert to the center of the country, which has the highest energy demand.[155]

The new Electricity Transmission System Law also established a new Independent Coordinator of the National Electricity System (*Coordinador Independiente del Sistema Eléctrico Nacional* or Coordinator) in charge of the new National Electric System[156] and of planning new transmission infrastructure.[157] This Coordinator "was conceived as a technical and independent organism [from the Ministry of Energy]."[158] Among its many duties, it is tasked with coordinating

151. Law No. 20936, Establece un Nuevo Sistema de Transmisión Eléctrica y Crea un Organismo Coordinador Independiente del Sistema Eléctrico Nacional, Julio 20, 2016, DIARIO OFICIAL [D.O.] (Chile).

152. Rudnick & Velásquez, *supra* note 5, at 422. *See generally* Rafael Ferreira et al., *The Expansion of Transmission: The Challenges Faced in South America*, 14 IEEE POWER AND ENERGY MAG., 2016, at 54, 60–61.

153. Flores-Fernández, *supra* note 88. The Chilean energy system used to have four independent subsystems or electricity grids, divided according to its geographical location. *Id.* Nonetheless, as planned in the 2014 Energy Agenda, and mandated by Law No. 20,936/2016, by November 2017 the two biggest subsystems or grids were connected, creating the National Electric System (*"Sistema Eléctrico Nacional"* or *"SEN"* for its acronym in Spanish), and representing 99.3% of the national installed capacity. *Id.* These systems were the Northern Interconnected System ("Sistema Interconectado del Norte Grande" or "SING" for its acronym in Spanish) and the Central Interconnected System ("Sistema Interconectado Central" or "SIC" for its acronym in Spanish). *Id.* This interconnection directly addressed the problem of transmission lines expansion to connect renewable energy hubs with energy demand. *Id. See also* Rudnick & Velásquez, *supra* note 5, at 418; Von Hatzfeldt, *supra* note 88, at 205; Javier García Monge & Pamela Delgado Moreno, ANÁLISIS DE BARRERAS PARA EL DESARROLLO DE ENERGÍAS RENOVABLES NO CONVENCIONALES 14, PROGRAME CHILE SUSTANABLE PROPUESTA CUIDADANA PARA EL CAMBIO (2011), https://www.chilesustentable.net/wp-content/uploads/2011/03/Analisis-de-Barreras-para-el-desarrollo-de-ERNC_nov2011.pdf (discussing the challenge to connect renewable energy hubs with demand through the expansion of transmission lines).

154. Osorio-Aravena et al., *supra* note 17, at 31.

155. *Id.*; *see* Flores-Fernández, *supra* note 88, at 183.

156. Law No. 20936, *supra* note 151, at Art. 1, No. 38, Art. 212. *See generally* Flores-Fernández, *supra* note 88, at 182–83.

157. Juan Francisco Mackenna, *Law 20,936: New Power Transmission Systems and New Independent Coordinating Body*, CAREY (Aug 9, 2016), https://www.carey.cl/en/law-establishes-new-power-transmission-systems-and-creates-an-independent-coordinating-body-for-the-national-power-system-law-no-20-936/.

158. Flores-Fernández, *supra* note 88, at 183.

the electricity market—including the economic transactions between the regulated actors,[159] authorizing connection to the transmission systems by third parties,[160] and overseeing the security of the electric system, such as the observance of technical safety requirements.[161] The Coordinator even participates in transmission expansion planning by preparing a proposal at the beginning of each year with transmission segments to be considered in further expansion projects, which are then analyzed by the National Energy Commission along with private actors that bid to develop those segments, and finally approved by the Ministry of Energy.[162]

Additionally, the Electricity Transmission System Law directs the Ministry of Energy to "prepare long-term energy scenarios"[163] and develop "a long-term energy plan" every five years "for different energy scenarios that include expansion of generation and energy demand, in a horizon of at least thirty years."[164] According to the Law, this energy planning process should include a wide range of considerations for possible development scenarios, such as the energy supply and demand projection scenarios, particularly for electricity, the identification of generation development poles,[165] the development of distributed generation, the role of international energy exchanges, and the interaction with environmental policies that have an impact and energy efficiency objectives.[166]

Other key transmission-related elements of this Law include, for example, heightened requirements to justify transmission expansion beyond the already existing reliability and least-cost production factors, such as competitiveness and resiliency benefits, the incorporation of scenario analyses and consideration of spare transmission capacity benefits in long-term transmission planning, and proactive transmission expansion for renewable energy hubs.[167] All of these transmission planning obligations imposed on Chilean governmental agencies "aim[] to select the set of projects that meet future transport needs at the minimum system costs for the planning horizon."[168]

D. How Chilean Regulations Addressed Contemporary Challenges of Electricity Transmission

As previously discussed, transmission development around the world faces multiple challenges, including planning problems, the grid's need for more flexibility, and the electric sector's need for both better investment coordination and

159. Law No. 20936, *supra* note 151, at Art. 1, No. 3, Art. 72-3.

160. *Id.* at Art. 1, No. 3, Art. 72-5.

161. *Id.* at Art. 1, No. 3, Art. 72-6.

162. *Id.* at Art. 1, No. 4, Art. 91.

163. Flores-Fernández, *supra* note 88, at 183.

164. Simsek et al., *supra* note 86, at 87–88. *See* Law No. 20936, *supra* note 151, at No. 3 Art. 83.

165. These development poles, or hubs, are defined in Chilean law as a location with resources for renewable energy power generation, where the use of a unique power transmission system is in the public interest because it is economically efficient for power supply. *See* Law No. 20936, *supra* note 151, at No. 4 Art. 85.

166. *See* Law No. 20936, *supra* note 151, at No. 3 Art. 83.

167. *See* Ferreira et al., *supra* note 152, at 61; Rudnick & Velásquez, *supra* note 5, at 421–22.

168. Fernando Fuentes & Pablo Serra, *Chilean Electric Transmission Regulation: From a Merchant Approach to Central Planning*, ENERGIES, 2022, at 1, 7.

vast increases in transmission capacity and infrastructure.[169] This section evaluates the effectiveness of the Chilean regulatory framework and its ability to address these challenges,[170] and sets the foundation for recommendations proposed in the following section. The discussion begins with identifying specific Chilean regulatory provisions that addressed the contemporary transmission problems identified in the first part of this article and continues with analyses of how those transmission regulations have been implemented.

1. Addressing Transmission Planning Problems

An important power transmission sector goal is "achieving efficient investment"[171] through generation and transmission investment coordination, or seeking the "optimal capacity, sequence and timing of transmission network investments."[172] As discussed below, the way that Chile's transmission investment planning and coordination has unfolded is the product of its particular characteristics, i.e., the Chilean power system promotes a free and competitive market, and the amount of State intervention in the development of the electric market power is limited.[173]

The modern Chilean electric regulatory framework was established by the 1982 "Decree with Force of Law" ("*Decreto con Fuerza de Ley*" or "DFL") No. 4, also known as the "General Law of Electrical Services" ("*Ley General de Servicios Eléctricos*" or "LGSE").[174] This law established two key principles to achieve efficient investment in the electric sector: "(i) the safe and cost-efficient operation of the electricity system, and (ii) the existence of a competitive market in the field of generation-transmission and a price market in the field of distribution."[175] Additionally, the LGSE distinguished between three energy segments: generation, transmission, and distribution, [176] which, as a result, promoted the establishment of separate regulations, and even the privatization and division of State-controlled companies.[177] Indeed, in the early 1970s, two state companies (Endesa and Chilectra) owned 90% of generation, 100% of over 500 Kva transmission, and 80% of distribution.[178] During the 1980s these two companies were divided into multiple companies to operate within one of the specific segments, and by the 1990s the majority of the energy sector was under private control.[179] In

169. *See* Section II.

170. Carrasco & Rosner, *supra* note 113; Osorio-Aravena et al., *supra* note 17, at 77; Simsek et al., *supra* note 86.

171. Hesamzadeh et al., *supra* note 19, at 1.

172. *Id.*

173. Flores-Fernández, *supra* note 88, at 179.

174. *Id.*

175. *Id.*

176. Ronald D Fischer & Pablo Serra, EFECTOS DE LA PRIVATIZACIÓN DE SERVICIOS PÚBLICOS EN CHILE: CASOS SANITARIO, ELECTRICIDAD Y TELECOMUNICACIONES 46 (2004).

177. *Id.* at 43.

178. *Id.* at 42.

179. *Id.* at 43-45.

fact, the LGSE largely left the development of electric projects to the private sector, "with the State playing a role of supervision, referential planning of investments, and analysis and calculation of prices and tariffs."[180]

Additionally, to facilitate modern transmission planning, the new Chilean regulatory framework on transmission and NCRE—which includes the Ministry's three step policy development and the subsequently enacted Electricity Transmission System Law, discussed above—promotes the adoption and formulation of broad and long-term power planning throughout the generation and transmission sector.[181]

Despite having these regulatory structures in place, challenges remain.[182] The demand for enhancing transmission and generation investment coordination persists, especially in linking NCRE hubs to demand centers, which are typically distant from each other in this particularly long country.[183] As some scholars have argued, challenges are not merely geographical, and "economic risks and strategic considerations curb the development of . . . coordinated transmission solutions,"[184] because there are many "difficulties associated to planning, coordination and allocation of the costs and risks of proactive transmission investments."[185]

To aid in overcoming these problems, professors from the University of Chile and Pontifical Catholic University of Chile developed a new study that evaluated the benefits that come from investment coordination on the transmission network.[186] Specifically, they focused on "the land use externalities of the necessary network infrastructure that serves to integrate coming renewable generation"[187] from a socio-environmental perspective.[188] Their results showed that by coordinating new transmission infrastructure, the costs on network investments and land use externalities are reduced by around 21%, compared with a non-coordinated scenario.[189] Specifically, the costs they evaluated included "the network investment monetary cost and the socio-environmental (land use externality) cost associated with new lines (in addition to the cost of operating the power system, i.e. economic dispatch of generation . . .)."[190] The study concluded by calling on network regulators to develop more suitable methods to "recognize land use externalities from various network plans and determine the set of new expansions,"[191] and to create "appropriate mechanisms for coordination of the needed network

180. Flores-Fernández, *supra* note 88, at 179.
181. *Id.*
182. *Id.*
183. Rudnick & Velásquez, *supra* note 5, at 419.
184. *Id.* at 444.
185. *Id.*
186. Matamala et al., *supra* note 22, at 251.
187. *Id.* at 252.
188. *Id.* at 259.
189. *Id.*
190. Matamala et al., *supra* note 22, at 256.
191. *Id.* at 259.

expansions,"[192] including "institutional arrangements,"[193] and "cost-reflective network charges that encourage coordination."[194]

2. Signs of Increased Flexibility

As discussed above, due to the enormous growth of highly variable electric power from NCRE sources, traditional expansion-planning models must be flexible by addressing resilience and reliability.[195] Chilean regulations have adopted different approaches to enhance flexibility within the transmission sector in the face of disruptions from NCRE variability.[196] For example, the three stages of the Long-Term Energy Policy, and the Electricity Transmission System Law, which enacted most of the Policy's vision, promoted the interconnection of the two largest electric subsystems of the country to increase resilience and reliability.[197] Additionally, both the Long-Term Policy and the Electricity Transmission System Law recognized the necessity of greater flexibility by establishing a gradual adaptation of the electricity grid for the efficient incorporation of NCRE, with a proactive planning approach that promotes periodic reviews of the transmission grid design.[198]

Resilience concerns are grave given climate change scenarios that could disrupt wind patterns used by turbines[199] or water availability for hydro-generation.[200] Chile is also prone to earthquakes and other natural disasters, which is a foreseeable factor endangering power supply, so the country's energy policies should be ready to address "quick changes and unexpected disasters."[201] The new Electricity Transmission System Law considers these factors by adding resilience to the benefits that would justify transmission expansion plans.[202]

3. Increasing Capacity and Extension of Transmission Infrastructure

As discussed above in section II.C., to appropriately respond to NCRE generation needs, transmission infrastructure must also expand and increase in capacity. That expansion allows renewable energy hubs to connect with load centers and increases the resilience and flexibility of the grid at the same time.[203] To facilitate that expansion, regulators and the private sector must optimize major investments through a proactive transmission planning approach.[204]

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192. *Id.* at 256.
193. *Id.*
194. Matamala et al., *supra* note 22, at 256.
195. *See* Section II.
196. Matamala et al., *supra* note 22, at 252.
197. Fuentes & Serra, *supra* note 168, at 10.
198. *See* Law No. 20936, *supra* note 151, at No. 3 Art. 83.
199. Simsek et al., *supra* note 86, at 100.
200. Esteban Gil et al., *Addressing the Effects of Climate Change on Modeling Future Hydroelectric Energy Production in Chile*, ENERGIES, 2021, at 1, 19.
201. Simsek et al., *supra* note 86, at 100.
202. Law No. 20936, *supra* note 151, at No. 4 Art. 87 letter a.
203. *See* Section II.C.; Fuentes & Serra, *supra* note 168, at 10.
204. *See* Section II.A.

Chile's Long-Term Energy Policy successfully sets a proactive planning vision.[205] For example, it acknowledges the advantages of the type of adequate and timely development of electricity transmission infrastructure borne from proactive planning.[206] This policy also promotes the inclusion of holistic social and local considerations into the decision-making processes of transmission expansion, through the development of land-use planning.[207] Furthermore, as previously discussed, the 2050 Policy and the new Electricity Transmission System Law together delegated long-term planning duties to multiple agencies, which all clearly recognize the need to expand and adapt transmission infrastructure for NCRE.[208] Moreover, the new Chilean Electricity Transmission System Law incorporated the need to expand and increase the capacity of transmission infrastructure, by incorporating scenario analysis and consideration of spare capacity benefits in long-term transmission planning.[209] Indeed, this law explicitly discusses proactive transmission expansion for renewable energy hubs.[210]

As scholars have thoughtfully observed, transmission expansion and integration of NCRE should also consider "local energy markets and microgrids to provide an alternative for centralized energy production and long-distance energy transmission."[211] Addressing distributed generation and demand-side resources will increase resilience throughout the grid.[212] For example, in 2013, Chile passed Law No. 20,571/2013, which allowed the creation of a net billing scheme for residential power generation,[213] which mandates payment for energy injected from NCRE into the electricity system by customers whose installed capacity is less than 100 kW.[214] Although a full exploration of Chile's distributed generation efforts lies outside the scope of this article, the net billing scheme, enacted to "promote self-consumption and distributed generation, in addition to efficient and environmentally friendly generation," was an integral step to modernizing Chile's grid more broadly.[215]

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205. MINISTRY OF CHILE, LONG TERM ENERGY PLANNING IN CHILE (2018), https://www.irena.org/-/media/Files/IRENA/Agency/Webinars/LTES_IEA-and-Chile/20181128_LTES-CEM-PELP.pdf?la=en&hash=45FC6D46E617F4AB8527E50BC580449189BE77F1.

206. ENERGÍA 2050, *supra* note 146, at 65, 104.

207. *Id.*

208. Flores-Fernández, *supra* note 88, at 183; Simsek et al., *supra* note 86, at 87–88.

209. Law No. 20936, *supra* note 151, at No. 4 Art. 87. *See* Rudnick & Velásquez, *supra* note 5, at 422.

210. Law No. 20936, *supra* note 151, at No. 4 Art. 85. *See* Section II.C.3.

211. Simsek et al., *supra* note 86, at 99.

212. *See* Section III.D.2.

213. David Watts et al., *Potential Residential PV Development in Chile: The Effect of Net Metering and Net Billing Schemes for Grid-Connected PV Systems*, RENEWABLE AND SUSTAINABLE ENERGY REV., 2015, at 1037, 1050. Although there is an ongoing discussion on whether to develop new regulations that allow "time integration periods used in Net Billing schemes to accelerate the residential PV market and incentivize investment in distributed residential PV." *Id.*

214. Varas et al., *Evaluation of a net billing incentive mechanism for distributed generation in Northern Chile*, Symposium on Energy, Efficiency and Sustainability, 2015, at 2.

215. *Id.* at 3.

4. Assessing Chilean Regulatory Effectiveness from its Contemporary Implementation Challenges

Despite the regulatory efforts to promote the growth and flexibility of the transmission network, Chile still needs to develop and build new transmission systems to harness and transport the NCRE produced in remote areas to the largest load centers of the country.[216] Scholars from Universidad Autral de Chile, University of Jaén, and LUT University have estimated that Chile must increase "at least 1.5 times" the existing transmission capacity from the north to the capital, to ensure a sustainable transition through renewable energy.[217] In fact, given the current "plan to decommission all coal-fired power plants by 2040," there will be an increasing demand for more NCRE, especially for solar projects in the north and wind farms in the south of Chile.[218] The country is also planning for "the electrification of cities through electromobility, new heating and air conditioning systems in residences, commerce and industry, as well as the replacement of fossil fuels with green hydrogen,"[219] all of which will also increase NCRE demand.[220]

According to official Chilean governmental data, as of May 2022, there are 263 NCRE power plants in construction, for a total of 4,860 MW.[221] In the twelve months before May 2022, a total of 11,432 MW of power generation projects obtained their environmental permits, which are one the last major permits before beginning construction.[222] These figures show a clear trend of increasing amounts of NCRE generation in Chile's energy mix, which will, in turn, demand more transmission infrastructure.[223]

Despite the policies and regulations set in place by the Ministry of Energy and the Chilean Congress, there is a consensus within the Chilean energy market sector that NCRE generation is growing at a much faster pace than the transmission lines that would be needed to transmit the produced energy.[224] Indeed, although the interconnection of the country's main transmission networks has been successful, "the NCRE spillover trend [or the loss of energy generated due to the inability to transmit it to load] has increased in the last years . . . although with fluctuations explained by the entry into service of lines connecting the locations

216. Osorio-Aravena et al., *supra* note 17, at 17.

217. *Id.* at 14.

218. Rudnick & Velásquez, *supra* note 5, at 419.

219. Jorge Molina Alomar, *Transmisión Eléctrica: Clave Para Aprovechar El Auge de La Generación Limpia, Requiere de Urgente Inversión En Infraestructura Para Evitar La Pérdida de Energía*, PAÍS CIRCULAR (2021), https://www.paiscircular.cl/industria/transmision-electrica-clave-para-aprovechar-el-auge-de-la-generacion-limpia-requiere-de-urgente-inversion-en-infraestructura-para-evitar-la-perdida-de-energia/.

220. MINISTRY OF ENERGY OF CHILE, CARBONO NEUTRALIDAD EN EL SECTOR ENERGÍA: PROYECCIÓN DE CONSUMO ENERGÉTICO NACIONAL 2020 36, 53 (2020), https://energia.gob.cl/sites/default/files/pagina-basica/informe_resumen_cn_2019_v07.pdf.

221. COMISIÓN NACIONAL DE ENERGÍA DE CHILE, REPORTE MENSUAL: SECTOR ENERGÉTICO JUNIO 2022, VOL. NO. 88, 5 (2022).

222. *Id.* at 21.

223. *Id.*

224. Molina Alomar, *supra* note 219; Fuentes & Serra, *supra* note 168, at 9–12.

of NCRE plants to large demand centers."[225] In this sense, the "continued rapid expansion of NCRE absorbed the new [transmission] capacity, recording January 2022 as the highest monthly energy loss on record,"[226] because of bottlenecks and congestion, and the following months with similar loss percentages.[227] As a result, the transmission sector companies are under pressure, and on September 2020, it founded its own trade association to push and lobby for improvements in the coordination required between the key stakeholders to plan and execute transmission projects quickly enough to keep up the pace of NCRE generation increase.[228]

The steps taken by Chilean lawmakers and regulators have supported faster development of new transmission lines. Specifically, there are two major projects in recent years that have benefited from these actions.[229] One project is the upgrade of Cardones-Polpaico, the largest line in the central-north regions of Chile with 468 miles line of 500 kV to increase its resilience and transmission capacity by 85% in five years, as proposed by its controller ISA Interchile.[230] This project was submitted to the National Energy Commission for consideration the first semester of 2021, just one year after the beginning of operations for the initial Cardones-Polpaico transmission line, given the increasing demand from NCRE.[231] It has been argued by its controller that this expansion —if approved— could be built faster than the original project, considering the existing transmission line and the improvements on transmission regulation.[232]

The second project is the construction of the Kimal-Lo Aguirre transmission line, which would run parallel to the Kapatur-Cardones line —already interconnected with the Cardones-Polpaico line.[233] This project was included in the 2017 expansion plans of the Chilean authorities, its adjudication process was completed four years later on December 2021, and it is estimated to enter into operation in ten years.[234] Despite the new regulations, the adjudication process still took four

225. Fuentes & Serra, *supra* note 168, at 10. *See* Molina Alomar, *supra* note 219.

226. Fuentes & Serra, *supra* note 168, at 10. *See* VALGESTA NUEVA ENERGÍA, BOLETÍN INFORMATIVO: AÑO 12 NO. 5, 4 (2022) available for download at https://valgesta.com/inicio/en/noticias/.

227. *See* VALGESTA NUEVA ENERGÍA, *supra* note 226, at 4.

228. *See* Molina Alomar, *supra* note 219; ELECTRICIDAD, NUEVO GREMIO EN EL SECTOR ELÉCTRICO: ASOCIACIÓN DE TRANSMISORES DE CHILE (2020), https://www.revistaei.cl/2020/09/23/nuevo-gremio-en-el-sector-electrico-asociacion-de-transmisores-de-chile/; Jorge Alomar Molina, *Acelerar Los Proyectos de Transmisión Eléctrica, El Principal Desafío Del Nuevo Gobierno Para Impulsar La Transición Energética*, PAÍS CIRCULAR (2022), https://www.paiscircular.cl/agenda-2030/acelerar-los-proyectos-de-transmision-electrica-el-principal-desafio-del-nuevo-gobierno-para-impulsar-la-transicion-energetica/ ("We all have to 'step up the pace.' For the development of the transmission works that decarbonization requires, both good planning and execution with the highest standards are required. In both aspects, the contribution of all authorities, both technical and political, central and local, working hand in hand with the companies, is key.").

229. *See* Molina Alomar, *supra* note 219.

230. *Id.*; VALGESTA NUEVA ENERGÍA, BOLETÍN INFORMATIVO: AÑO 11 NO. 12, 2 (2021), available for download at https://valgesta.com/inicio/en/noticias/.

231. EL DIARIO FINANCIERO, INTERCHILE LANZA PROYECTO PARA AUMENTAR CAPACIDAD DE CARDONES-POLPAICO CON INVERSIÓN DE CASI US $ 1.700 MILLONES (2020), https://acera.cl/interchile-lanza-proyecto-para-aumentar-capacidad-de-cardones-polpaico-con-inversion-de-casi-us-1-700-millones/.

232. *Id.*

233. Matamala et al., *supra* note 22, at 251-52.

234. Fuentes & Serra, *supra* note 168, at 10.

years to be completed, even when transmission development progress in Chile within the next five to ten years is critical for securing the grid's necessary capacity and resilience, and its ability to avoid NCRE spillovers.[235]

According to Professors Fuentes and Serra from the Economy Schools of Diego Portales University and University of Chile, these NCRE curtailments have three potential explanations.[236] First, the new transmission projects are late, "and their implementation was too sparing to avoid RE [renewable energy] curtailments."[237] Second, the "sociocultural variables that have delayed transmission investments," have not been appropriately taken into consideration.[238] Third, the curtailments can simply be attributed to a "lack of capacity in the country to build all the new transmission projects required by the rapid expansion of NCRE."[239]

Their analysis concentrates on the execution timing of transmission expansion projects, and concludes that "[i]mplementation difficulties that systematically delay the start-up of planned works explain" the curtailment of NCRE due to congestion.[240] In particular, "[t]he increasing empowerment of civil society in the decision-making processes of new investments is relevant in explaining delays, especially in approving environmental permits."[241] Accordingly, the authors call for more "realistic timelines"[242] estimates in the planning, bidding, permitting, and execution of transmission projects, and for reducing these timelines by fast-tracking their implementation, especially within stages outside of the sole jurisdiction of energy authorities, such as environmental impact assessment procedures.[243]

In summary, during recent decades, Chile has developed a strong regulatory framework to address some of the most pressing contemporary issues on power transmission and NCRE integration.[244] The country has developed regulatory and policy instruments, assessed above in this article and by other scholars, in three broad analytical categories — transmission planning problems, increased flexibility, and increased capacity and extension of transmission infrastructure.[245] The effectiveness of these regulatory and policy reforms is now being reflected in the changing energy matrix, regulatory compliance, and other statistics discussed above showing how NCRE has thrived in Chile.[246]

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235. *See* ENERGÍA ESTRATÉGICA, CARLOS FINAT: «PROBABLEMENTE ESTEMOS ATRASADOS 5 O 10 AÑOS EN LAS LÍNEAS DE TRANSMISIÓN QUE SE NECESITAN HOY DÍA» (2020), https://www.energiaestrategica.com/finat-advierte-atrasos-en-obras-electricas-que-condicionaran-el-crecimiento-de-las-renovables-en-chile/ ("We are probably 5 to 10 years behind in the lines that are needed today.").

236. Fuentes & Serra, *supra* note 168, at 10.

237. *Id.*

238. *Id.*

239. *Id.*

240. Fuentes & Serra, *supra* note 168, at 13.

241. *Id.*

242. *Id.*

243. *Id.*

244. Fuentes & Serra, *supra* note 168, at 3.

245. *Id.* at 10; *see* Molina Alomar, *supra* note 219.

246. *See* Section III.A.

However, the work is not yet done. The effectiveness of these regulations will be tested by the current transmission network scenario and its expected future trajectory, which reveals an ever-increasing gap between the NCRE generation and the transmission capacity of the country. Indeed, NCRE spillover effects have reached historic numbers in 2022.[247] Therefore, the current regulatory framework will need further improvements to enhance its effectiveness and keep up the pace of NCRE generation, such as addressing the challenges that Fuentes and Serra raised regarding environmental permits and land-use agreements, among others, which lie outside the exclusive domain of energy regulation.[248]

IV. TWO REGULATORY LESSONS

Countries need to develop regulatory approaches that ensure a fast-paced and robust development of NCRE to avoid the catastrophic scenarios posed by climate change.[249] Section II of this article proposed three broad analytical categories to assess the regulatory effectiveness of transmission regulations on integrating NCRE, and Section III focused on Chile's transmission regulations as a case study. Subsequently, the article assessed the regulatory effectiveness of these regulations and their challenges and solutions, including timely implementation of new infrastructure, increase of transmission capacity, grid resilience, and enhanced transmission and generation coordination. Despite the multiple implementation constraints that the Chilean regulatory framework continues to face, this section distills two main lessons from the Chilean case for other countries attempting to develop a regulatory framework for successful NCRE transmission integration.

These lessons are flexible and should be adapted on a case-by-case basis because the ability for these lessons to be extrapolated into another regulatory framework depends on the specific characteristics of the country. For example, each country's unique natural resources and existing environmental conditions could influence the development of specific NCRE. Moreover, the preexisting regulatory and administrative framework could be decisive: for example, in the United States, state policies may be in tension with federal policies regarding planning, permitting, construction, and cost allocation of transmission infrastructure.[250]

A. The First Brick in the Wall: A Comprehensive Long-Term Energy Policy

The first lesson is that the most important regulatory action to promote the development of NCRE is the establishment of a Long-Term National Energy Policy. In Chile, this energy policy was divided into about three stages: an energy roadmap, an energy agenda, and the 2050 energy policy.[251] Each of these policy

247. *See* Fuentes & Serra, *supra* note 168, at 10; *see also* Molina Alomar, *supra* note 219.

248. *See* Fuentes & Serra, *supra* note 168.

249. *Strengthening and Implementing the Global Response*, INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, https://www.ipcc.ch/sr15/chapter/chapter-4/.

250. Reed et al., *supra* note 73, at 2–3; Johannes Saurer & Jonas Monast, *Renewable Energy Federalism in Germany, and the United States*, 10 TRANSNAT'L ENV'TAL L., 293, 297 (2021).

251. Flores-Fernández, *supra* note 88.

stages should be supported by an inclusive and participative process.[252] In Chile, the policy development process incorporated perspectives from every relevant stakeholder in the energy sector, including academics, technicians, companies, and communities.[253]

The Chilean 2050 Policy, established in 2012, is a useful illustration of the importance of a national energy policy because it served many roles at different regulatory stages.[254] First, it served to define national goals, such as the will to favor NCRE over fossil-fueled powered generation and the decision to engage in proactive transmission planning to address NCRE issues.[255] This policy also served as a roadmap to guide the legislative agenda promoted by the Chilean government to tackle the main NCRE transmission issues described in prior sections.[256] This legislative process then resulted in the development of the new Electricity Transmission System Law, which set forth standards for regional grid interconnection, long-term planning obligations, and substantive transmission planning transformations, including the proactive transmission expansion of renewable energy hubs and amendments to the definition of new transmission projects' routes,[257] all to ensure a flexible, resilient, and reliable system.[258]

Indeed, long-term energy policies like the 2050 Policy can have a profound impact on the promotion and growth of NCRE and related transmission infrastructure, particularly when promoted by a high-level agency mandated specifically to address energy issues, like the Chilean Ministry of Energy.[259] Data from the Association of Chilean Energy Generators (*Asociación de Generadoras de Chile)* shows that NCRE generation capacity in the Chilean electrical matrix increased from 5% in 2014 to over 20% by 2020,[260] positioning Chile as the second most attractive country for energy transition investment in the world in 2021.[261] Chile's Long-Term Energy Policy also served as a roadmap for private actors in the power generation sector because it incentivized commitments to early decommission of new coal plants.[262]

In summary, national long-term energy policies can be the first brick in the wall in establishing transformative and progressive regulatory reform to achieve NCRE integration and to build the transmission needed to deploy NCRE. From a regulatory effectiveness lens, a national long-term policy serves as a comprehensive first step to tackle a wide variety of power transmission issues, including most

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252. Fuentes & Serra, *supra* note 168, at 8.

253. *See id.* ("This participatory planning reduces the risks of inefficient expansions by improving electricity generation and consumption forecasts with stakeholders' inputs.").

254. Flores-Fernández, *supra* note 88;. ENERGÍA 2050, *supra* note 146, at 130–37.

255. ENERGÍA 2050, *supra* note 146, at 130–37.

256. HOJA DE RUTA 2050, *supra* note 142.

257. *See* Section III.C.3.

258. Fuentes & Serra, *supra* note 168, at 10.

259. Flores-Fernández, *supra* note 88.

260. Pérez Errázuriz, *supra* note 78, at 29; O'Ryan et al., *supra* note 106, at 1; ASOCIACIÓN DE GENERADORAS DE CHILE, *supra* note 106, at 44.

261. CLIMATESCOPE BY BLOOMBERNEF, *supra* note 107. *See* Section III.A.

262. Pérez Errázuriz, *supra* note 78, at 35.

of the transmission planning problems described in prior sections, like the need for increased grid flexibility and capacity.[263]

Stepping back, however, success with a long-term energy policy and the enactment of innovative laws require political continuity in the policy agenda of successive governments.[264] In Chile, despite their different political factions, the country's multiple Presidential Administrations have maintained a similar policy approach towards NCRE, which has allowed the adoption and implementation of national long-term policies to thrive.[265] Indeed, the Chilean "regulations and public policies promoted have been successful, [because] they show a constant and exponential increase in the participation of these type of sources in the electricity matrix (especially solar and wind) in the short and medium term."[266] However, there is a worldwide need to elucidate how our societies can "accept and use the technological changes," and which and how extensive are the key contemporary barriers "to government policy regarding the energy transition in Chile."[267] Only with that understanding could a more comprehensive and effective approach be shaped for further advances.

B. Toward a New Electricity Transmission System Statute

The second lesson from the Chilean case is the importance of enacting a transmission system-specific statute, or reforming an existing statute to address transmission system concerns more comprehensively.[268] The Chilean case study shows that the adoption of a transmission-specific statute allows governments to enhance grid modernization by incorporating multiple regulatory tools into the transmission sector.[269] For example, the recent Chilean Electricity Transmission System Law facilitated the interconnection of the two largest regional grids in the country, provided for a scenario-based long-term planning approach to transmission grid expansions, and allowed for the consideration of NCRE integration in transmission planning decision-making processes.[270]

To be fully comprehensive, any electricity transmission system statute should explicitly include provisions to resolve the interconnection issues that NCRE face within conventional transmission systems. Some scholars have argued that, in Chile, "there are no clear policies to promote the connection of these projects."[271] On the contrary, the new Electricity Transmission System Law establishes a new transmission legal category called "development poles transmission system" ("*sistemas de transmisión para polos de desarrollo*"), comprised of transmission

263. *See* Section IV.A.
264. Flores-Fernández, *supra* note 88.
265. *Id.* at 178-80.
266. *Id.* at 173-74.
267. Osorio-Aravena et al., *supra* note 17, at 17.
268. *See* Section IV.A. and Section IV.B.
269. *See* Law No. 20936, *supra* note 151.
270. *Id.* at Art. 1, No. 3, Art. 72-6. *See also* Flores-Fernández, *supra* note 88.
271. Saldivia & Guiloff, *supra* note 92, at 666.

lines and electrical sub-stations specially created for these development poles.[272] These development poles, or hubs, are defined in Chilean law as a location with resources for renewable energy power generation, where the use of a unique power transmission system is in the public interest because it is economically efficient for the region's power supply.[273] The Ministry of Energy must identify these development poles within its long-term energy plans and prepare a technical report that includes a strategic environmental impact assessment of the plans that include those development poles.[274] Consequently, the Electricity Transmission System Law established a specific legal entity that mandates the planning of new transmission lines to hubs where NCRE plants would be located.[275]

In summary, the direct promotion of NCRE connectivity to the grid through a comprehensive regulatory approach and a long-term energy policy could be decisive in supporting the exponential growth of NCRE in a country's energy matrix. Such a long-term approach would enhance regulatory effectiveness by establishing the framework to begin solving transmission planning problems, including investment coordination difficulties and how to sufficiently increase transmission infrastructure capacity to address complications arising from increasing NCRE deployment. The development of transmission-specific statutes will also support the need for grid flexibility, because the intermittency and variability of NCRE can be managed more easily with a robust and expansive transmission grid that connects multiple NCRE hubs together with a country's main grid system.

Finally, as previously discussed, the enactment of a statute is not the end, but just the beginning of the path towards effective NCRE transmission systems. Careful attention to the quality of the statute's implementation, such as the timely planning and construction of new transmission infrastructure developed from these reforms, will be essential to determine its effectiveness. In fact, as previously analyzed, it could be possible that major implementation constraints arise from legal and regulatory areas outside of energy regulation, including environmental permitting.[276] Other factors may also impact the effectiveness of a statute, including the multiple interpretations that the actors carrying out the statute might have of the statute's meaning and purpose,[277] or the impacts of court interpretations of the statute under judicial review.[278]

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272. Law No. 20936, *supra* note 151, at No. 4 Art. 75.

273. *Id*. at No. 4 Art. 85.

274. *Id.*

275. *Id.*

276. *See* Section IV.

277. *See generally* Jerry L Mashaw, *Norms, Practices, and the Paradox of Deference: A Preliminary Inquiry into Agency Statutory Interpretation*, 57 ADMIN. L. REV. 501 (2005); Abbe R Gluck & Lisa Schultz Bressman, *Statutory Interpretation from the Inside-An Empirical Study of Congressional Drafting, Delegation, and the Canons: Part I*, 65 STAN. L. REV. 901 (2013); Christopher J. Walker, *Inside Agency Statutory Interpretation*, 67 STAN. L. REV. 999 (2015); Aaron Saiger, *Agencies' Obligation to Interpret the Statute*, 69 VAND. L. REV. 1231 (2016).

278. *See generally* T.R.S. Allan, *Judicial Deference and Judicial Review: Legal Doctrine and Legal Theory*, 127 L. Q. REV. 96 (2011); Wendy Wagner, *Revisiting the Impact of Judicial Review on Agency Rulemakings: An Empirical Investigation*, 53 WM. & MARY L. REV. 1717 (2011).

V. CONCLUSION

This article assessed the regulatory effectiveness of the Chilean electricity transmission sector in the development and integration of NCRE. The article proposed and considered three analytical categories in analyzing transmission challenges: transmission planning problems, the need for increased flexibility, and the need for increased transmission infrastructure capacity and growth. Through these lenses, the article identified key Chilean regulations and policies that influenced the transition toward a more sustainable energy matrix, including a 2050 Long-Term Energy Policy, a new Electricity Transmission System Law, and the resulting interconnection of major regional grids in Chile.[279] Then, through an assessment of the Chilean regulatory framework, the article identified the main continuing challenges of the transmission sector, including how to timely build new infrastructure or upgrade existing infrastructure.

Finally, the article distilled two regulatory lessons. The first lesson is the importance of a long-term energy policy for supporting a transmission sector that integrates NCRE, which should include an inclusive and participatory process that identifies the main priorities, principles, and directives for the electric power sector. This long-term policy can serve as a roadmap to define and legitimize specific regulatory actions to ensure a successful transmission transition and adaptation of NCRE generation. The second lesson is the importance of enacting or reforming a comprehensive electricity transmission system statute. Despite the implementation challenges that emerge after statutory enactment, such a statute would be critical to establishing regional grid interconnections, considering NCRE in the long-term planning, or taking other needed steps to modernize the transmission sector.

In summary, as illustrated by the Chilean case study, the transmission sector has been and will continue to be a protagonist in the renewable energy transition. Countries that fail to recognize the urgency and importance of modernizing their transmission grids and governing regulations could compromise their timely transition to NCRE.

279. Law No. 20936, *supra* note 151, at Art. 1, No. 3, Art. 72-6.