Ministerio de Energía

Gobierno de Chile

PELP

PLANIFICACIÓN ENERGÉTICA DE LARGO PLAZO

DEFINITIVE REPORT

April 22, 2025

MESSAGE FROM THE MINISTER OF ENERGY

DIEGO PARDOW LORENZO

The Long-term Energy Planning is a fundamental public policy instrument to ensure sustainable, resilient and fair development for our country. This tool allows us to connect the most important goals of our sector, presents in our National Energy Policy and our climate commitments, through a prospective process to prioritize and balance decisions in different contexts and under different circumstances.

One of the main results of the PELP is to define and materialize the expansion and optimization in infrastructure that the system will require to materialize the commitments in terms of energy transition.

This instrument allows us to define long-term energy scenarios, electric generation development poles and the projection of energy demand and supply over the next 30 years. It is a live process that is carried out every five years and that can be updated annually, understanding that the energy sector and the transition itself is a dynamic process that is subject to multiple factors that we must constantly analyze.

This process invites us to incorporate economic projections, the effects of climate change, territorial perspectives, technological advances and possible geopolitical changes, all through an active process of citizen participation, inter-institutional work and technical analysis.

This second five-year process incorporates for the first time the definition of Electric Generation Development Poles (PDGE) in the provinces of Antofagasta and Tocopilla, enabling the transmission systems for development poles to promote economies of scale in this area. The determination of the PDGE was carried out with a robust Strategic Environmental Assessment.

The PELP is not an isolated public policy, but is nourished by different sources of information and includes other national instruments, such as the Nationally Determined Contribution (NDC) or the Long-term Climate Strategy (LTCS), which we present every five years to the international community, as well as at the sectoral level it has contributed to the Sectoral Plan for Mitigation and Adaptation to Climate Change in Energy, the Green Hydrogen Action Plan 2023-2030 or the Decarbonization Plan.

This instrument allows us to anticipate the challenges of the future, respond with strategic vision to the needs of our communities and guide investment decisions towards a cleaner, safer and more accessible energy system for all.

Diego Pardow Lorenzo
Minister of Energy

MESSAGE FROM THE UNDERSECRETARY OF ENERGY

LUIS FELIPE RAMOS BARRERA

Continuing to cultivate and strengthen institutions is fundamental for the development of policies with a long-term vision. The Long-term Energy Planning allows us to project in a serious and quantitative manner the energy future of our country, providing the sector with important attributes that facilitate public policy decision making.

Our sector requires certainty in the different time scales, considering that investments require a long-term financial structure in order to materialize.

Defining an energy future with possible concrete routes, built through a participatory process, is what Long-term Energy Planning allows not only the sector, but Chile and its institutions as a whole.

This process, regulated in the General Law of Electrical Services, which today finalizes its second version with the period 2023-2027, has allowed us to project in a synergic way the energy future of the country to guide the development of the necessary infrastructure and, in particular, of the electrical transmission. This policy has a State vision, through a robust and transparent participatory process, which is also complementary to our National Energy Policy and other sectoral instruments of the Ministry of Energy.

This new Long-term Energy Planning is the result of a solid work not only among the teams of the Ministry of Energy, but also with the various public institutions that have been part of it, as well as the general public through various instances throughout its development. We hope that the results of the PELP will also be a contribution to the work of the different key actors in the sector.

The participation of each person throughout this process has been crucial and we highlight the construction of a consensual view and agreements that have allowed us to project the evolution of the energy system, considering the important challenges that our sector is going through.

Luis Felipe Ramos Barrera
Undersecretary of Energy

EXECUTIVE SUMMARY

The Long-term Energy Planning (PELP) is a process established in the General Law of Electric Services (GLES) in its articles 83° to 86°. This process provides projection scenarios of energy supply and demand[1] and in particular electricity, considering the identification of generation development poles, distributed generation, international energy exchanges, environmental policies that have incidence and energetic efficiency objectives among others, elaborating their possible development scenarios. Likewise, the PELP considers within its analysis the strategic plans that the regions have in terms of energy. The PELP 2023-2027 process defined three scenarios: Slow Recovery, Carbon Neutrality and Accelerated Transition, associated to different development narratives of the country and the energy sector, which include external and modifiable factors.

The PELP 2023-2027 process introduces for the first time in the energy sector the Electric Generation Development Poles, which correspond to territorially identifiable areas in the country, located in the regions where the National Electric System (NES) is located, where there are resources for the production of electricity from renewable energies. The use of these resources, using a single transmission system, is of public interest because it is economically efficient for electric supply, and must comply with environmental and land use planning legislation. The PELP 2023-2027 process has identified Antofagasta and Tocopilla as candidate provinces for poles, and included these areas within its supply projection, resulting from the electric modeling process.

The current 2023-2027 process, which corresponds to the second planning of the Ministry of Energy[2] and which formally began on December 28, 2020, included the different stages mandated by the regulations, among them, Registration of Interested Parties, public hearings, publication of preliminary and definitive reports, Strategic Environmental Assessment process for the candidates for poles and the present definitive report. For its completion, the Energy Planning Decree for the period 2023-2027 will be issued, which will define development poles, empowering the National Energy Commission to propose transmission works for them for the first time.

Among the main results of the PELP 2023-2027 are the following:

- The expansion of generation contemplates, in a first stage, and in all scenarios, the development of wind energy in the Taltal area and from Maule to the south. On the other hand, by 2050, in the Carbon Neutrality and Accelerated Transition scenario, solar photovoltaic energy is developed to a large extent, leveraged by

[1] Energy scenario: Scenario that allows supplying the energy demand projection(s) in an efficient manner according to, at least, the current circumstances and expected trends in terms of prices and costs relevant to the sector, physical availability of energy resources, expected energy uses, prospective technological changes, and environmental and territorial conditions. Each scenario must consider an energy supply for such purposes.

[2] The current process is under Decree No. 92, of 2018, of the Ministry of Energy, approves Long-term Energy Planning, period 2018-2022. Available at: https://www.bcn.cl/leychile/navegar?idNorma=1116938&idVersion=2018-04-10

storage, in the northern area. The latter is closely related to the development of green hydrogen in that area.

- Transmission, under all three scenarios, indicates the need to expand capacity in areas with high wind potential. In particular, under the three scenarios, the need to expand the network between the Parinas substations and the Cumbre and Los Changos substations is identified. Likewise, the need to expand the capacity in the section between Alto Jahuel and Río Malleco by about 3,000 MW in a large part of this section within the next 20 years is also identified.
- This last need is aligned with those proposed by the National Energy Commission in its Annual Transmission Expansion Plan 2024, for the HVDC transmission work between Lo Aguirre and Entre Ríos for the same capacity.
- Antofagasta and Tocopilla were identified as candidate provinces for Generation Development Poles, using criteria that respond to the social-environmental-territorial and economic-technological dimensions.
- In the Province of Tocopilla, two renewable generation zones are designed, in the municipalities of Tocopilla and María Elena, with the purpose of compensating the power of the outgoing thermal generation in the municipality of Tocopilla and to be part of the green hydrogen value chain, within the framework of the bioceanic integration.
- In the Province of Antofagasta, three zones are designed, in the communes of Sierra Gorda and Taltal, prioritizing new territories with "site-specific" energy potentials, such as wind and Concentrated Solar Power (CSP), based on a mixed composition of the energy matrix.

On the other hand, regarding the future work of energy planning, some of the main milestones are:

- Publication of the Energy Planning Decree, period 2023-2027, as of July 2025.
- Development of technical studies to improve projections for green hydrogen and distributed generation, as well as methodologies for resilience.
- Formal initiation of the 2028-2032 process by December 31, 2025.
- PELP 2028-2032 participatory process, tentatively between January and April 2026.
- Preparation of the PELP 2028-2032 Preliminary Report between May and July 2026.
- Publication of the Preliminary Report PELP 2028-2032 in August 2026.
- From September 2026, Strategic Environmental Assessment of the candidates for Electric Generation Development Poles.
- In general, the Ministry of Energy will work on improving the procedures and timing of the planning process in order to shorten the total time.

CONTENTS

1. INTRODUCTION

1.1 WHAT IS LONG-TERM ENERGY PLANNING?

The Long-term Energy Planning (PELP) is a process established in the General Law of Electric Services (GLES)[3] in its articles 83° to 86 and regulated by Decree No. 134, of 2016, of the Ministry of Energy, which approves the Long-term Energy Planning Regulation (hereinafter, the regulation).

The PELP is developed by the Ministry of Energy every five years and must include different energy supply and demand expansion scenarios, in a horizon of at least thirty years, and particularly electricity, considering the identification of generation development poles, distributed generation, international energy exchanges, environmental policies that have an impact and energetic efficiency objectives, among others, elaborating their possible development scenarios. Likewise, planning should consider within its analysis the strategic plans that the regions have in terms of energy.

In addition, as it is an ongoing process, the Ministry of Energy may issue in April of each year a Background Update Report (BUR) containing a comparative analysis between the demand projection, macroeconomic scenarios and other background information considered in the energy scenarios defined in the Energy Planning Decree in force and the variables mentioned at the date of the analysis, in order to define and quantify the differences, identify the impact on the energy scenarios of the definitive report and the relevance of updating the relevant background information.

The Electric Generation Development Poles (PDGE) are places prioritized by the Ministry of Energy, with a long-term view, to generate renewable energy, in harmony with the territory and the communities, also promoting local development, enabling key conditions to contribute to the commitments and goals established in strategic instruments, such as the National Energy Policy, the Framework Law on Climate Change and, particularly, the Nationally Determined Contribution (NDC) of Chile, in line with reaching the carbon neutrality goal by 2050 at the latest.

Likewise, the five-year processes of the PELP have three main stages: the definition of long-term energy scenarios, the projections of energy supply and demand, and the Electric Generation Development Poles (PDGE).

1.2 STRATEGIC VISION

The Long-term Energy Planning is an instrument that allows anticipating, through a prospective process, the challenges that, in different time horizons, the energy sector could face. In particular, the projections of energy demand and supply that are the result of each scenario built and defined allow to respond to the needs of people, productive sectors and territories, so as to

[3] Available at: https://www.bcn.cl/leychile/navegar?idNorma=258171

balance and make synergy between economic development, environmental commitments and the needs of society.

This exercise, which is continuous in a five-year process, provides the tools to the Ministry of Energy, its related institutions and the key actors of the sector in general, to guide decision-making and, in particular, possible future investments in energy infrastructure that allow a just, safe and resilient transition, in line with climate goals and State policies that govern the progress of a sector as important as the energy sector, which not only has a job in itself, but is also the engine of development of the whole country, both from the productive point of view and the welfare of people.

It also plays an important role in the identification of new technologies or energy sources, which could make it possible to meet projections or even accelerate the objectives that have been set. However, as in any prospective process, it is essential to constantly review the assumptions and projections that have been made, and therefore the background update stage, as well as the same update every five years of the PELP, allows to strengthen the results and provide greater levels of certainty, also taking into account the limits and gaps that this may mean.

1.3 TRANSMISSION DEVELOPMENT

The PELP is the main input that guides the expansion and development of Electric transmission. The energy scenarios and the projection of the Electric supply outline the reinforcements, expansions and new infrastructure of the electric grid. The following diagram presents the phases of the current energy planning process, as well as the various public and private institutions involved, promoting permanent coordination among them, which has been consolidated in the PELP 2023-2027 process.

electric transmission is fundamental to enable the environmental and climate goals that have been established as a country. The construction of a long-term vision in a participatory manner provides the transmission expansion process with a fundamental input that allows planning the expansion works to be carried out in the short term, in such a way that they are consistent with a medium and long-term vision.

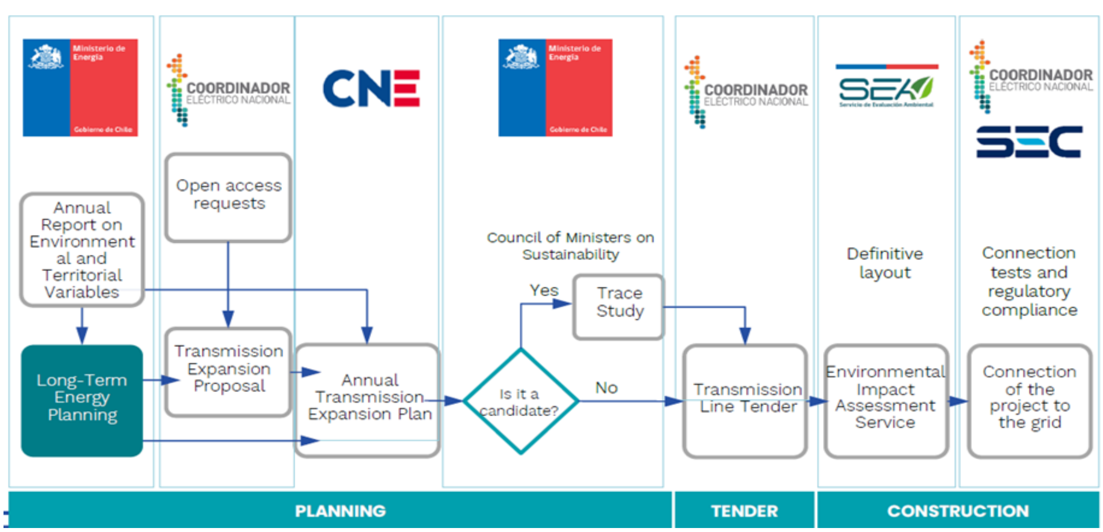


Figure 1: Phases of the current energy planning process and institutions involved.

2. ELABORATION PROCESS

2.1 STAGES

This section summarizes how the different steps of an energy planning process are connected, starting with the long-term energy scenarios and culminating with the impact and infrastructure requirements in order to materialize the energy vision.

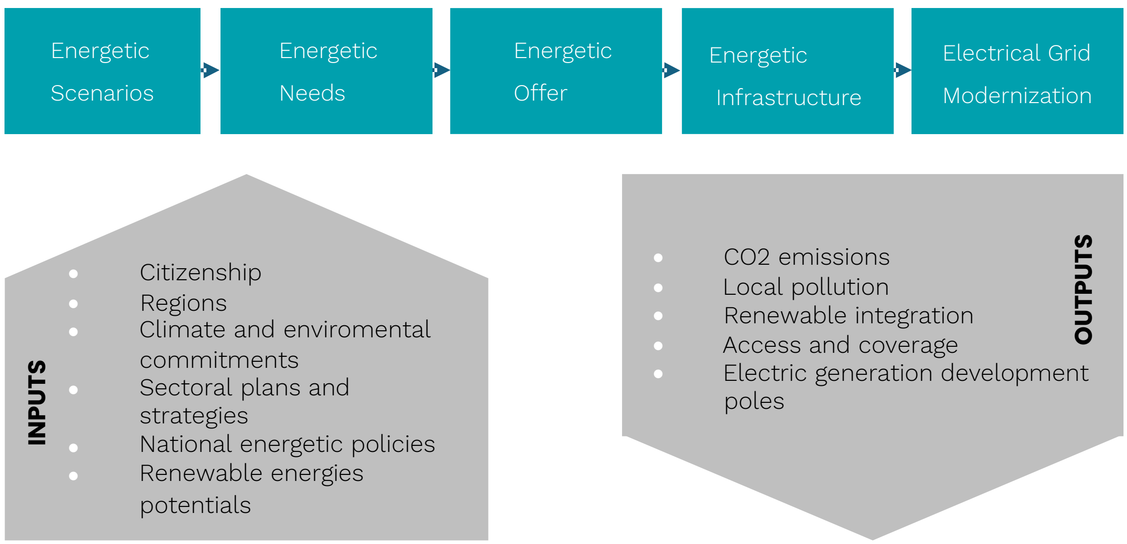


Figure 2: Inputs considered for the construction of the new energy scenarios.

Energy scenarios

They are defined as the scenario that allows supplying the energy demand projection(s) efficiently according to, at least, the current circumstances and expected trends in terms of prices and costs relevant to the sector, physical availability of energy resources, expected energy uses, prospective technological changes and environmental and territorial conditions. Each must consider an energy supply for such purposes.

Thus, the process begins with the definition and joint construction of them, through a technical work together with a participatory process, where the different inputs coming from the citizenship, from the different regional visions and contexts, from climate and environmental commitments at the country level, as well as the sectoral instruments of the Ministry of Energy or its related institutions, must be considered.

In addition, one input is the identification of renewable potentials in the national territory, considering the role that renewable energies play in the energy transition and, therefore, a harmonic process is required in the planning and development of projects.

Energy needs

Once the energy scenarios have been defined, energy planning characterizes and projects the energy needs of society as a whole, both for the short, medium and long term, i.e., the energy uses that will be required by the different sectors of society, aligned with sectoral policies and the country's climate commitments, as well as the development of technologies.

Energy supply

Once the energy demand that will be required by society has been identified, it is necessary to identify and project the energy requirements needed to supply this demand (energy supply) together with the necessary options for supply, such as electricity, fossil fuels, biofuels, low-emission fuels, among others, in a cost-efficient manner.

In order to achieve the country's environmental and climate commitments, a fair, safe and resilient energy transition is essential, not only to reduce local and global emissions levels, but also to provide a reliable and quality energy supply for people and the different productive activities. Thus, one of the objectives of energy planning is to identify the efficient energy supply to meet society's projected energy needs. Energy planning considers all the projected energy uses and all the available energy supply, to then define how much of it will be covered through electricity, allowing to guide the expansion of electric transmission through the projection of the matrix in a defined time horizon, considering its territorial location, capacity and technology.

Energy infrastructure

The process continues with the identification of alternatives for the necessary infrastructure to support such demand, projecting, in an indicative manner, the location of future electric generation projects in the territory and, on the other hand, projecting the infrastructure for electric transmission based on such projects for each of the energy scenarios.

Modernization of the electric grid

The energy planning process allows for an analysis of the different technological alternatives that make it possible to achieve the projected energy future for each of the scenarios. In addition to the different technological options for electric generation, investment alternatives are analyzed to make better use of the existing infrastructure, through the optimization and reinforcement of facilities, as well as the expansion of required works.

Likewise, technological alternatives are analyzed that allow migrating from the operation of the current electric grid to the electric grid that is envisioned for the long-term, understanding that current decisions must enable the expected sustainable development and be consistent with energy projections.

2.2 CITIZEN PARTICIPATION

The General Law of Electrical Services mandates a registry of citizen participation so that any natural or legal person interested in participating in the process can do so.

Thus, the Long-term Energy Planning Regulation[4] defines the guidelines and requirements of the participatory stages, which are essential to generate instances of dialogue and collective reflection, open to citizens, on the opportunities and challenges of the energy sector in a long-term horizon, allowing to address social, environmental, territorial, cultural and technological aspects, in line with the standards of the Ministry of Energy regarding the co-construction of its public policies.

For the PELP 2023-2027 process, the following moments in the participatory process are highlighted[5]:

- Stakeholder registration process[6]: Allows access to all products generated throughout the process, enabling the possibility of making comments on them, which should be duly considered and responded to by the Ministry of Energy.
- Co-construction workshops: Virtual instances of participatory work in which technical aspects were discussed from a citizen perspective.
- Public hearings[7]: First initial hearing for the presentation of the work plan, second hearing to present the progress of the workshops, in addition to the hearings to launch the Preliminary Report and Definitive report.
- Observation to the Preliminary and Definitive reports: As established in the regulations, the Stakeholder Registry can make observations to the Preliminary Report and Definitive report, which should be duly answered and/or considered in the following reports[8].

More information on the participatory and citizen deliberation process of the PELP 2023-2027 has been incorporated in Annex 8.1.

[4] Decree No. 134, of 2016, of the Ministry of Energy. Available at: https://www.bcn.cl/leychile/navegar?idNorma=1098751

[5] More details can be found on the PELP website: https://energia.gob.cl/pelp/proceso-participativo

[6] Exempt Resolution No. 31, of 2020, of the Ministry of Energy, which declares open the registration process of the citizen participation registry of the Long-term Energy Planning process indicated in the General Law of Electric Services, and establishes its terms and conditions. Available at: https://energia.gob.cl/sites/default/files/documentos/1871207.pdf

[7] The material and record of the hearings and workshops is available here: https://energia.gob.cl/pelp/audiencias

[8] The comments and respective responses for both reports are available at: https://energia.gob.cl/pelp/repositorio

3. ENERGY SCENARIOS AND MODELING ENVIRONMENT

3.1 WHAT IS AN ENERGY SCENARIO?

The regulation defines it as a scenario that allows supplying the energy demand projections in an efficient way according to, at least, the current circumstances and foreseen trends in terms of prices and costs relevant to the sector, physical availability of energy resources, expected energy uses, prospective technological changes and environmental and territorial conditions. In addition, each scenario must consider an energy supply for such purposes.

Through the construction of energy scenarios, the aim is to narrow the range of future possibilities, understanding the uncertainty that the next decades represent, and taking into account the commitments and goals, mainly in the energy and climate fields that Chile has acquired in the last time.

Within the framework of the Long-term Energy Planning process, the energy scenarios have the particular objective of guiding the expansion of electric transmission, however, they also allow:

- Design and evaluate new or developing public policies, both in the energy sector and in other related sectors.
- Identify opportunities for the development of innovative technological solutions, in order to take the actions required for their adoption and implementation.
- To survey specific needs of communities and territories throughout Chile regarding the quality of energy services and the development of infrastructure projects.
- Develop additional analyses and studies, both by the Ministry of Energy and other institutions, both public and private.
- Contribute to the design and definition of climate goals, both in the energy sector and others (mining, transportation, infrastructure, among others) or at the national level.

The concept of scenario is widely used by various institutions and agencies related to governmental or international energy issues[9], where an energy scenario provides a conceptual framework for the energy reality under study. A particular case is the National Energy System Operator of Great Britain (NESO), where scenarios point to decarbonization and the social change that this implies, while for the European Network of Transmission System Operators (ENTSO) they are an instrument for defining climate and energy objectives, based on technological preferences and social and economic aspects, both national and local.

[9] International Energy Agency (IEA), International Energy Council (WEC), UK Electric System Operator (ESO), European Network of Transmission System Operators (ENTSO), International Renewable Energy Agency (IRENA), among others.

3.2 CONSTRUCTION OF 2023-2027 SCENARIOS

The energy scenarios were constructed jointly with the Registry of Citizen Participation, in the following round of workshops:

- Workshop 1 - External[10]: Introduction and leveling, illustrative examples and presentation of external factors and their combinations.
- Workshop 2A and 2B[11] - Tensions: Systematization of workshop 1, presentation of modifiable factors and practical work around the stresses involved in the scenarios.
- Workshop 3 - Technical[12]: Presentation of the preliminary scenarios and practical work around the inputs that emerged from the participatory processes.
- Public Hearing 2 - Scenarios[13]: Presentation of the new long-term energy scenarios.

It should be noted that this construction process was carried out during 2021, so it is important to place the general context of that year, marked by the COVID-19 pandemic started in 2020. In addition, this may explain the absence of other issues that have been relevant to the sector, such as the geopolitical context, which emerged after that period.

On the other hand, energy scenarios are built on a list of factors, which are those elements that represent a given characteristic as important and can be classified as external or modifiable, according to the incidence or capacity of influence that society will have on them.

3.3 ENERGY SCENARIOS 2023-2027

On this occasion, the following three (3) long-term energy scenarios were defined: Slow Recovery (SR), Carbon Neutrality (CN), and Accelerated Transition (AT).

Slow Recovery

The economic and social impact of the COVID-19 pandemic, at all levels, translates into a slowdown of the economy and, in particular, of the energy transition. In Chile, given the lower availability of resources, the focus is on economic reactivation and, in energy matters, priority is given to actions aimed at improving the quality of service.

For this scenario, the measures are focused on advancing Chile's commitments and the energy sector to advance in electromobility and energetic efficiency, but a low technological transformation, derived from a slow cost reduction of renewable solutions, translates into an uncertainty for the fulfillment of climate commitments.

---

[10] Developed on May 4, 2021.

[11] Developed on May 11 and 18, 2021, respectively.

[12] Developed on June 8, 2021.

[13] Developed on June 25, 2021.

Carbon Neutrality

Chile, through the Framework Law on Climate Change[14] , has set the commitment to move towards a development low in greenhouse gas (GHG) emissions and other climate forcing, until reaching and maintaining the neutrality of greenhouse gas emissions by 2050, adapting to climate change, reducing vulnerability and increasing resilience to the adverse effects of climate change. Thus, this energy scenario puts at its core the fulfillment of this goal hand in hand with improved global and local economic conditions, as well as a rapid fall in the costs of clean technologies.

In addition, advancing in the regulation of solid biofuels to comply with minimum technical specifications of quality, as provided by Law No. 21,499[15], as well as in new technologies (replacement of heaters or district heating) and the advancement of energetic efficiency measures.

Another relevant aspect of this scenario is the adoption of new technologies that allow reaching higher levels of electromobility, efficiency measures in the productive sectors and the development of the green hydrogen industry.

Accelerated Transition

The rapid economic and social recovery after the COVID-19 pandemic, as well as a broad development of clean technological alternatives, allow the energy transition to be accelerated. With a 100% emission-free electric system by 2050, based on renewable energies and storage systems, an accelerated electrification of consumption is enabled.

Chile deepens the integration of electromobility, the decarbonization of the productive sectors and a broad takeoff of green hydrogen and synthetic fuels, both for domestic consumption and export.

At the residential level, the replacement of heaters, district energy and thermal insulation of homes, allow the transition to new alternatives free of global and local pollutant emissions.

All of the above allows, in this energy scenario, to advance the carbon neutrality goal to 2050, fulfilling it before the legal commitment.

[14] Law No. 21.455. Available at: https://www.bcn.cl/leychile/navegar?idNorma=1177286

[15] Law that regulates solid biofuels. Available at: https://www.bcn.cl/leychile/navegar?idNorma=1183783

3.4 FACTORS

Table 1: Summary of factors by energy scenario PELP 2023 - 2027.

<table>
<tr><th>GROUP</th><th colspan="2">FACTOR</th><th>RECOVERY</th><th>CARBON NEUTRALITY</th><th>ACCELERATED TRANSITION</th></tr>
<tr><td>Cross-cutting</td><td colspan="5">Resilience and adaptation to climate change</td></tr>
<tr><td rowspan="3">External</td><td colspan="2">Economic growth</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="2">Fossil fuel prices</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="2">Decreasing costs of NCRE technologies</td><td>Slow decrease</td><td>Medium decrease</td><td>Rapid decrease</td></tr>
<tr><td rowspan="7">Local and global emissions</td><td colspan="2">Climate GHG mitigation commitments</td><td>NDC and CN 2050 uncertain</td><td>NDC and NC 2050</td><td>NDC and NC advance</td></tr>
<tr><td rowspan="4">Decrease pollution local residential residential</td><td>Dry firewood</td><td>High in urban area</td><td>High in urban area Long-term use decreases</td><td>Substantial decrease in the use of firewood, the remaining is dry</td></tr>
<tr><td>District heating</td><td>Base</td><td>Medium</td><td>High</td></tr>
<tr><td>Replacement of heaters</td><td>Base</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Thermal insulation</td><td>Base</td><td>Medium</td><td>High + net zero buildings</td></tr>
<tr><td colspan="2">Carbon price</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="2">Closure of coal-fired power plants</td><td>Current</td><td>Accelerated</td><td>Accelerated +</td></tr>
<tr><td rowspan="7">New technologies</td><td colspan="2">Electromobility</td><td>Current strategy</td><td>Carbon neutral levels</td><td>Greater than carbon neutral</td></tr>
<tr><td colspan="2">Green hydrogen (H2V)</td><td>Natural trend</td><td>Carbon neutral levels</td><td>Green H2 strategy</td></tr>
<tr><td colspan="2">NES storage</td><td>Medium</td><td>High</td><td>High+</td></tr>
<tr><td rowspan="3">Energy system + decentralized /user user control</td><td>Distributed generation</td><td>Base</td><td>High</td><td>High+</td></tr>
<tr><td>Intelligent demand demand</td><td>Air conditioning management</td><td>EM Time Management Climate management</td><td>Intelligent EM management HVAC management</td></tr>
<tr><td>H2V production</td><td>Low on-grid production Low export</td><td>Medium on-grid production Medium export</td><td>High on-grid production Optimistic export</td></tr>
<tr><td colspan="2">Cost of Gas with Carbon Capture and Storage (CCS)</td><td>High</td><td>Medium</td><td>Low</td></tr>
<tr><td rowspan="2">Energetic efficiency</td><td colspan="2">Efficient use of CCS</td><td>EE Law</td><td>EE+ Act</td><td>EE+ Act and Net zero buildings</td></tr>
<tr><td colspan="2">Efficient use in Transportation, Industry and Mining</td><td>EE Act</td><td>EE+ Act</td><td>EE++ Law High penetration of renewables in thermal/motive uses</td></tr>
<tr><td>International integration</td><td colspan="2">Energy import/export</td><td>Current</td><td>H2+ export</td><td>H2+ and synthetic fuels export</td></tr>
</table>

External factors

External factors correspond to relevant aspects in the configuration of an energy future, so their evolution determines in an important way the energy development in each scenario. They are called external because society as a whole has little capacity to make decisions to strongly influence such a factor in the short term, but can achieve it in the medium or long term. This is the case of national economic growth, expressed through the evolution of GDP; price trends of fossil fuels and the costs of renewable electric generation technologies.

Modifiable factors

These correspond to public decisions and policies that could be adopted as a country and over which society can exert influence. They are a representation of how to react in different scenarios, considering different variables and a context where resources are limited.

1. Operation of the power grid

Focused on the process of closing coal-fired power plants, as well as generation based on other fossil fuels, such as gas and diesel.

The closure of coal-fired power plants is assumed to be a process that can be accelerated depending on the economic conditions of the country and the consequent enabling of new technologies that allow their replacement in the electric system. While the use of natural gas in the electric generation sector is considered for the transition towards less emission-intensive solutions, allowing the replacement of coal, as these plants are withdrawn from the electric system and economic and technological conditions allow it, their participation in the matrix is declining and even, in an optimistic scenario, only the operation of this type of plants with clean fuels and/or with the implementation of emission capture solutions is considered.

2. Local and global emissions

This group of factors includes the reduction of greenhouse gases (GHG), the reduction of local pollution at the residential level and the value of the emissions tax. These are related to the decarbonization of the energy matrix, and improvements to air quality.

Chile is a country that has a solid climate institutional framework through the Framework Law on Climate Change which, among its climate change management instruments, mandates the development of Sectoral Mitigation and Adaptation Plans, among which is the energy plan[16], which are a concrete and sectoral downscaling of national level instruments such as the Nationally Determined Contribution (NDC) or the Long-term Climate Strategy (LTCS), as well as defining the goal of achieving carbon neutrality and climate resilience by 2050 at the latest.

Likewise, the PELP and its results is one of the main inputs of the Energy Sectoral Plan for Mitigation and Adaptation to Climate Change[17], published by the Ministry of Energy in December 2024. In that sense, the results of this instrument, in terms of emissions, are in tune with the analyses presented in this definitive report and process.

Local pollution in the cities of central and southern Chile, due to the consumption of firewood that does not comply with quality specifications, is a priority problem that is

[16] Published in December 2024, the Energy Sectoral Plan for Climate Change Mitigation and Adaptation is available at: https:.//energia.gob.cl/cambioclimatico

[17] More information on the Plan is available at: https://energia.gob.cl/cambioclimatico. Plan available at: https://energia.gob.cl/sites/default/files/documentos/20241213_proyecto_definitivo_plan_sectorial_energia_13_dic.pdf

considered in all scenarios at . Thus, the regulation of the use and commercialization of firewood in the urban areas of the center-south of the country will be included as a base. To the extent that economic and technological conditions allow it, along with a greater impetus from the State to address this challenge, more transformative and innovative actions are considered, such as the development of district heating solutions, replacement of heaters and even the refurbishment of existing homes.

3. New technologies

This includes a more decentralized energy system and a more active role of the user, together with the incorporation and adoption of new technologies. This is a key aspect that facilitates and enables the materialization of climate commitments and the energy transition itself.

The development of emerging technologies such as electromobility, hydrogen and green ammonia, the development of carbon capture, use and storage (CCUS) applications or energy storage systems, together with others that strengthen the reliability of a highly renewable grid, are highlighted. The different technologies are considered to have a greater or lesser level of integration depending on the projected economic conditions of the country, and their international development, as well as the possible impetus of the State as an enabling factor.

The alternative of having a more decentralized energy system with a more proactive role of the user translates into the development of distributed generation, as well as community solutions, both from the point of view of energy demand and production. It also addresses the challenge of hydrogen and green ammonia production in Chile, for which the opportunity for this industry to be developed centrally (3 or 4 production areas), depending on the economies of scale required by an export market, and/or in a more decentralized way, according to the territorial distribution to meet local demand.

4. Efficient use of energy

This refers to the efficient use in commercial, public and residential sectors (CPR) and transportation, industry and mining, as a necessary condition for sustainable productive development. In particular, it considers a growing role of energetic efficiency measures in homes, in line with better economic conditions, derived from the Energetic Efficiency Law (Law No. 21,305), and the relevance in the sector of meeting the energetic needs associated with the thermal demand of homes and productive sectors, mainly in conjunction with a greater availability of new technologies that allow a replacement of thermal and motor uses to clean energies. At the same time, policies and actions are promoted to make an efficient use of energy by minimizing energetic demand through behavioral changes and intelligent demand management.

5. International integration

Establishment of networks, both physical and commercial, of energy infrastructure with international markets that present opportunities for the massive production of clean energies, as well as emission-free synthetic fuels, such as those derived from green hydrogen, where energy exports can be triggered. In line with the considerations regarding the deployment of the hydrogen and green ammonia industry, the export of this energy and its derivatives is included in two scenarios.

The export and exchange of electricity between Chile and its neighboring countries is a constant work in the Ministry of Energy, from a technical, political and strategic perspective. In this case, Planning reviews it as a space of opportunity and security contribution to the future system.

3.5 CHARACTERIZATION BY SECTORS

Scenarios can also be defined according to the different sectors of the economy. For the work of building energy scenarios within the framework of the PELP, the following are considered: electric generation, land, maritime and aviation transportation, industry, which includes cement, steel, paper, among others, and copper mining along with other minerals, and the commercial, public and residential sectors.

Each of these sectors has a particular characterization, according to the trends of the different factors that make up each of the corresponding energy scenarios. Thus, for example, the transportation sector will be clearly defined by the electromobility factor, but also the innovation and development of new technologies that could be deployed in the most optimistic scenarios, for example, with air transportation using synthetic -cleaner- fuels and the maritime sector using green hydrogen as fuel.

Electric generation

For the Slow Recovery scenario, natural gas plants play a key role in replacing electric generation from coal-fired plants that are phased out of the system according to the current schedule, and in the long term contribute greatly to the flexibility required by the system to balance the massive inflow of wind and solar generation.

While, for the Carbon Neutrality scenario, existing natural gas plants continue to operate as they incorporate technologies that significantly reduce their environmental externalities, while coal-fired generation accelerates its exit from operation, given the application of new emissions regulations. There is an increase in the penetration of storage technologies, mainly batteries, providing flexibility functions in the electric system as these technologies become more competitive.

Finally, under conditions of Accelerated Transition, renewable energies, the development of zero-emission synthetic fuels, a greater penetration of storage technologies and an accelerated exit of coal from the electric matrix, allow achieving carbon neutrality in advance. This objective is achieved not only at the centralized level, but also with a strong boost to the development of small-scale distributed photovoltaic technology.

Transportation (land, maritime and air)

In a Slow Recovery, moderate growth of the electric and hybrid vehicle fleet, conducive to the goals established according to the current Electromobility Strategy, influenced by the country's economic conditions and with consumers still very aware of the cost of these technologies.

In the case of Carbon Neutrality, the adoption of light and medium zero-emission vehicles, mainly electric, is a key component towards the goal of achieving Carbon Neutrality. In the case of heavy transport, there are also important levels of penetration of technologies associated with the use of green hydrogen produced in Chile.

And in an Accelerated Transition, modal shift is promoted in terms of greater use of non-motorized modes of transport and public transport. In addition, high levels of electrification of private vehicles are observed, as well as the use of green hydrogen and synthetic zero-emission fuels in the case of heavy transport. No more internal combustion vehicles (gasoline and diesel) will be sold after 2035. The national maritime and air transport subsectors will also reduce their emissions significantly in the long term.

Industry and Mining

For the Slow Recovery scenario, the industry and mining sectors will sustain a trend evolution, in a gradual process of incorporating technological solutions and energetic efficiency measures effectively promoted by the Energetic Efficiency Law.

While in Carbon Neutrality there is a greater penetration of sustainable energies that replace the use of fossil fuels in thermal uses in industry and mining. CCS solutions are developed in those processes where fuels cannot be substituted. The desalination industry, under the umbrella of the growth of renewable energies, is growing significantly as a necessary means to ensure the operation of productive activities.

In an Accelerated Transition, industrial and mining demand are making a successful transition to a low-emission consumption matrix, in which electricity and hydrogen predominate. In turn, sustainable energy supply is predominant in the thermal uses of these sectors. On the other hand, CCS solutions are implemented in industrial processes that are difficult to decarbonize. There is significant growth in the desalination industry to ensure human consumption and the supply of productive activities.

Building (commercial, public and residential)

In the Slow Recovery scenario, the Energetic Efficiency Law facilitates a growing incorporation of energetic efficiency actions in these sectors, mainly developing efforts to achieve significant reductions in local pollutant emissions, highlighting important actions to improve the thermal insulation conditions of homes, such as the update of thermal regulations for new homes and local district energy initiatives that take advantage of municipal waste and forestry surpluses for the thermal use of part of the housing and public and commercial buildings.

Carbon Neutrality, on the other hand, represents a greater penetration of energetic efficiency actions, enabled by the Energetic Efficiency Law, with measures that concern important efforts to reduce both local pollutant emissions and greenhouse gases. Fossil fuels can be replaced by electric and/or zero-emission technologies, mainly in the most energy-intensive thermal uses, to the extent that the actions promoted are profitable in economic terms.

Finally, in an Accelerated Transition, energy savings are achieved through the implementation of energetic efficiency actions, hand in hand with the renovation and thermal insulation of residential, public and commercial buildings. Fossil fuels and firewood without quality specifications can be displaced by electricity, hydrogen, low-emission fuels and new technologies for most of the intensive uses of these sectors. At the local level, district energy initiatives are being developed that take advantage of municipal waste, geothermal resources and industrial surpluses for the thermal use of part of the housing and public and commercial buildings. A significant reduction of local pollutants for the benefit of people's health is highlighted.

3.6 METHODOLOGICAL RELATION PROJECTION MODELS

The construction of the long-term energy scenarios mainly considers the operation of three simulation tools: an energy demand projection model, based on the LEAP platform, an electric system investment optimization model, based on the AMEBA platform, and a distributed resources model, based on agent interactions.

The tool used for the construction of long-term energy demand scenarios corresponds to the *Long-Range Energy Alternatives Planning System* (LEAP)[18] , which consists of an energy systems simulation software used for the analysis of energy policies in the medium and long term, through the integrated representation of energy demand through the *bottom-up* methodology of each of the country's economic activities, according to the structure of the National Energy Balance (BNE), presenting all the information with a regional breakdown, considering the different final uses of energy in each sector.

The three models used are related to each other and to other sources of information according to the scheme presented below:

[18] More information at: https://leap.sei.org/

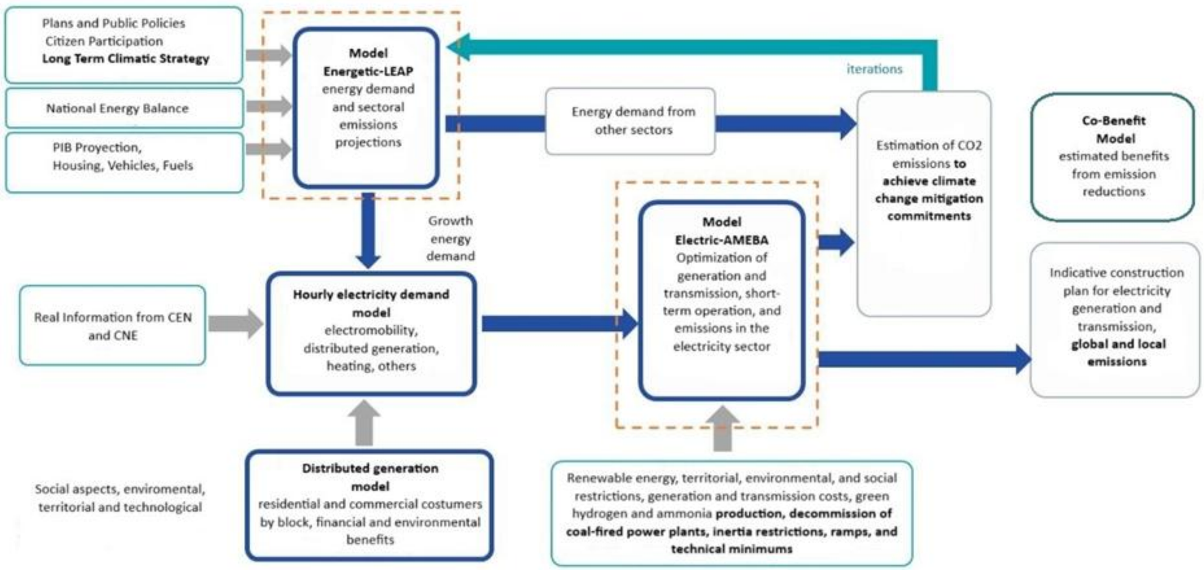


Figure 3: Methodological relationship of the PELP 2023 - 2027 projection models.

Energy demand projection model

The model allows the representation of all energy sources in the country, in accordance with the BNE. The modeling with a *bottom-up* approach, developed in LEAP, allows, through the projection of the main activity data and socioeconomic variables, the estimation of future energy demand. The main advantage of this methodology is that it describes the energy systems, in particular the technologies and parameters that characterize them, attaining a detailed characterization of the different energy end uses. For example, in the industrial sector, end uses for heat, motive power, lighting, etc. are characterized. In the residential sector, the end uses for heating, domestic hot water, cooking and lighting are characterized.

Thus, this characterization facilitates the analysis of the impact of energy and climate policies in the medium and long term. For example, its functionalities include accounting for sources and sinks of greenhouse gas emissions in the energy sector, and analyzing pollutant emissions.

Among its main inputs is the National Energy Balance, which allows establishing the baseline in terms of energy consumption for each of the sectors of the economy (industry, mining, transportation, commercial, public and residential) with regional disaggregation and for each energy source (electricity, oil derivatives, natural gas, solid biofuels, among others). Projections of socioeconomic variables, such as population growth and Gross Domestic Product (GDP), are also incorporated.

Power System Optimization Model

The simulations that determine the long-term trade-offs between generation, transmission and demand are performed in the energy systems analysis platform

AMEBA[19]. This platform allows solving long-term problems such as co-optimization of investment in transmission, generation and storage, as well as short-term problems such as *Unit Commitment*.

The generation and transmission works plans described throughout this report were determined through the investment optimization model. This model optimally solves a long-term centralized planning problem, which aims to determine the future expansions of the NES both in terms of generation and storage supply, as well as the necessary transmission reinforcements, in order to jointly minimize investment, operation and non-supplied energy costs. The model incorporates technical constraints on the operation of power plants, power flow in the transmission grid, water flows by river basins for multiple reservoirs, among others.

This can be summarized in the following optimization problem:

Minimum cost = Operating costs + Investment costs + Failure cost.

Subject to:

- Technical constraints of the facilities.
- Operational constraints related to a safe operation of the power system.
- Operational constraints associated with the operation of the hydrological basins.
- Investment restrictions.
- Expected trajectory of reservoir levels.

in which;

- Operating costs: includes expected annualized generation costs and emission taxes.
- Investment costs: expected investment costs and annualized COMA (Cost of Operation, Maintenance and Administration) of the expansion in generation, storage and transmission.
- Failure cost: includes the expected cost of unserved energy, system security deficits and energy constraints.

Distributed resource model

An agent-based model is used to estimate the adoption of distributed generation technologies in the residential, commercial and industrial sectors, respectively, using photovoltaic solar panels by 2050 in Chile. The modeling tool considers that the most relevant factors for the individual adoption of this technology are based on a multidimensional decision that considers: the *payback* period, the economic income of the sector (resolution by blocks), communication influence between agents and environmental benefits, which are balanced through weights or weights adjusted with the available historical data. The project trajectories resulting from this

[19] More information at: https://www.spec.cl/#seccionAmeba

model are subtracted from the base electric demand, in each bus considered in the electric model and for each scenario.

Hourly electric demand model

This model is based on an analysis of the hourly electric sales of the base year, where through the K-Means cluster methodology, an approximation of the types of customers and their respective demand profiles is identified. Subsequently, the electric demand per bus is reconstructed by adding the energy of each customer identified and adjusted with the real energy values. With the identification of the type of customer per bus, it is possible to differentiate their consumption at hourly level, and by type (basal, air conditioning and electromobility) which, added to the production of distributed generation, are transformed into electric demand profiles up to 2060.

The models and tools used for the projection of the energy supply and demand vectors are structured in such a way that the result obtained is developed from a sequential execution of the models, i.e.: in the first instance, the volumes of electric energy necessary to satisfy the final energy uses of the national economic activity are estimated (without considering the production of hydrogen and ammonia). Once the final electric demand for the entire period of analysis is obtained, it is processed within the hourly profiles of electric consumption (base consumption, electric vehicles, air conditioning), discounting distributed generation, and subsequently incorporated as an hourly demand per bus, to the model that optimizes electric planning.

4. ENERGY PROJECTIONS

4.1 CONSIDERATIONS

National Energy Balance

The National Energy Balance is an annual statistical report of the Ministry of Energy, which seeks to compile all energy transactions occurring in the country within a calendar year in order to characterize the production, sale, and national energy consumption. It accounts for all types of energy, both primary (crude oil, natural gas, coal, etc.) and secondary (gasoline, diesel, liquefied gas, etc.) for all economic sectors of the country (industry, mining, transportation, commerce, households, etc.). The PELP 2023-2027 considers the information corresponding to the BNE for the year 2022; however, at the date of publication of this report the data for the year 2023 is already available[20] and will be considered in the next planning processes.

The National Energy Balance is divided into three main parts that represent the flow of energy from its supply to its consumption: supply from primary energy sources (primary energy production matrix); energy transformation centers (production of oil derivatives, electricity and other minor fuels); and final uses (final energy consumption in each economic sector).

1. Primary energy matrix

In 2022, the primary energy matrix in Chile was 327,753 Tcal, where fossil resources (crude oil, coal and natural gas) accounted for 60% of the total, with a 26% share of biomass. These figures highlight the challenge of decarbonizing the economy in all productive sectors.

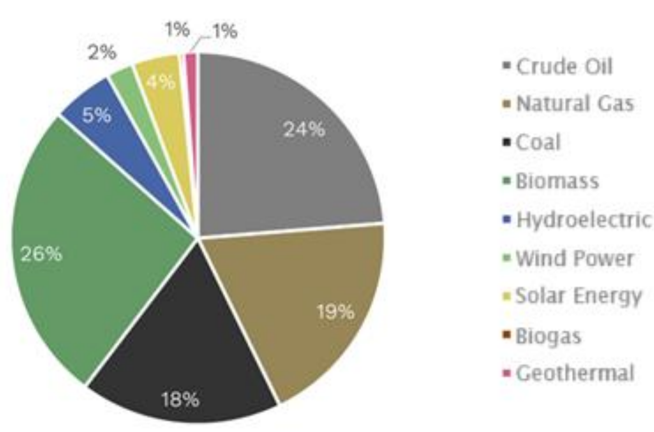


Figure 4: Primary energy matrix year 2022.

[20] Available at: http://energiaabierta.cl/visualizaciones/balance-de-energia/

2. Sources of the primary energy matrix

In 2022, 43.7% of our primary supply is obtained from domestic sources, highlighting biomass, hydro, wind and solar energy, while 56% of the primary supply comes from imports of crude oil, natural gas and coal[21] , and the remaining 0.4% corresponds to stock variations. Likewise, no energy exports were recorded that year.

3. Consumption in transformation centers

The consumption matrix in transformation centers represents all primary and secondary energy consumption used for direct transformation to other energy sources for specific purposes. The main transformation centers in the country correspond to electric generation, refineries, the iron and steel industry (composed of coke ovens and blast furnaces), and methanol production from natural gas.

In the course of 2022, the transformation centers processed 278,885 Tcal, 4% less than the energy consumed in 2021 for such purposes. Electric generation is the main transformation center with 63%, followed by the oil refinery with 32%, while the iron and steel industry represents 2% and the remaining 3% in others.

4. Final energy consumption

Final energy consumption is represented through the secondary energy matrix, and corresponds to the energy destined to the consumer sectors of the national economy, both for energy and non-energy use. For the year 2022 this value was 327,696 Tcal, 7% more than in 2021.

Petroleum derivatives and electricity are the main components of the secondary matrix due to their cross-cutting use in all economic sectors. In terms of sectoral consumption, the Industry and Mining sectors correspond to the sectors that demand the most energy, with 37%, followed by the Transportation sector with 34% of final consumption. These sectors consume the largest amount of Chile's energy, accounting for 72% of the total. With a smaller share, the Residential - Sanitary sector has 18% of final consumption, followed by the Commercial - Public sector and Self-consumption, with 5% and 4% of participation, respectively.

[21] These three energy sources are also produced locally, but to a lesser extent. 98.5%, 80.9% and 99.8% of the primary supply of crude oil, natural gas and coal energy sources come from imports.

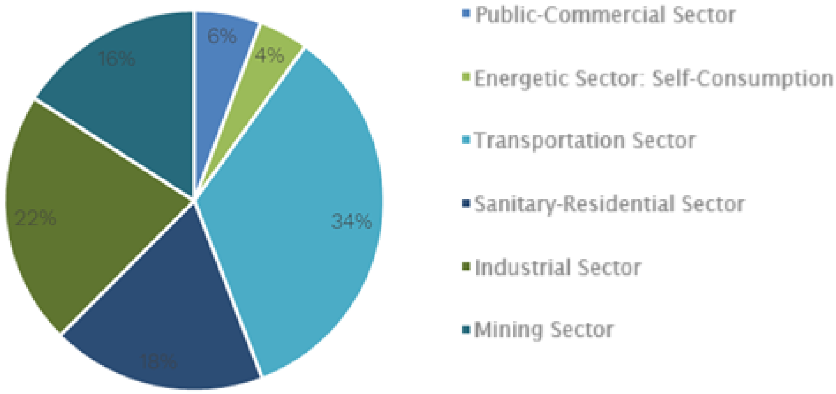


Figure 5: Final energy consumption by sector 2022.

Growth projections

The energy model also considers growth projections of socioeconomic variables and productive activities in the country, such as population growth, housing, public and private transportation, mining-industrial production [22], among others. The main sources of information are the Casen Survey[23], the SEC, COCHILCO, among others. Likewise, in the case of activity levels (or *drivers*), these directly or indirectly define the energy requirements of the different sectors. The list of each economic activity considered is detailed in the Table 6 of Annex 8.3.

On the other hand, population growth is one of the main determinants of the evolution of the energy projections and between 2017-2060 an average interannual population growth rate of 0.25% is presented, the detail by decade can be found in Figure 54 of Annex 8.3.

Based on the projection of inhabitants at the national level, distributed regionally, both the energy demand projection model and a projection of housing at the national level are established, which considers the historical trend of the rate of inhabitants per dwelling and the economic growth curve considered in each energy scenario. An example of the housing projection for the Carbon Neutral scenario is shown in Annex 8.3.

Economic Growth

The energy scenario simulation work presents a projection of national economic growth for the period 2018-2060 according to each scenario. The GDP projection was made by the Budget Office, an agency under the Ministry

[22] Includes cellulose, copper and iron.

[23] National Socioeconomic Characterization Survey. More information at: https://observatorio.ministeriodesarrollosocial.gob.cl/encuesta-casen

of Finance, based on a standard output growth model, which considers a Cobb-Douglas production function.

In this model, GDP depends on the productive factors capital and labor (which is composed, in turn, of employment and human capital), and on productivity. This is defined by the following formulation:

$$Y_t = K_t^{\alpha}(A_t H_t)^{1-\alpha} = K_t^{\alpha}(A_t h_t L_t)^{1-\alpha}$$

Where the term Y denotes GDP, K capital, A productivity, h human capital and L employment. The parameter α, represents the share of capital in the level of production (GDP) and, consequently, $1-\alpha$ corresponds to the share of labor in production. Thus, GDP growth will be determined by the growth of the four factors mentioned above.

In the Table 2, below, the annual variation rates of the average GDP for each decade are presented for the scenarios elaborated and in the Figure 56 of the Annex 8.3 this projection is graphed.

Table 2 : Average annual variation rates of Gross Domestic Product (GDP) by period and PELP scenario.

SCENARIO	2021 - 2030	2031 - 2040	2040 - 2050	2051 - 2060
Slow Recovery	3,0%	1,5%	0,7%	0,3%
Carbon Neutral	3,1%	1,7%	0,9%	0,5%
Accelerated Transition	3,3%	1,9%	1,1%	0,7%

4.2 MEASURES BY SECTORS OF THE ECONOMY

The construction of energy scenarios was carried out in a participatory manner and based on the definition of external and modifiable factors, which were grouped according to their different areas or impacts, and follow different trends according to the scenario in which they are located. Thus, three external factors (economic growth, population and electric generation costs) and more than 20 modifiable factors were considered and developed, included and modeled in the LEAP tool.

This is done through the incorporation of more than 50 measures and actions derived from different public policies or consistent with them, technological development and adoption, technical feasibility, among others. These, in turn, have an impact on energy demand and, therefore, on global and/or local emissions.

The following is a description of each of the measures and actions simulated in the scenarios in the demand projection model (LEAP), with the respective penetration levels, where those measures in the electric sector (which are simulated in the AMEBA tool and described in the following chapter) are not considered.

Industry and mining

In the industry and mining sector, mitigation measures and actions are based on the Energetic efficiency Law and energy management systems (EMS), the National

Hydrogen Strategy (2020)[24], from which also derives the Green Hydrogen Action Plan 2023-2030 (2024)[25], and the National Cooling and Heating Strategy (2021)[26].

There are important technological transformations in the Carbon Neutrality and Accelerated Transition scenarios, especially for the replacement of green hydrogen, replacing fossil fuels, in motor uses, reaching up to 92% of participation in non-copper mining by 2050, in addition the three scenarios consider high levels of electrification of the industrial and mining sectors. Details can be found in Table 7 of Annex 8.3.

Commercial and public

The commercial and public sectors have the lowest number of mitigation actions and measures due to the difficulty of modeling these sectors, as well as the lack of detailed information at the consumption level in the segment. Some actions related to energetic efficiency programs in the public sector are simulated, where energy consumption has been identified, but they do not result in relevant changes in energy demand. The list can be found in Table 8 of Annex 8.3.

Residential

The residential sector has a series of measures related to introducing renewable energies in homes, reducing the energy demand of homes through improvements in appliance standards and improvements in thermal insulation, changing heating methods to less polluting technologies and electrification of consumption.

The penetration levels proposed for the measures represent an important energy transformation for this sector and the efforts made in each scenario for the thermal envelope of the houses are highlighted, even proposing an important volume of construction of houses with *Net Zero* standard[27] in the Carbon Neutrality and Accelerated Transition scenarios, and are mainly based on the goals set out in the preliminary draft of the National Strategy of Carbon Footprint in Construction of the Ministry of Housing and Urbanism (2021)[28], the Long-term Climate Strategy of the Ministry of Environment (2021)[29] and the update of the National Energy Policy of the Ministry of Energy (2022)[30].

[24] Available at: https://energia.gob.cl/sites/default/files/estrategia_nacional_de_hidrogeno_verde_-_chile.pdf

[25] Available at: https://energia.gob.cl/sites/default/files/documentos/plan_de_accion_hidrogeno_verde_2023-2030.pdf

[26] See https://caloryfrio.minenergia.cl/

[27] *Net Zero Building* is defined as a building with net zero energy consumption, which during its life cycle (production, construction, operation, end of life), manages to minimize its embodied carbon emissions and offset any remaining carbon balance. However, for the purposes of the LEAP modeling performed here, a *Net Zero Building* is considered to be a home that achieves 75% of total demand savings, discounting the savings from the building standard.

[28] Available at: https://participacionciudadana.minvu.gob.cl/consultas-ciudadanas-virtuales/consulta-p%C3%BAblica-estrategia-nacional-de-huella-de-carbono-en-la

[29] Available at: https://cambioclimatico.mma.gob.cl/wp-content/uploads/2021/11/ECLP-LIVIANO.pdf

[30] Available at: https://energia.gob.cl/sites/default/files/documentos/pen_2050_-_actualizado_marzo_2022_0.pdf

Here, in all scenarios, the electrification of heating energy consumption in the long-term stands out, in line with the evolution of public policies and leveraged by improvements in the thermal envelope of the housing stock at the national level. Notwithstanding this, it is important to highlight the contribution of policies aimed at the commercialization and control of the compliance of solid biofuels with minimum technical quality specifications, such as Law 21.499. Details can be found in the Table 9 of Annex 8.3.

Transportation

The measures in the transportation sector focus on three main aspects: electromobility in private vehicles and public transportation; implementation of energetic efficiency standards in different vehicle segments; and the use of green hydrogen to replace diesel in tractor-trailers and commercial flights at national level.

The electromobility measures are based on meeting the goals of the Electromobility Strategy (2021)[31] , which was updated through the Roadmap for the Advancement of Electromobility in Chile (2023)[32] , which establishes concrete actions by 2026 to massify the use of this technology. On the other hand, the Energetic efficiency Law seeks to promote the renewal of the vehicle fleet with more efficient technologies and an emphasis on electromobility, mandating the establishment of energetic efficiency standards for new vehicles[33] . Finally, the use of green hydrogen is introduced in the heavy truck segment, with high penetration levels in all scenarios, reaching up to 84% by 2050. Details can be found inTable 10 of Annex 8.3.

4.3 ENERGY MODELING RESULTS

Energy demand

The national energy demand concentrates the energy demand of all economic activities (industry, mining, transportation, commerce, public sector and residential sector) established in the national territory. Two of the main determinants of energy demand correspond to the number of inhabitants and economic growth prospects.

As presented in a previous section, both variables show a growth in the period between 2020 and 2060. Therefore, a significant growth in energy demand is expected for all the long-term energy scenarios constructed: between 24% and 28% with respect to 2020, depending on the energy scenario.

---

[31] Available at: https://energia.gob.cl/sites/default/files/estrategia-nacional-electromovilidad_ministerio-de-energia.pdf

[32] Available at: https://energia.gob.cl/sites/default/files/documentos/hoja_de_ruta_para_el_avance_de_la_electromovilidad_en_chile_acciones_concretas_al_2026.pdf

[33] More information at: https://energia.gob.cl/ley-y-plan-de-eficiencia-energetica

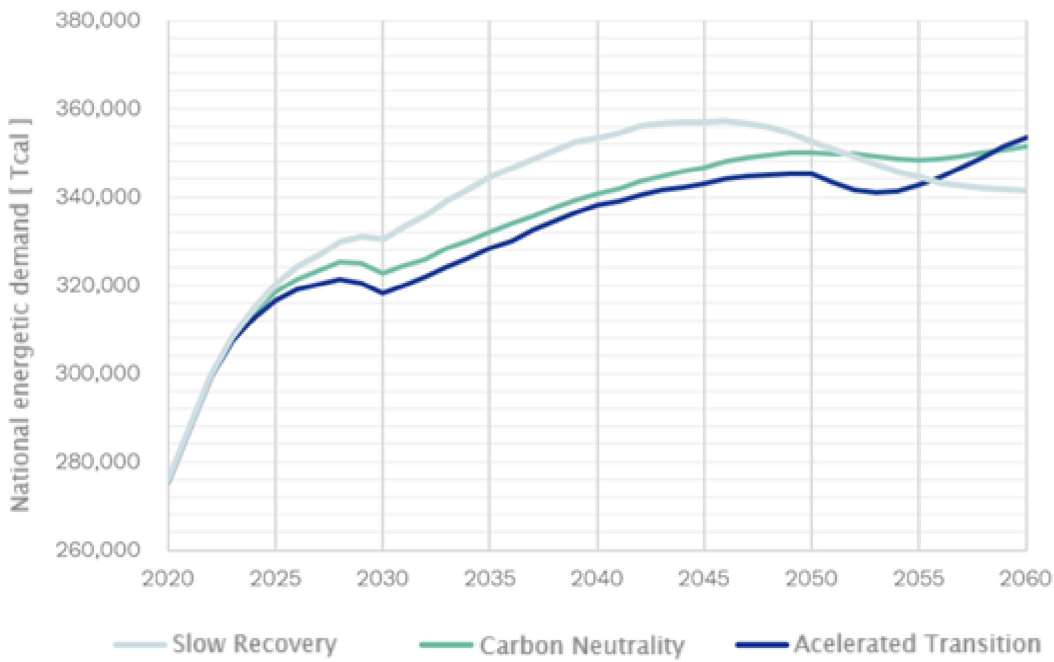


Figure 6: Projected national energy demand for the three simulated scenarios.

The growth is explained by the evolution of the energy demand of the transportation sector, which currently represents more than 37% of the national energy demand, and which presents growth rates in 2060 that vary between 25% and 46% depending on the energy scenario with respect to 2020. Mining also stands out, which accounts for 19% of the national energy demand, with growth rates ranging from 45% to 60% by 2060, depending on the energy scenario with respect to 2020.

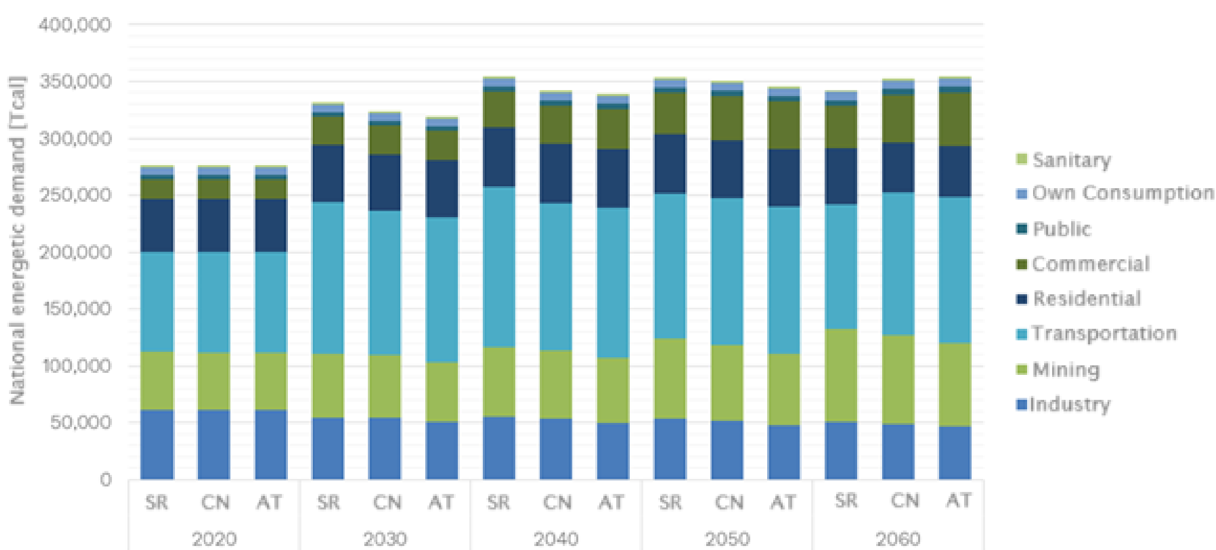


Figure 7: Projected energy demand disaggregated by sectors of the economy for the Slow Recovery (SR), Carbon Neutrality (CN) and Accelerated Transition (AT) scenarios.

The magnitude of energy demand growth at national level has behind it the performance of each of the economic sectors, which do not always present a growth trend, like the national average, in their consumption similar to that of the national aggregate, motivated by the different perspectives of energy behavior and evolution of each sector, added to the energetic efficiency and GHG mitigation efforts that are being considered in each of the economic sectors.

Within these sectors that, despite having a significant growth in their production, have reductions in their energy consumption due to increased process efficiency or change to cleaner and more efficient energy sources, the industrial sector stands out, which shows a decrease in its energy demand in 2060 with respect to 2020 in all scenarios. In the Slow Economic Recovery Scenario, industry reports a 17% reduction in demand with respect to 2020, while in the Accelerated Energy Transition scenario, there is a 24% reduction in industrial energy demand.

It is essential to highlight that the final demand for renewable energy in Chile's final consumption (excluding the production of electricity from renewable sources) will experience a significant growth by 2060. In general, a notable increase in demand is observed mainly due to the minimal penetration, at present, of (modern) renewable sources in final energy uses (the consumption of wet or uncertified firewood by households is not considered a modern renewable fuel). The increase observed in the different energy scenarios to 2060 is explained by the sustained growth of direct renewable applications such as solar thermal systems in households, and mainly by the expected consumption of green hydrogen and derivatives in long-distance land freight transport, as well as in mining (extraction machinery) and industry (*blending*).

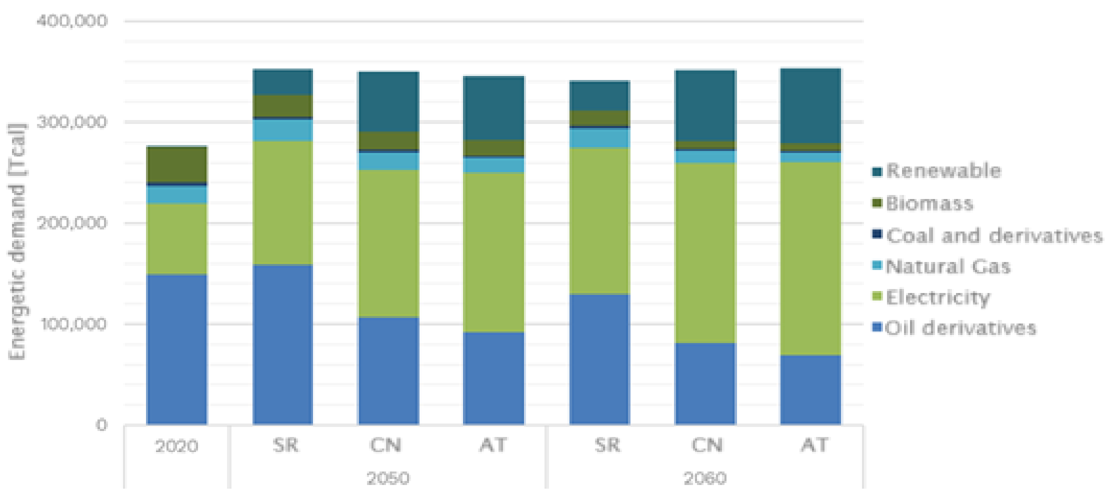


Figure 8: Projected energy demand disaggregated by energy type for the Slow Recovery (SR), Carbon Neutral (CN) and Accelerated Transition (AT) scenarios.

Energy intensity

In the analysis of an economy's energy performance, one of the main quantitative indicators corresponds to energy intensity. Energy Intensity measures the ratio between energy use or demand and Gross Domestic Product (GDP). Given that each of the energy scenarios designed consider a heterogeneous set of efforts associated with energetic efficiency, mitigation of greenhouse gas emissions and reduction of local pollution, this indicator has been constructed for each scenario.

Based on the long-term projections of energy demand resulting from each scenario, energy intensity is reduced in all scenarios. By 2060, a reduction of 28% of the energy intensity obtained for the slow recovery scenario, and up to a 36% reduction of the energy intensity obtained for the accelerated energy transition scenario compared to 2020.

Table 3: Energy intensity according to each scenario.

ENERGETIC INTENSITY [TCAL/MM CLP 2013]					
SCENARIO	2020	2030	2040	2050	2060
Slow Recovery	1,9	1,7	1,6	1,4	1,4
Carbon Neutrality	1,9	1,6	1,5	1,4	1,3
Accelerated Transition	1,9	1,6	1,4	1,3	1,2

Transportation sector

The energy demand of the transportation sector, including passenger land transport, freight transport, rail, maritime and air transport, grows in all scenarios by 2060; however, it is only in the last decade of 2050-2060 where the Carbon Neutrality (CN) and Accelerated Transition (TA) scenarios reach an increase relative to the Slow Recovery (RL) scenario that manages to differentiate to a greater extent the final demands of the scenarios. That is, demand in 2020 starts at around 88,000 Tcal total for the transport sector and multiplies between 1.2 and 1.4 times in 2060.

Energy demand for passenger transport decreases in all scenarios by 2050, however, freight transport and the air sector increase considerably, growing ~0.8 and ~6.6 times by 2060 respectively.

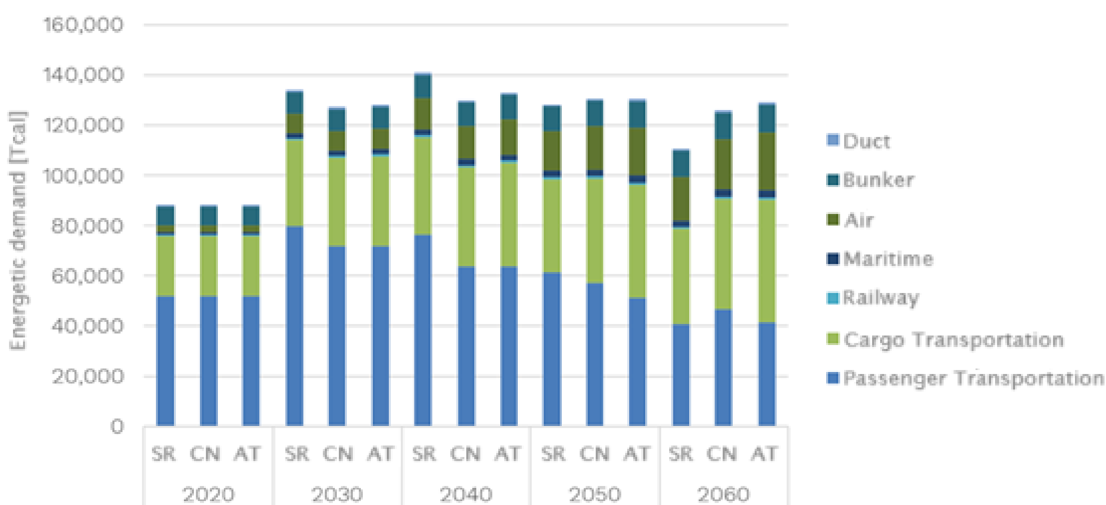


Figure 9 : Energy demand of the transportation sector under the Slow Recovery (SR), Carbon Neutral (CN) and Accelerated Transition (AT) scenarios.

Relevant changes are observed in the share of land transport (passengers and freight), which goes from ~86% in 2020 to ~70% in 2060 in the Accelerated Transition scenario, and air transport, which goes from ~3% to ~18% from 2020 to 2060 in the same scenario.

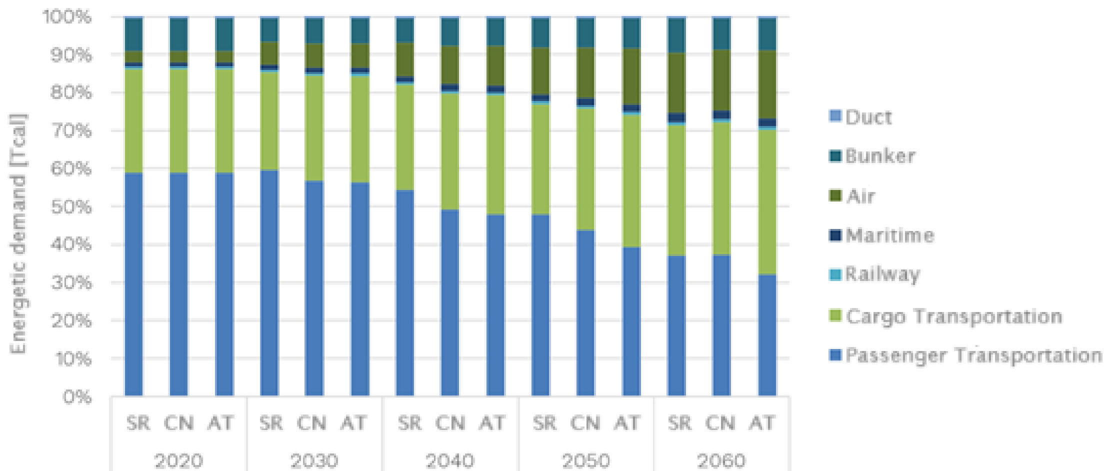


Figure 10: Relative composition of transportation sector energy demand under the Slow Recovery (SR), Carbon Neutral (CN) and Accelerated Transition (AT) scenarios.

The total energy demand for land passenger transport decreases in all scenarios in the long-term by about 10-20% compared to the beginning of the period. By 2060, reductions in demand are observed for all modes of transport with the exception of the motorcycle category, which has a low share in total demand. At the same time, it is interesting to note that in the 2030s, the total demand for passenger transport increases considerably and then begins to decline consistently as electromobility measures are implemented.

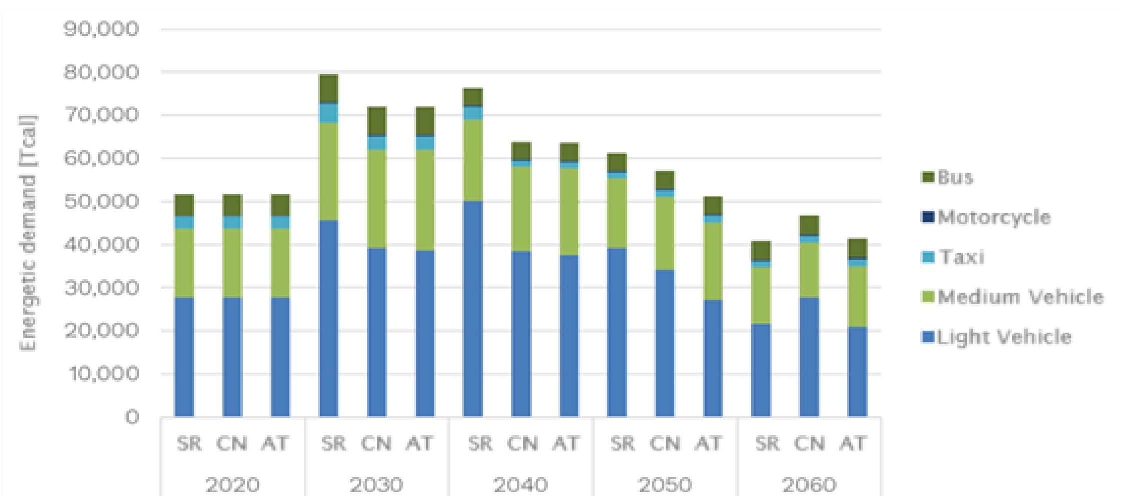


Figure 11: Land transport energy demand according to each transport mode under the Slow Recovery (SR), Carbon Neutral (CN) and Accelerated Transition (AT) scenarios.

It is also relevant to analyze the regional distribution of energy demand for transportation (by land, rail, national and international maritime, and national air transport), which Figure 12 for the three scenarios studied. The three regions with the highest transport demand account for almost 50% of the total demand, with the Metropolitan Region standing out, which alone accounts for 32.8% of transport energy use in the Recovery scenario, reaching up to 30% in the Accelerated Transition Scenario in 2050. The Metropolitan region is followed by the Antofagasta region, whose share is in the 10% range, and, in third place, the Maule region, which accounts for 9-10% of transport demand.

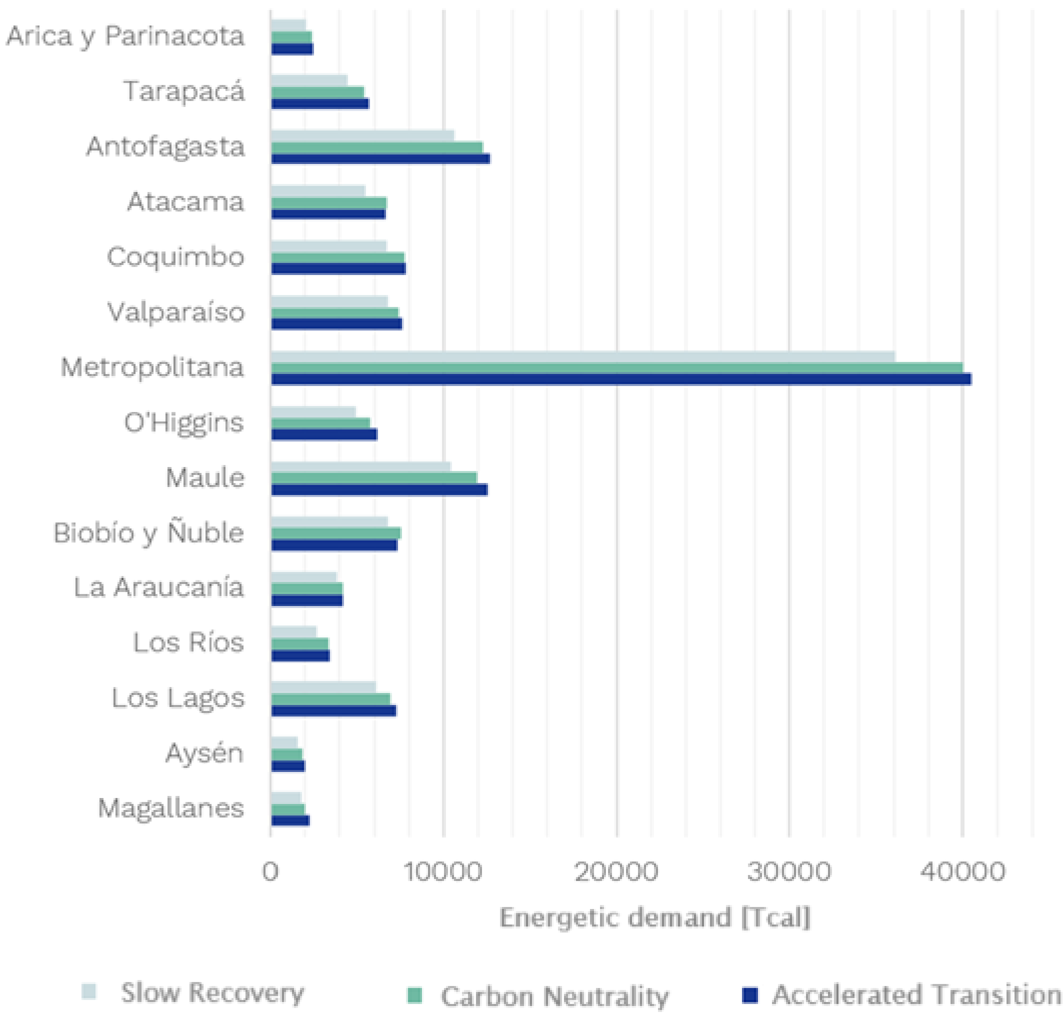


Figure 12: Regional distribution of energy demand in the land transport sector under the three simulated scenarios.

Residential sector and housing heating

The construction of energy scenarios in the residential sector involves major transformations in terms of the thermal quality of existing and new housings, considering a significant number of buildings with a net zero standard by 2060. At the same time, there are important changes in the use of heating technologies. These transformations are visible in the energy demand results of the three scenarios.

All scenarios show a sustained drop in energetic demand for heating in housings[34] , with the steepest drop occurring in the Accelerated Transition (AT) and Carbon Neutrality (CN) scenario by 2060. This drop is due to the major transformation in the thermal insulation of the existing housing stock and new construction in the latter two scenarios, which considerably reduces the heating demand of housings.

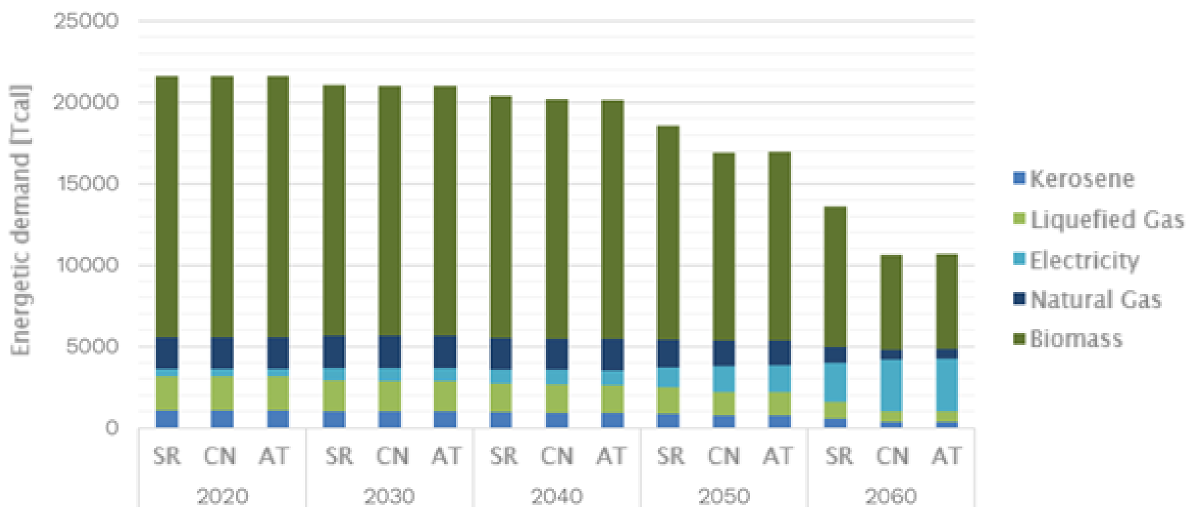


Figure 13: Projected energy demand for residential heating under the Slow Recovery (SR), Carbon Neutral (CN) and Accelerated Transition (AT) scenarios.

As can be seen in Figure 14, by 2060 the composition of the heating matrix is also very similar in the CN and TA scenarios. It is observed that the Accelerated Transition (AT) scenario has reduced by 63% the demand for firewood and biomass with respect to 2020, reaching a share of 54.8% in the heating demand in 2060. Electric demand increases 6.2 times with respect to 2020 in the TA scenario, as a result of the electrification measures described above. Meanwhile, the RL scenario in 2060 reduces only 47% of firewood compared to 2020 and increases its electric demand for heating by 4.5 times compared to 2020.

[34] The analysis includes only home heating because apartment heating accounted for less than 2% of residential heating energy demand.

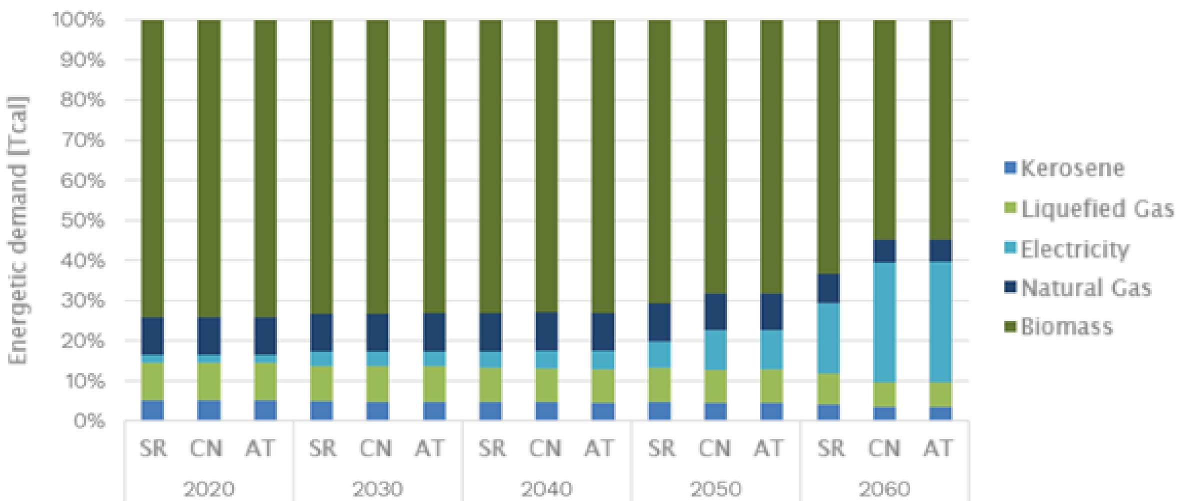


Figure 14: Share of energy in energy demand for residential heating under the Slow Recovery (SR), Carbon Neutrality (CN) and Accelerated Transition (AT) scenarios.

Industrial Sector - mining

In the period 2020 to 2060, industrial demand grows 18%, 13% and 7% under the Slow Recovery, Carbon Neutrality and Accelerated Transition scenarios, respectively. Also, as economic conditions increase between scenarios, the electrification, both directly and indirectly, of consumption increases.

4.4 REGIONAL DISTRIBUTION OF ENERGY DEMAND

The following graphs show the final energy demands in 2060 for each energy scenario. The regions of Antofagasta, Atacama, Metropolitan and Biobío-Ñuble concentrate almost 70% of the industrial and mining demand in 2060, without significant variations in their regional participation among the three scenarios. Demand in Antofagasta is mainly driven by mining, which accounts for 94% of this demand. In the Metropolitan Region, 81% of its demand comes from industry, while in the Biobío-Ñuble region, which has no mining activity, industrial energetic demand represents the total.

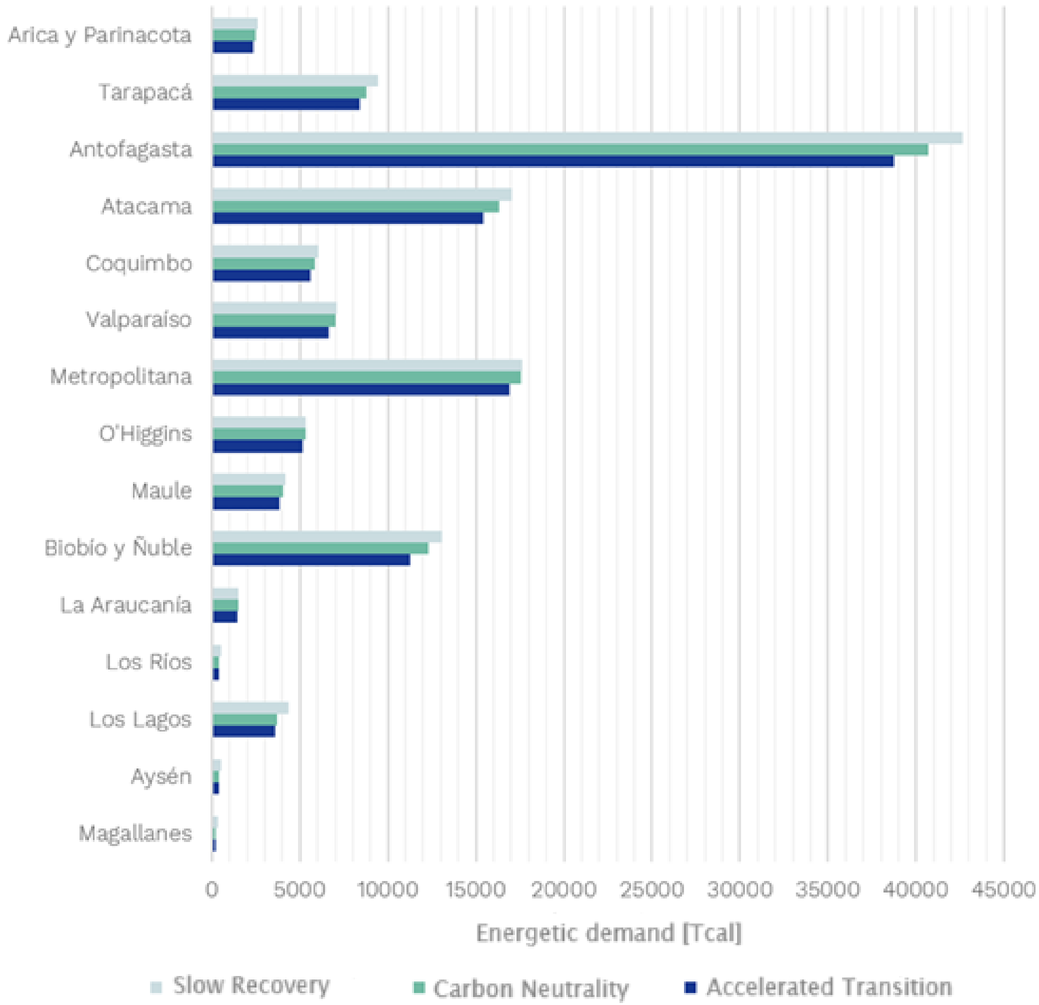


Figure 15: Regional distribution of the projected energy demand of the mining and industrial sectors under the three simulated scenarios.

Electric demand for domestic uses

Electric demand increases its relevance throughout the time period analyzed in each of the energy scenarios considered. The decarbonization of the electric matrix, on the one hand, enables electricity as an important means of decarbonizing energy uses currently supplied through fossil fuels, while, on the other hand, the demand for electricity for the production of green hydrogen for domestic consumption, both through fuel cell technology and internal combustion engines, also has this important attribute of reducing emissions.

The relevance of electricity in the final consumption energetic matrix is clearly observed when evaluating its electrification indicator. The following graph shows the electrification indicator for each energy scenario, constructed from the proportion of the total national energetic demand that is supplied by electricity, considering also the electricity required for the production of green hydrogen for domestic consumption.

At present, electricity has a share of 24% in the final energy matrix, which grows uninterruptedly throughout the analysis period, reaching between 47% and 73% of the matrix by 2050, depending on the energy scenario.

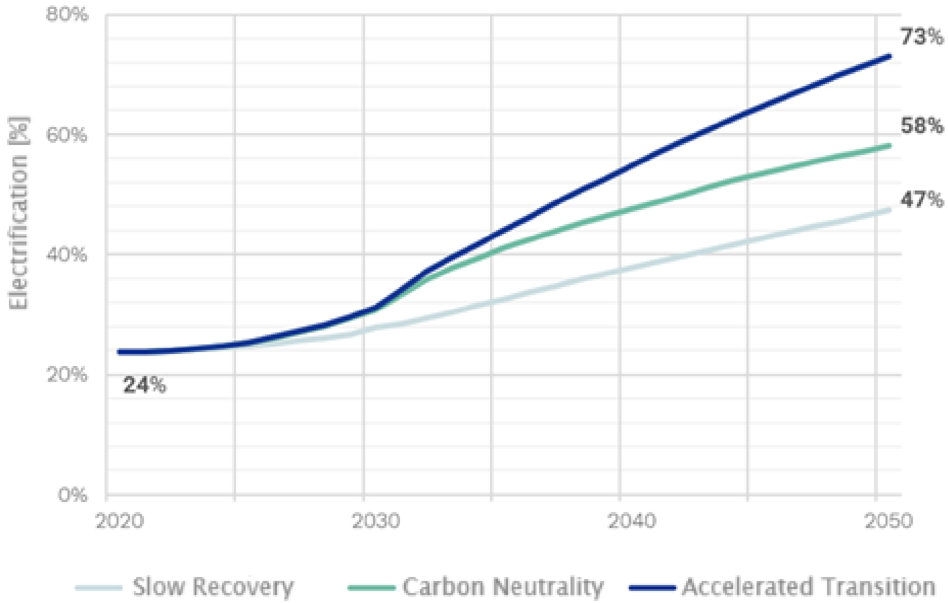


Figure 16: Electrification level of the final energy consumption matrix.

Hydrogen demand

As explained in the previous section, the national demand for hydrogen has an important impact on the growth of electric demand over the period 2020-2060 in each of the energy scenarios. Electric demand, particularly for the production of green hydrogen through electrolysis technology, for domestic consumption (but not for export) is expected to represent between 26% and 53% of total domestic electric demand by 2060. Therefore, it is important to evaluate how the final demand for hydrogen is distributed throughout the regions of the country, according to each energy scenario, which is presented Figure 17 , below.

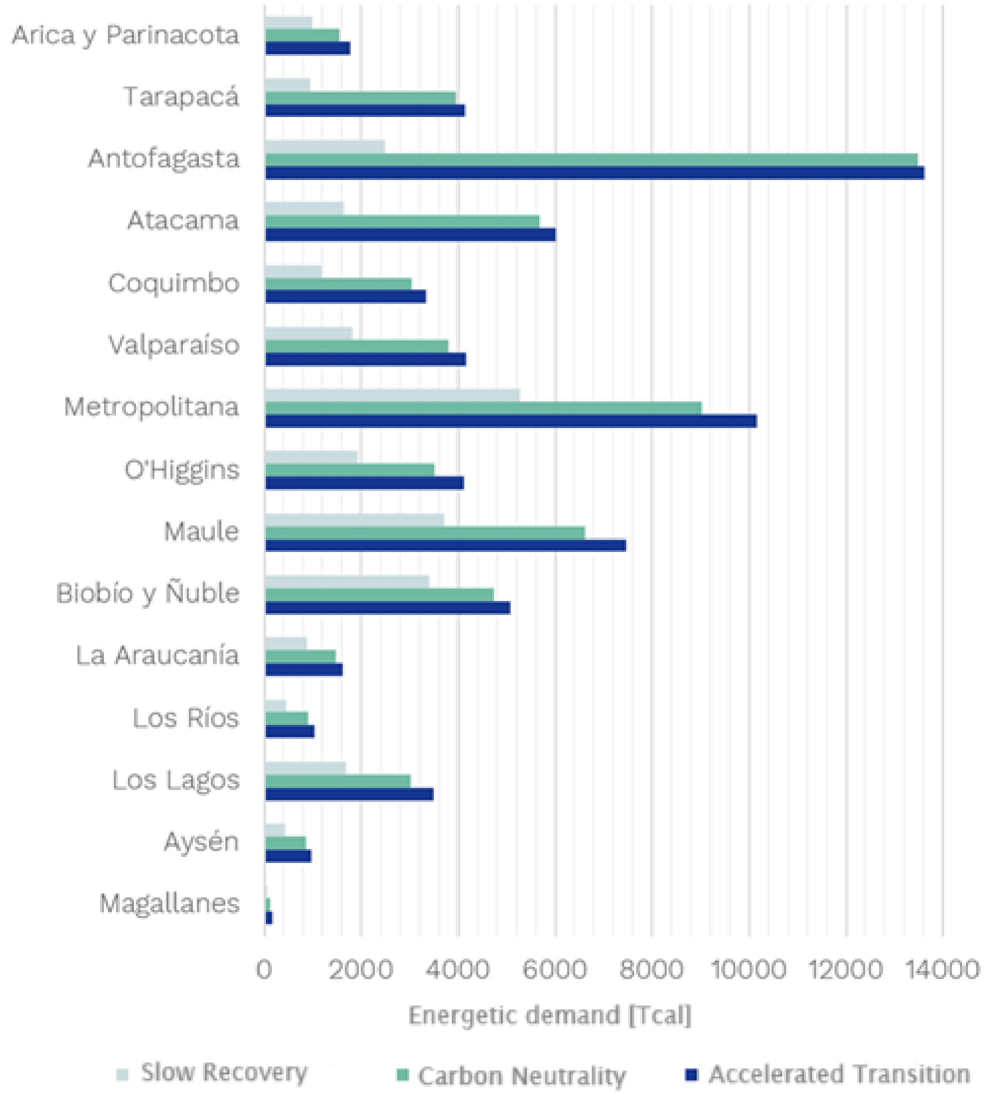


Figure 17: Regional distribution of green hydrogen energy demand.

The regions of Antofagasta and Metropolitan stand out with a greater participation in the regional distribution of the final hydrogen demand, with Antofagasta representing between 9 and 22% of the national demand, depending on the energy scenario; while the Metropolitan region represents between 15% and 20% of the national hydrogen demand depending on the energy scenario. In total, an approximate demand of 26,871 Tcal, 61,822 Tcal, and 67,157 Tcal is expected in the Slow Recovery (SR), Carbon Neutrality (CN) and Accelerated Transition (AT) scenarios, respectively.

The final energy use of green hydrogen, depending on the scenario considered, has a share of between 8% and 19% in the national energy matrix by 2060, with road freight transportation (tractor-trailers, and medium and light cargo transportation) and motor uses in mining being two of the most important components of the final hydrogen demand, representing a share of 59% for the first case, and between 24% and 33% for the second case, depending on the scenario.

5. ELECTRIC SECTOR PROJECTIONS

5.1 NATIONAL ELECTRIC SYSTEM AND CONSIDERATIONS

Current generation of the NES

As of the date of publication of this report, the generation park of the National Electric System has 36,347 MW of installed capacity (maximum gross power), of which 48% corresponds to NCRE plants. The detail is presented below.

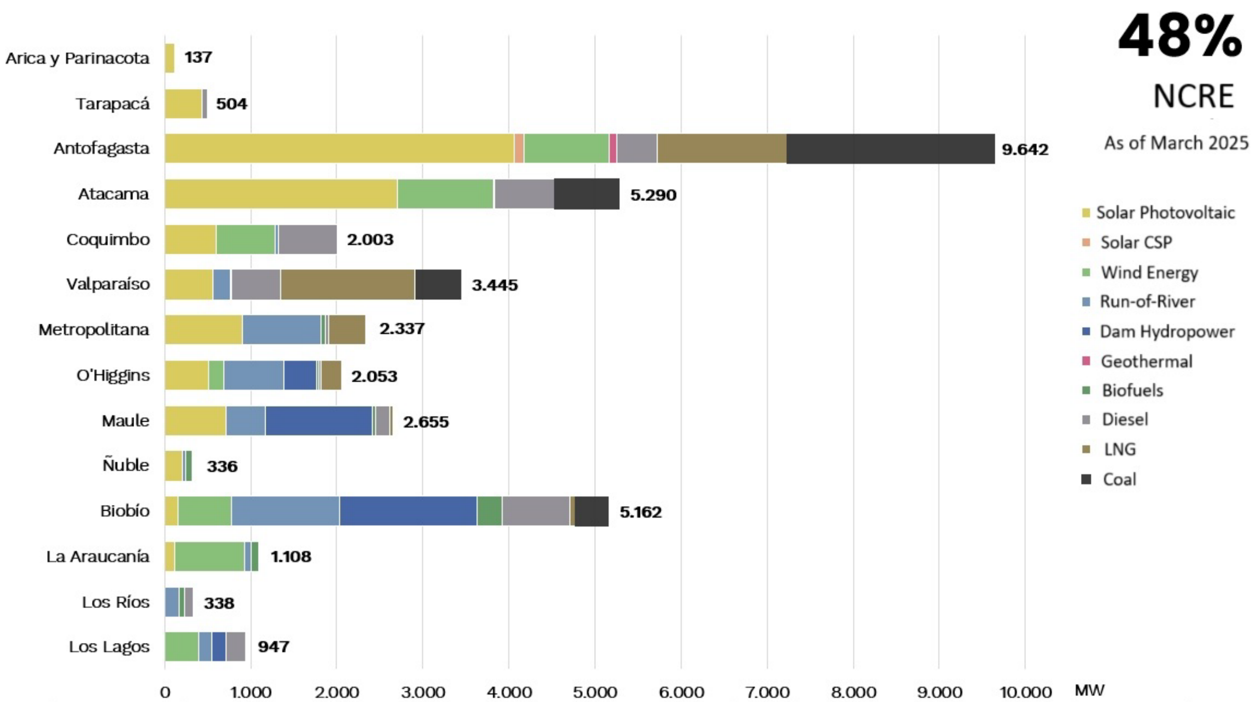


Figure 18: Generation by region of the National Electric System (NES) as of March 2025

Territorial considerations

The above shows the challenges of energy development at the territorial level, especially due to the great renewable energy potential that Chile has, as well as the retirement of coal-fired power plants, the opportunities for new technological developments, the need for energy infrastructure, compatibility with other local uses and interests, environmental protection, among others, which lead to increasingly consider the sensitivities, potential and opportunities of the territory.

Therefore, since 2014, the Ministry of Energy has been incorporating territorial considerations in energy development, which was formalized through the first National Energy Policy (2015)[35] and then in Law 20.936 that establishes a new system of

[35] Available at: https://energia.gob.cl/sites/default/files/energia_2050_-_politica_energetica_de_chile.pdf

electric transmission and creates an Independent Coordinator of the National Electric System (2016)[36].

The PELP 2023-2027 process proposed, since its inception, to strengthen and deepen these territorial considerations to contribute in having results that allow a sustainable and balanced approach in its territorial deployment, which is also in charge of the results of the participatory spaces. In a transversal way to the planning process, work has been done to raise territorial awareness of the PELP modeling through the consideration of Environmental Variables[37] and Territorial[38] in the framework of the identification of energy generation potentials based on renewable sources that serve as input for such modeling.

On the one hand, we have considered those variables that affect the use of renewable resources, called technical factors, such as height, slope of the terrain, wind speed, radiation, etc. that, applying the minimum continuous area standard and plant factor estimated for each technology, make up the technical generation potential, which is detailed in the Table 11 of the Annex 8.5.

Territorial Valuation Objects (TVO)

On the other hand, those variables that affect the development of energy generation have been identified, valuing them according to a legal-normative criterion, according to their incidence and degree of conditioning established in the current legal order and, to a project development criterion, according to their incidence in the processing and execution terms of the projects. When the variables analyzed are evaluated on the basis of these criteria, they are called Territorial Valuation Objects (TVO); among which, for this process, those of high incidence or conditioning to the development of this type of projects are selected.

In the consideration of the TVO of high incidence or conditioning to the development of energy generation projects based on renewable sources, according to the planning decisions taken in the process, they have been exposed to different treatments:

- TVO not considered: Two valued variables were identified that could not be incorporated due to technical limitations, such as the case of the Virgin Region Reserve (there is currently none decreed) and Archaeological Sites (there is no official information available at the national level). In the latter case, this variable was taken up again in the planning of the PDGE.
- Excluded TVO: Set of 22 assessed variables that, although they do not constitute a restriction, the convenience of avoiding them is determined, for which they are excluded from the potential for energy generation based on renewable sources that enters the

[36] Available at: https://www.bcn.cl/leychile/navegar?idNorma=1092695

[37] Environmental variable shall be understood as the element of the environment in its different dimensions, natural or artificial, that is subject to probable or frequent changes, derived from the activities and/or energy generation projects susceptible to generate effects on the baseline condition.

[38] Territorial variable shall be understood as that which has been established in an instrument of land use, planning or management and which affects or conditions the location of the power generation.

model , such as national parks, monuments and sites of cultural significance, among others.

- Sensitized TVO: Set of 5 variables valued with respect to which it is determined to promote the use of alternative soils through a surcharge of 10% and 20% (depending on the percentage of land that is affected by these variables) to its development that is applied to the potential for energy generation based on renewable sources modeling, in order to make alternative soils more competitive. This framework includes variables such as indigenous lands with recognized rights (Law N° 19.253) and Zones of Tourist Interest (ZOTI) only for wind potential to collect the landscape variable, among others.

In the Table 12 and the Figure 57 of Annex 8.5 detail the methodological treatment for the TVO and summarize the process, respectively. Thus, the PELP results for all the scenarios defined have this territorial sensitization and the PDGEs also incorporate these considerations.

5.2 RENEWABLE POTENTIAL

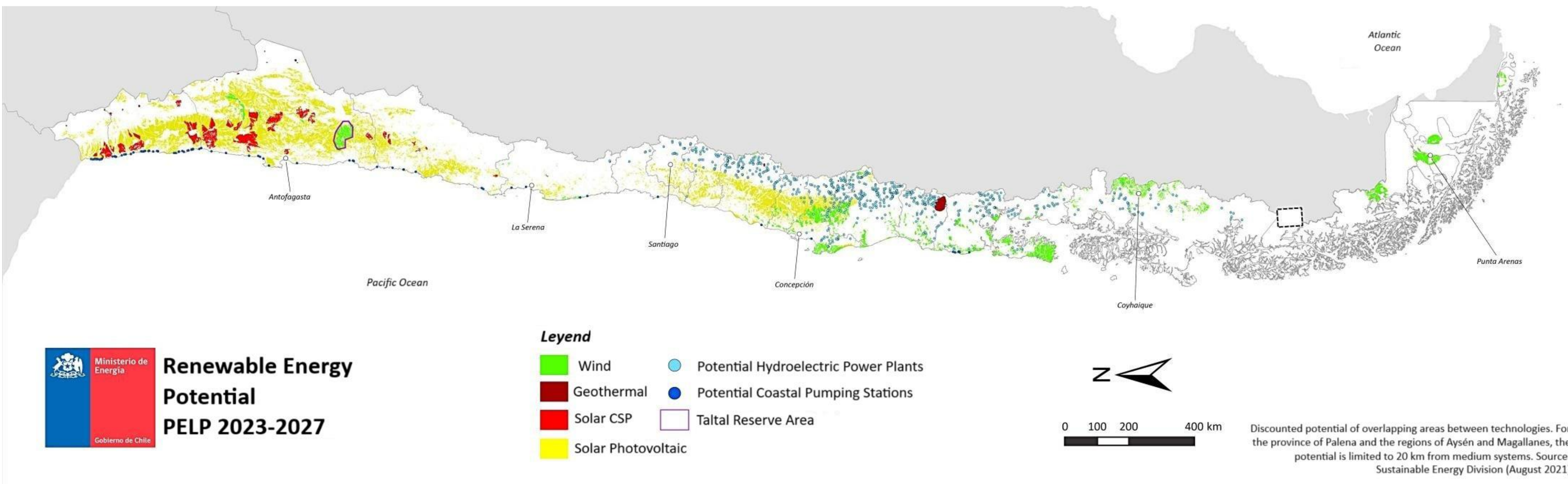
The map contains the technical renewable potential for all the regions of the country that have been considered in this opportunity, which is analyzed from the environmental and territorial variables before entering as candidates for the electric optimization model. In order not to consider more than one energy use in each territory, the potential considers discounting overlapping areas between technologies, considering the following prioritization: 1) Wind, 2) Geothermal, 3) Solar CSP, and 4) Solar PV[39].

Regarding the Solar CSP potential, an analysis was performed that optimized the best territories for siting projects based on three configurations: CSP with 6, 9 and 13 hours of storage. The total potential for energy planning purposes is presented below.

Table 4: Total potential (GW) by technology.

TECHNOLOGY	POTENTIAL (GW)
Solar PV	2.068
Wind	81
Solar CSP	152
Geothermal	4
Hydroelectric	10
Hydraulic Pumping	42
Total	**2.375**

[39] For the province of Palena and the regions of Aysén del General Carlos Ibáñez del Campo and Magallanes and Chilean Antarctica, the potential is limited to 20 km, measured from the transmission or distribution systems in the respective medium-sized systems. In this way, this development of renewable potential at the national level will allow extending the energy planning analysis to regions where the National Electric System is not located.


Atlantic Ocean
Antofagasta
La Serena
Santiago
Concepción
Coyhaique
Punta Arenas
Pacific Ocean
Ministerio de Energía
Gobierno de Chile
Renewable Energy Potential PELP 2023-2027
Leyend
Wind
Geothermal
Solar CSP
Solar Photovoltaic
Potential Hydroelectric Power Plants
Potential Coastal Pumping Stations
Taltal Reserve Area
N
0 100 200 400 km
Discounted potential of overlapping areas between technologies. Fo
the province of Palena and the regions of Aysén and Magallanes, the
potential is limited to 20 km from medium systems. Source
Sustainable Energy Division (August 2021

5.3 TECHNOLOGY INVESTMENT COSTS

Costs of generation technologies

The following are the projections of investment costs of generation technologies where the main sources of information are:

- Generation Technologies Cost Report, National Energy Commission, to adjust the starting point of costs.
- For cost projections, sources such as NREL's *Annual Technology Baseline*[40] and IEA's *Annual Energy Outlook*[41] are used.
- Geothermal technology costs come from the Geothermal Roundtable conducted during 2017 and 2018.

In addition, on this occasion a cost breakdown analysis was performed, identifying what is related to the technological maturation itself, and the components associated with other items, such as land, construction and commissioning in national terrain, among others.

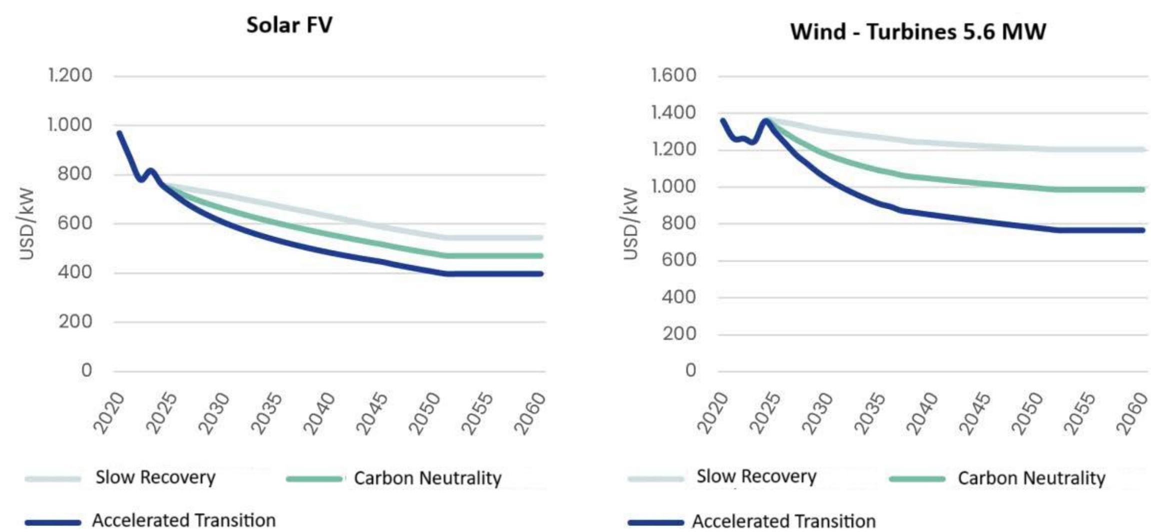


Figure 19: Investment costs of solar photovoltaic and wind generation technologies.

[40] NREL: National Renewable Energy Laboratory.

[41] IEA: International Energy Agency.

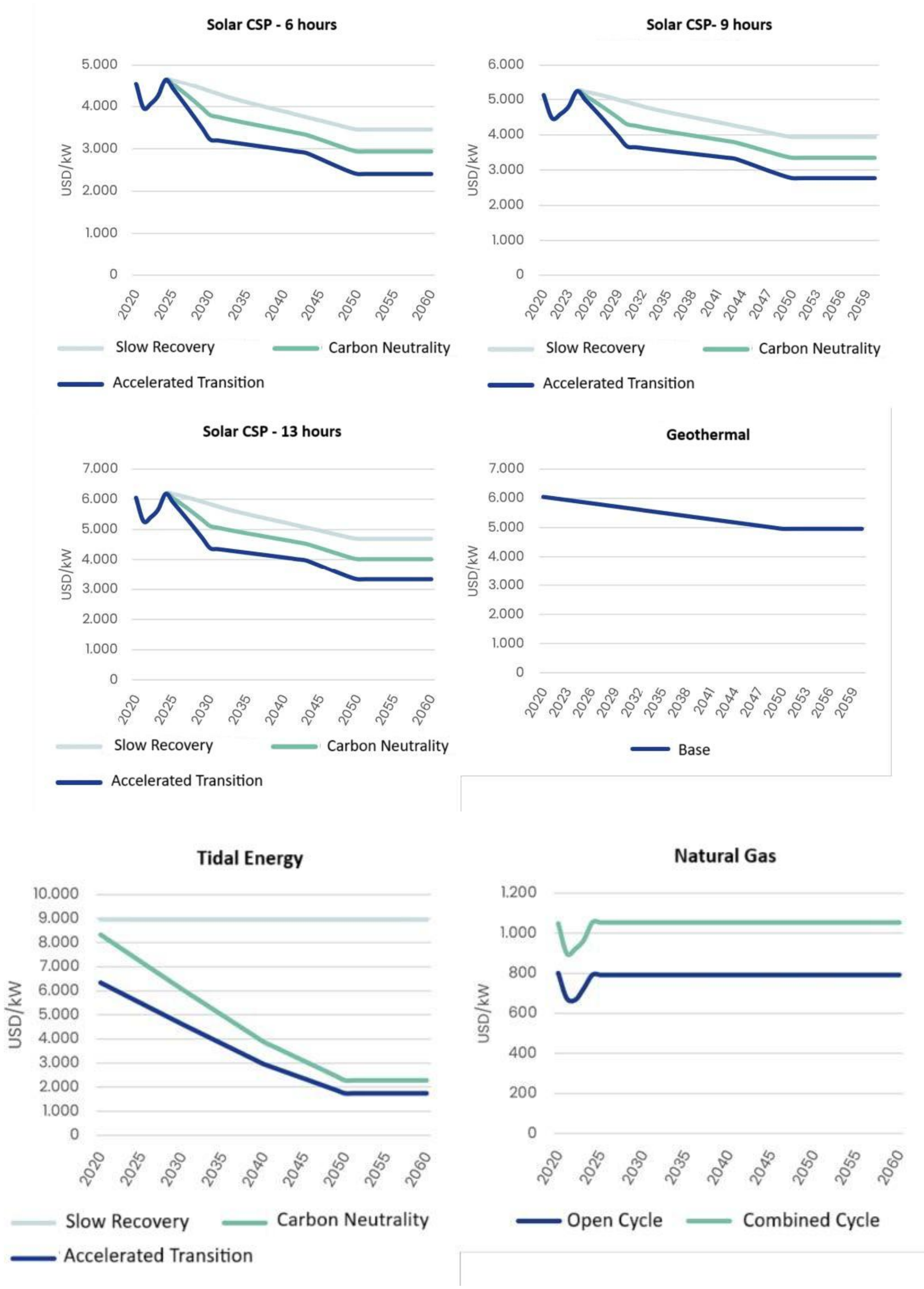


Figure 20: Investment costs of solar CSP, geothermal, tidal and natural gas generation technologies.

Storage technology costs

The following are cost projections for storage technologies, where the main source is the U.S. National Renewable Energy Laboratory (NREL).

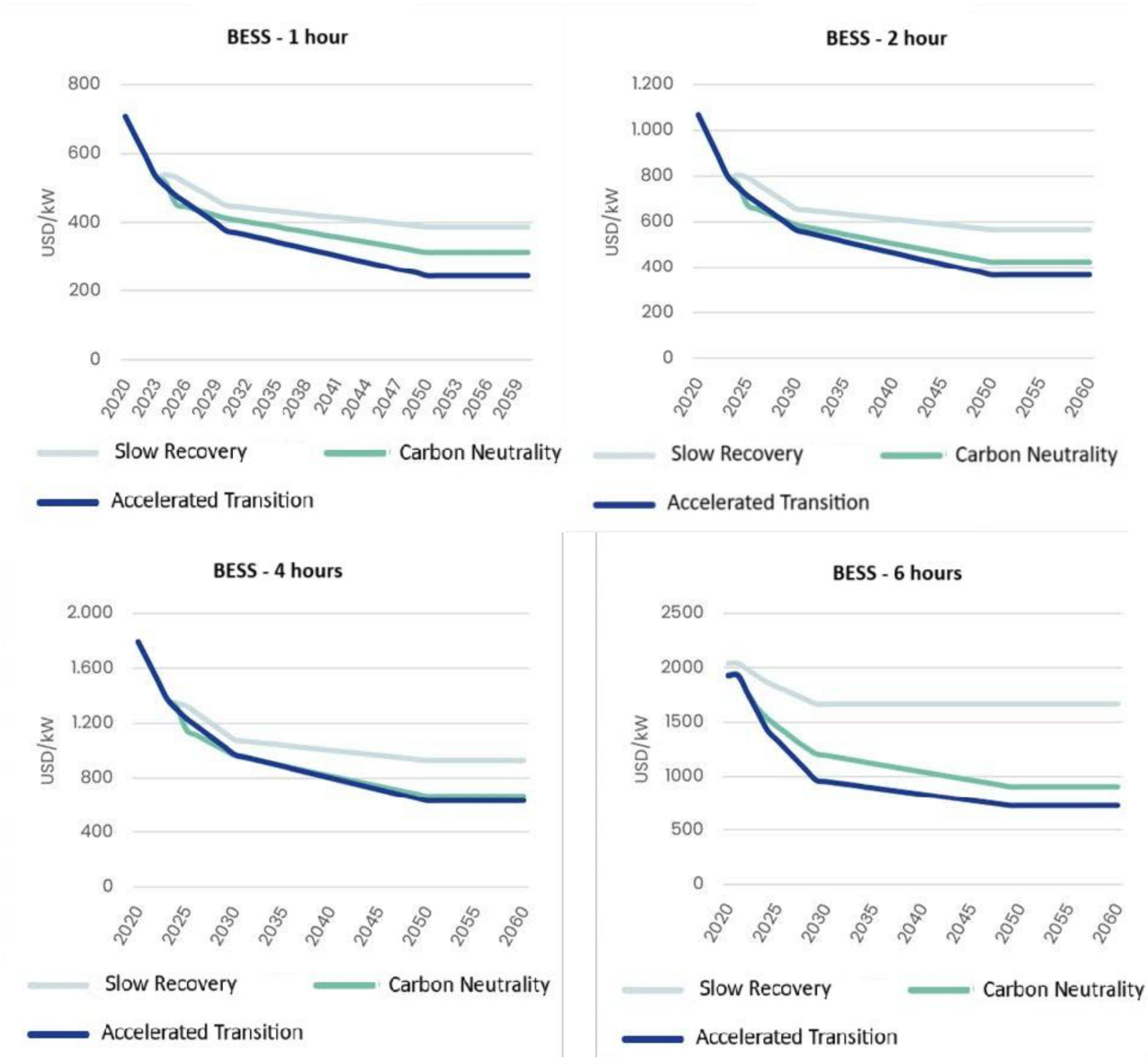


Figure 21: Investment costs of 1-, 2-, 4-, and 6-hour BESS storage technologies.

Figure 22: Investment costs of 8-hour BESS storage technologies, compressed air storage and hydraulic pumping.

5.4 FOSSIL FUEL PRICES

This section presents fossil fuel price projections. The main source of information is the methodology published by the CNE, based on the U.S. Department of Energy (DOE).

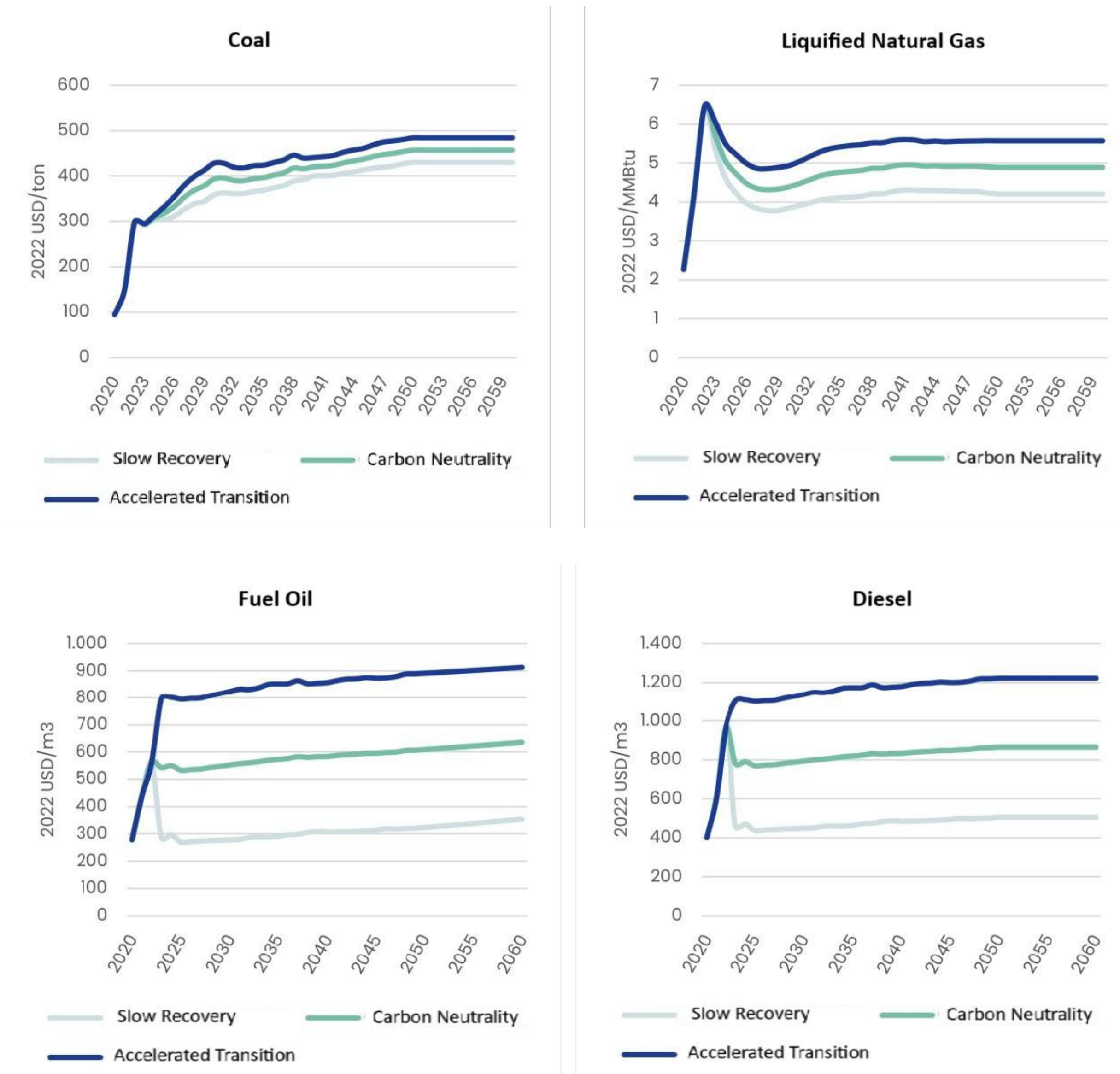


Figure 23: Fossil fuel price projections (2022 USD/ton)

All of the above graphs show the impact of the war in Ukraine on the price of fossil fuels used in power generation. Thus, some international sources mentioned above indicate that these price increases could be maintained in the long-term, while other more optimistic sources point to a drop in prices to pre-war levels.

5.5 TRAJECTORY OF RETIREMENT AND/OR RECONVERSION OF COAL-FIRED POWER PLANTS

Three coal-fired power plant retirement trajectories have been established for the purpose of evaluating the energy scenarios of the 2023-2027 PELP. To generate these trajectories, both the Public-Private Agreement for the Retirement and/or Reconversion of Coal-Fired Plants (2019)[42], held between the Government of Chile and the companies that own coal-fired plants, as well as the Exempt Resolutions of the CNE, the public announcements made by the companies regarding retirement and/or reconversion, and the potential effects of the new emission limit requirements of the expected regulations, have been taken into account.

In particular, the Carbon Neutrality scenario is constructed taking into account this information, and is sensitized in such a way that the installed capacity of power plants decreases to zero before (Accelerated Transition scenario), or after (Slow Recovery scenario) it, as presented in Figure 24 . Thus, the Slow Recovery scenario considers a total retirement of coal-fired plants by 2040, while the Carbon Neutrality scenario considers total retirement by 2035, and the Accelerated Transition scenario considers total retirement by 2033, all with a steep retirement slope during this decade.

The plants that have been considered as reconverted in the three scenarios are the following:

- Mejillones Electric Infrastructure (IEM): modeled as a reconversion to gas, in accordance with its Environmental Qualification Resolution (RCA). In the model, such reconversion starts operating as of 2026, according to the CNE Exempt Resolution[43]
- Hornitos: Modeled as a reconversion to biomass, according to its RCA. In the model, such reconversion begins to operate from 2026, according to the CNE Exempt Resolution .[44]
- Andina: Modeled as a conversion to biomass, according to its RCA. In the model, such reconversion begins to operate from 2026, according to the CNE Exempt Resolution .[45]
- Guacolda: Modeled as a reconversion to *co-firing* that progressively advances. Thus, by 2030, it is considered with a 30% ammonia contribution in two units (U1 and U2), while by 2033 it is considered with a 50% ammonia contribution from its five units (U1, U2, U3, U4 and U5).
- Angamos: Modeled as a conversion to Carnot Batteries in its two units according to its RCA[46] . In the model, both units cease their

[42] Available at: https://energia.gob.cl/sites/default/files/decreto_exento_n_50.pdf

[43] More information available at: https://www.cne.cl/prensa/prensa-2024/3-marzo-2024/cne-aprobo-solicitud-de-exencion-de-plazo-a-engie-energia-chile-para-reconversion-de-central-a-carbon-en-mejillones/

[44] Exempt Resolution No. 468, of 2024, of the National Energy Commission.

[45] Idem.

[46] RCA available at: https://seia.sea.gob.cl/archivos/2023/12/12/Proyecto_Alba.pdf. More information available at: https://seia.sea.gob.cl/expediente/ficha/fichaPrincipal.php?modo=normal&id_expediente=2157280115

operation in the last block of 2025 and a Carnot Battery expansion candidate emerges for each unit in 2026.

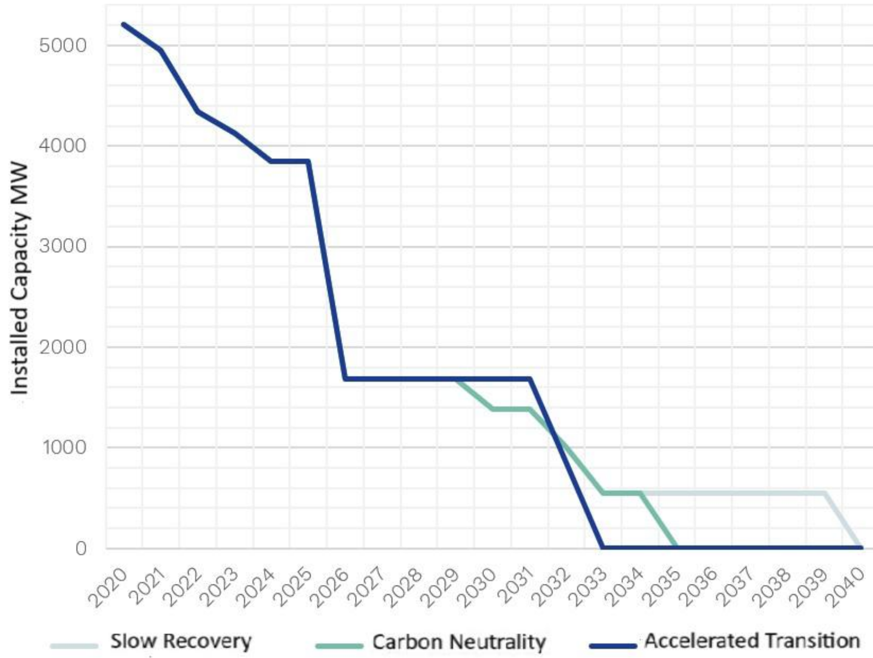


Figure 24: Trajectory of installed capacity of coal-fired power plants under the three simulated scenarios.

It should be noted that this is a prospective exercise that is incorporated in the electric model of the Long-term Energy Planning and materializing these retirement and/or reconversion routes requires in-depth work and exhaustive procedures that involve a series of decisions and institutions, such as the National Electric Coordinator, the National Energy Commission and the Superintendence of Electricity and Fuels, in addition to the companies that own the plants themselves.

5.6 EMISSIONS TAX TRAJECTORY

Law No. 20.780, tax reform of 2014, through its Article 8°, introduces an annual tax to fiscal benefit that will tax air emissions of particulate matter (PM), nitrogen oxides (NOx), sulfur dioxide (SO2) and carbon dioxide (CO2), produced by establishments whose fixed sources, made up of boilers or turbines, which individually or as a whole, add up to a thermal power greater than or equal to 50 MWt (thermal megawatts) of nominal thermal power, considering the upper limit of the energy value of the fuel. Law No. 21,210, on tax modernization approved in 2020, through its Article 16°, replaced the technical threshold (50 MWt) by an emissions threshold, taxing establishments whose emitting sources that individually or as a whole emit 100 or more annual tons of particulate matter (PM) or 25,000 or more annual tons of carbon dioxide (CO2). This new limit, together with other modernization changes such as the emissions compensation system, came into effect in 2023.

Overall, the green tax on stationary sources in Chile has taxed, on average, 31.6 million tons of CO2 per year and more than 34 thousand tons of local pollutants since its entry into force. Likewise, it has collected more than 1,109 million USD for

CO2 and more than 146 million USD in local pollutants, where 97% of the accumulated collection comes from the "Generation" sector. From a territorial perspective, the commune of Mejillones (Antofagasta) is the one with more taxed emissions, followed by Coronel (Biobío), Huasco (Atacama), Puchuncaví and Quillota (Valparaíso) and Tocopilla (Antofagasta).

It should be noted that in 2023, with the entry into force of the new emissions limit, the electric generation segment will account for 67% of the emissions tax collection, since new emission-intensive items, such as cement, glass, foundries, began to be taxed, modifying the sector's contribution.

In order to capture the cost of the externality produced by pollution from fossil fuel power generation sources, an increasing trajectory of the emissions tax on taxed sources is considered.

For the purposes of the electric projections, three increasing paths of the emissions tax (CO2 only) were used, considering the following assumptions:

- Incorporation of the value to the variable cost: all scenarios consider the value of the emissions tax the year 2028 with the current value of 5 USD/tonCO2, in order for the electric generation dispatch to consider this levy.
- After 2028, each scenario has an annual increase with different rates, being these more pronounced from 2034.
- Finally, by 2040, values of 20, 35 and 40 USD/tonCO2 are reached for this Slow Recovery, Carbon Neutrality and Accelerated Transition scenario, respectively. These values are then held constant for modeling purposes but could change depending on conditions and further discussions on this instrument.

It should be noted that the Ministry of Energy's own analysis indicates that an increase in the value of the tax on emissions could lead to an increase in electric tariffs for end customers (free and regulated). In this sense, and notwithstanding the importance of making progress in improving the corrective tax, it is essential that these measures be associated with tariff protection mechanisms and the strengthening of existing public policies, with a special focus on the most vulnerable customers and where the distributive impacts are concentrated.

On the other hand, an increase in the value of the tax on emissions should not be analyzed in isolation, but as part of a package of policies and instruments that allow giving an economic value to the externalities of fossil fuel-based generation sources, such as the Voluntary Agreement for the Retirement and/or Reconversion of Power Plants, where external analyses have valued it at approximately 20 USD/ton/CO2[47].

[47] An example of this is the analysis of the Chilean Association of Renewable Energies and Storage A.G. (2022). Available at: https://www.acera.cl/wp-content/uploads/2023/07/2022-Estudio-Cero-Emisiones.pdf

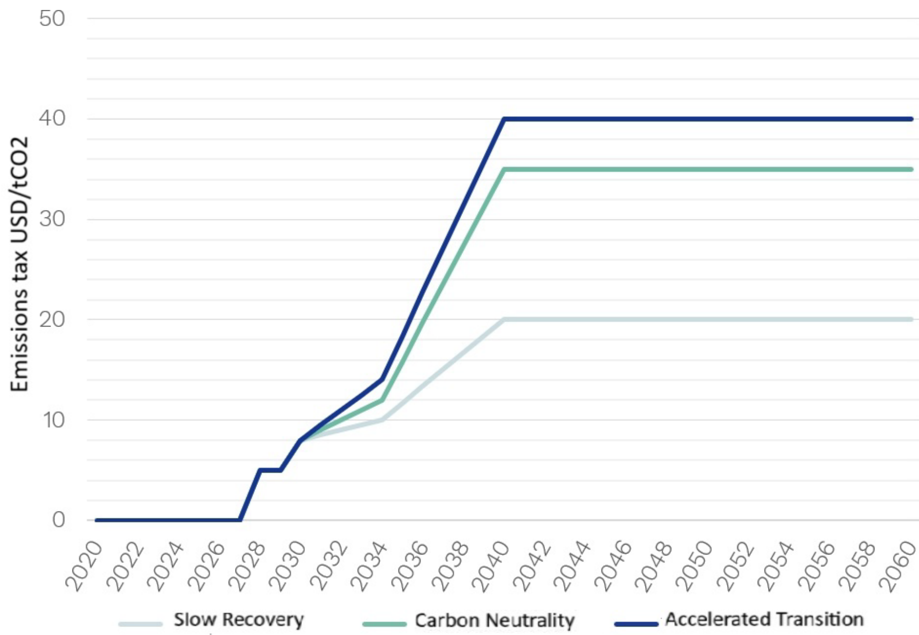


Figure 25: CO2 emission tax trajectories under the three simulated scenarios .[48]

5.7 POWER SYSTEM MODELING

This section presents the assumptions and relevant information for power system modeling.

Distributed generation

The projections that estimate the integration of distributed generation to 2060 in the PELP, under a *NetBilling* style concept, are based on an internal development that considers the NREL methodology and its Pysam library. This tool considers an agent-based model (ABM) that interacts between the residential, commercial and industrial sectors, differentiating each of the country's regions for the adoption of photovoltaic technology. For this, the penetration level of previous years is considered, in addition to GDP projections, energy prices, investment costs, geo-referenced plant factor and electric demand.

Transmission Grid

Given the development, processing and construction times of new transmission projects, it has been considered that for the decade 2020-2034 the structural transmission system can be expanded only with expansions and/or reinforcements of up to 500 MW of capacity.

From the year 2035, the possibility of developing transmission projects with higher capacity of up to 1500 MW is considered. By 2040, a new possibility is enabled for

[48] It should be noted that between 2020 and 2027 the emissions tax appears with cost 0 USD/tonCO2 because it is outside the calculation of the variable cost, being null for the purposes of the model.

expansion for an additional 1500 MW. Finally, by 2050, an additional 1000 or 2000 MW are enabled, depending on the area. Thus, the capacity of the expansion candidates between the different nodes of the system is in the range between 4300 to 6000 MW, depending on the nodes considered.

Regarding the transmission network flow, a linearized DC flow was considered, with impedances analogous to those of the reduced network used by the National Electric Coordinator[49] , taking care that the capacities are also analogous. These capacities are related to the compliance with the N-1 criterion and the joint distribution of the 220 and 500 kV system.

Operating constraints

In order to represent some of the operating challenges that the system faces and will face in the medium and long-term with the massive entry of variable renewable generation, a primary and secondary reserve restriction was considered, considering the most unfavorable case according to the Complementary Services Report year 2025[50] (December 2024 version), issued by the National Electric Coordinator. This restriction was considered the same for all the hourly blocks simulated, given that there is no projection methodology for these reserves.

Thus, the reserve amounts for primary control of upstream and downstream frequency (CPF+ and CPF-, respectively), and secondary control of upstream and downstream frequency (CSF+ and CSF-, respectively) are presented in Table 5 , below.

Table 5: Requirements for primary and secondary frequency control.

CPF+ Reserve [MW]	CPF- Reserve [MW]	CSF+ Reserve [MW]	Reserve CSF- [MW]
331	85	220	322

Hourly blocks

Each year was modeled using one representative day per month, with an hourly resolution. This allows to adequately capture the opportunities that the system has to supply demand variations by making use of energy from lower cost blocks. This can be achieved through the matching of available instantaneous generation, as well as through energy storage, for which it is necessary to have at least an hourly resolution, since short duration storage alternatives (1 to 2 hours) are available.

In addition, having an hourly resolution makes it possible to better represent the intraday variation of emerging consumptions, such as electromobility, air conditioning and green hydrogen.

[49] Reduced network of the NES Storage Study, available at https://www.coordinador.cl/wp-content/uploads/2023/09/2308-Estudio-de-Almacenamiento-2023.pdf.

[50] Complementary Services Report 2025, available at https://www.coordinador.cl/wp-content/uploads/2024/12/2024.12.20-Informe_SSCC_2025.pdf.

Synthetic hydrology with climate change

According to what was raised in the different PELP participatory workshops, and to the dry hydrological conditions of recent years, hydrological series that include the effect of climate change were considered, which are also used by the National Energy Commission in its planning processes .[51]

This hydrological series was generated using global general circulation models (MIROC-ESM CHEM model under a RCP 8.5 scenario) and calibrated hydrological basin models for the modeled plants. This series corresponds to a dry hydrology.

Wind and solar production profiles with climate change[52]

In the wind and solar photovoltaic generation profiles, the effect of climate change was included, allowing a better representation of this resource in the long-term. This was done by means of a study which, through global general circulation models (GCM), adjusted to the information on renewable potentials held by the Ministry of Energy, incorporated the effects of climate change on environmental variables into the wind and solar photovoltaic profiles.

These profiles have an hourly resolution and were selected using clustering techniques to identify representative profiles by month.

Electric demand profile

Electric demand is presented disaggregated according to four uses: the first corresponds to the demand for traditional uses, which has been extensively studied, while the others correspond to demand for electromobility, air conditioning, and green hydrogen production, and have an emerging demand character, whose profiles are still under study.

The profiles for air conditioning and electromobility were studied and projected in an undergraduate thesis of the University of Chile called *"Elaboration of demand profiles at distribution level for consideration in Long-term Energy Planning*".

H2V and Ammonia Production

Given the existing uncertainty regarding H2V production profiles, both for final consumption and ammonia production, profiles were determined that made use of a systemic cost minimization while meeting annual production goals.

[51] The hydrological series come from the study "Analysis of the Hydrological Statistics used in the processes of the National Energy Commission", available at https://www.cne.cl/wp-content/uploads/2020/12/Estudio-An%C3%A1lisis-de-la-Estad%C3%ADstica-Hidrol%C3%B3gica.pdf.

[52] This work was carried out together with the Adolfo Ibañez University and the ORECC (Operation Research in Energy & Climate Change) ring project team, with whom Big Data techniques are also being incorporated on the profiles of renewable generation with Climate Change, which will be implemented in the PELP process.

Thus, in a first step, the optimal H2V production profile in terms of cost minimization is determined by running the power system expansion model. In this modeling, restrictions are considered in the H2V production that will supply the ammonia synthesis, since this H2V production is more inflexible, given the technical minimums and ramps of the Haber-Bosch process, as well as the hydrogen storage costs for this process.

Then, a variable production profile is obtained, which is used as an electric demand parameter for H2V production as an end-use, or for H2V production to synthesize ammonia, in the NES expansion determined by the model.

Storage

In order to better identify the fundamental role that storage solutions will play in electric systems, several types of technological solutions were modeled as storage candidates, which are listed below:

1. BESS type batteries, whose storage capacity varies between 1, 2, 4, 4, 6 and 8 hours, with an efficiency of 92% in the full charge cycle.
2. Compressed air solutions (CAES), which have a storage capacity of 4 hours with an efficiency close to 60%.
3. Carnot battery, which have a storage capacity of 4 or 12 hours, with an efficiency of 36%. This option was considered as a candidate for coal-fired plants that have indicated their interest in converting.
4. Hydraulic pumping plants in the northern part of the system, based on information that has been gathered by the Ministry of Energy regarding the potential that could be developed in the country.

Additionally, the works plan was updated incorporating the latest information available on storage projects to be installed in the following years.

Solar CSP Technology[53]

Three types of configurations for solar CSP technology were integrated, each with a different purpose. The first is a version with 6 hours of storage, whose purpose would be to be available at *peak* hours of the system, another with 13 hours of storage to be dispatched day and night, and an intermediate one with 9 hours of storage.

These configurations were built with SAM software, which not only generates a detailed definition of each part of the plant, but also generates a list of cost items of a typical project, allowing to obtain an investment cost that is used as a starting point for the respective investment cost trajectories.

[53] This work was developed together with CORFO, represented on that occasion by the Solar and Energy Innovation Committee and together with the Fraunhofer Chile team, with whom it was possible to generate thermal production profiles (under the tower and before salt storage) of CSP solar power plants, and for each of the locations where this technology is most efficient.

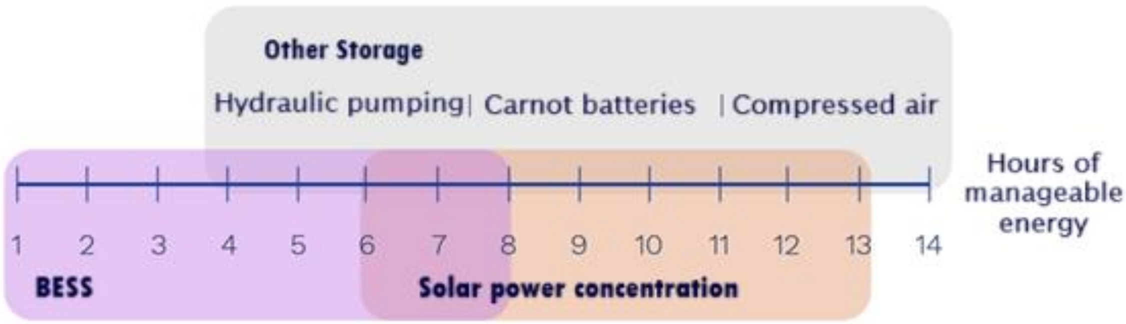


Figure 26: Storage technologies available as expansion candidates and their duration.

5.8 POWER SYSTEM MODELING RESULTS

This section presents the results of the electric projections.

Distributed generation

The distributed generation projections, obtained through agent-based modeling, are presented in Figure 27. It is worth mentioning that the modeled distributed generation means correspond to solar PV installed on rooftops, while PMGD means generation is entered in the model as stand-alone plants in their respective bus.

Distributed generation projections are discounted from the electric demand that enters the NES expansion electric model, according to the corresponding block, assuming that this capacity is fully utilized to prevent consumption.

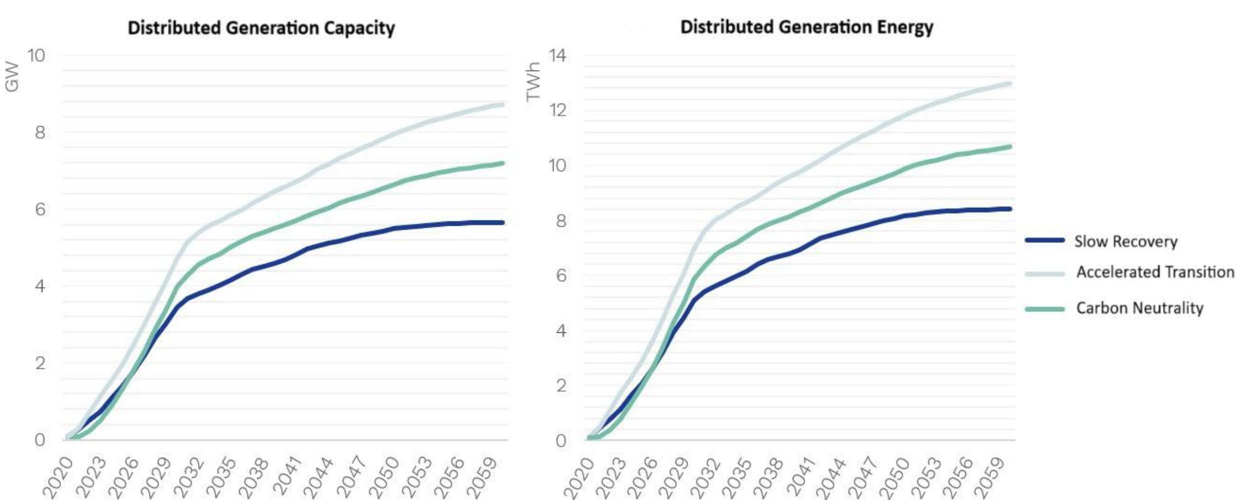


Figure 27: Installed capacity (left) and generation (right) corresponding to distributed generation facilities for the three scenarios modeled.

Electric demand

The electric demand that enters the NES expansion model is presented in Figure 34 for each year of the simulation horizon. In turn, the section on Daily demand and generation curves presents the hourly demand curves for this annual demand (Figure 34 to Figure 40).

It should be noted that, from the year 2035, the demand component related to H2V production starts to be predominant in the three scenarios, being higher than the rest of the emerging demands, such as electromobility and air conditioning.

This demand is entered into the NES expansion model, considering a scaling factor of 3.1%, seeking to represent the losses through this factor. The data reported in the database corresponds to the demand prior to the application of this scaling factor.

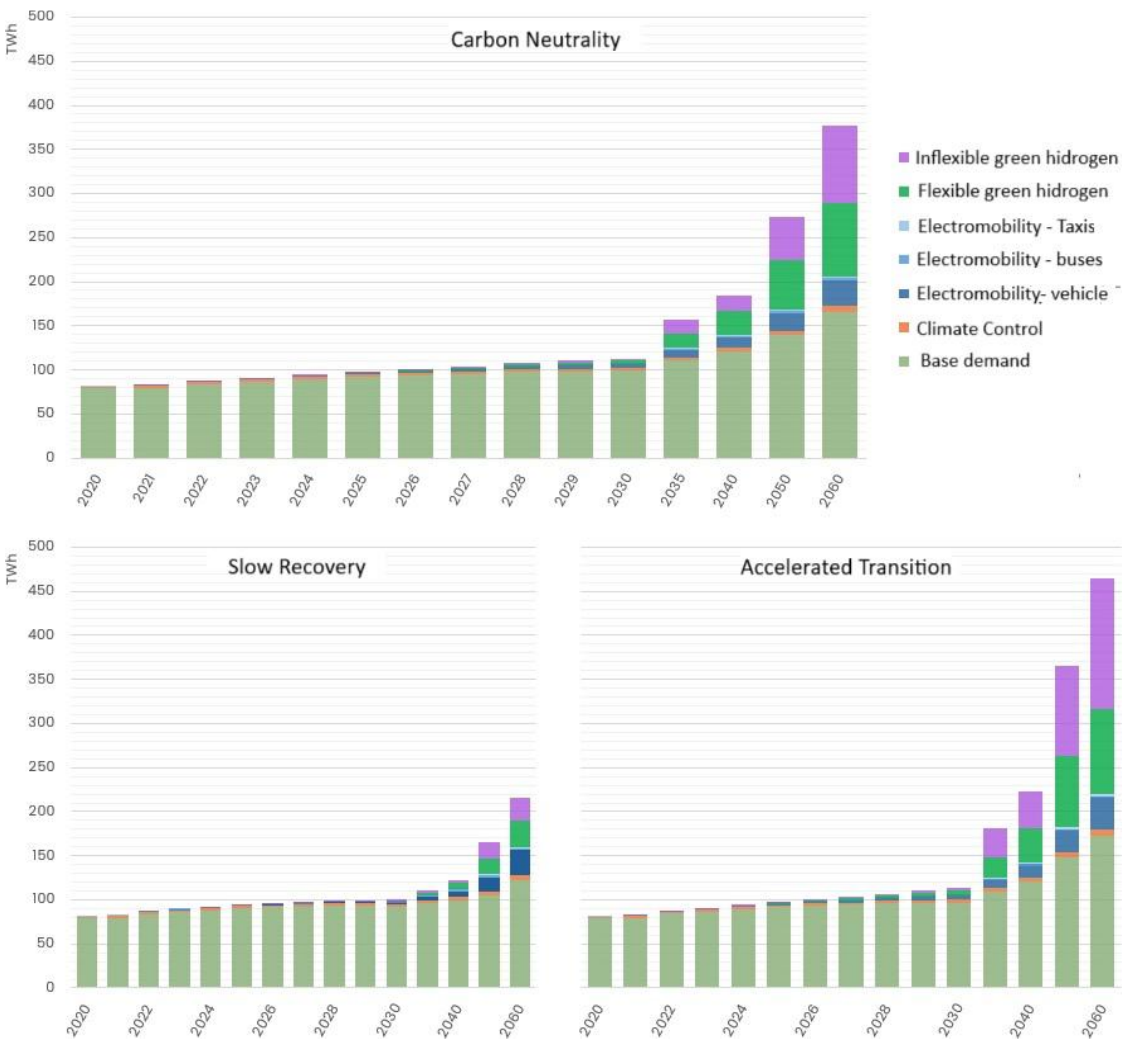


Figure 28: Annual electric demand and its components under the three simulated scenarios.

In the case of air conditioning and electromobility, their projection is defined based on the energy projection of these uses and an expected hourly distribution of these uses, while the case of hydrogen is detailed in Annex 8.5.

Installed capacity

The installed capacity of the National Electric System is shown in Figure 29 , indicating a sustained development of renewable energy sources, mainly wind and solar energy. This situation is consistent with the projects that have materialized in recent years, and with those that are under construction, where these energetic sources predominate.

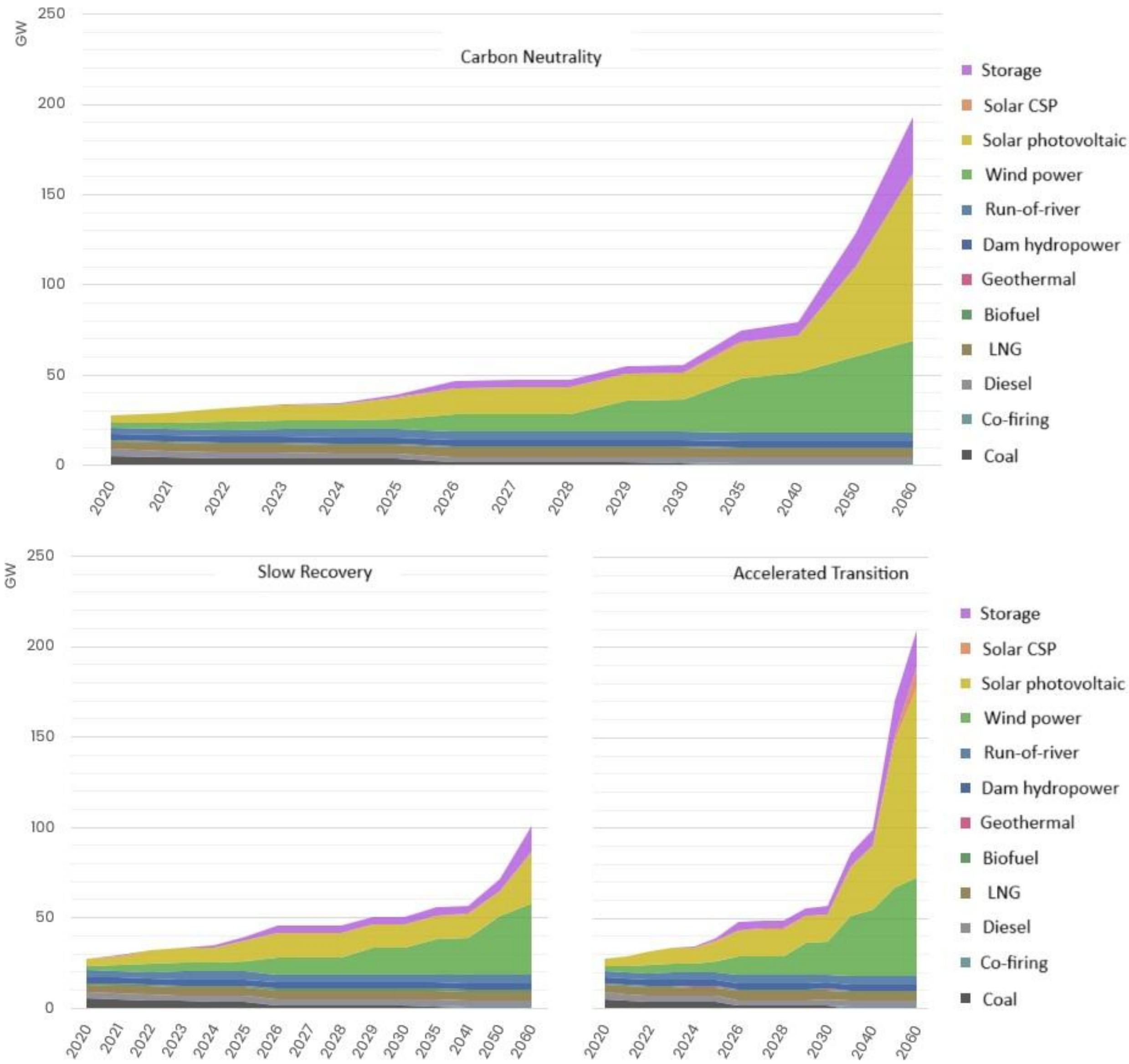


Figure 29: Installed capacity of the NES under the different scenarios.

Additionally, energy storage emerges as a cost-effective attribute for the expansion of the NES based on variable renewable sources. Observing the distribution of accumulated capacity by region, in Figure 30 , it is found that the development of storage occurs in regions with a significant development of solar photovoltaic capacity, highlighting the complementarity between this energy source and the ability to accommodate economic energy blocks towards higher cost hours.

By 2030, the projected need for medium-duration storage, in addition to ongoing development, is projected to range from 2.0 to 2.9 GW, depending on the scenario. Meanwhile, by 2030, the need for generation infrastructure amounts to between 15 and 20 GW, depending on the scenario, which is composed of solar PV and wind alone.

From 2030 to 2050, the north of the country mainly presents a development based on solar photovoltaic energy as shown in Figure 30 , with the exception of the Antofagasta Region, which additionally develops wind energy. On the other hand, the central and southern zone, from the Biobío Region to the south, expands its generation capacity mainly through wind energy.

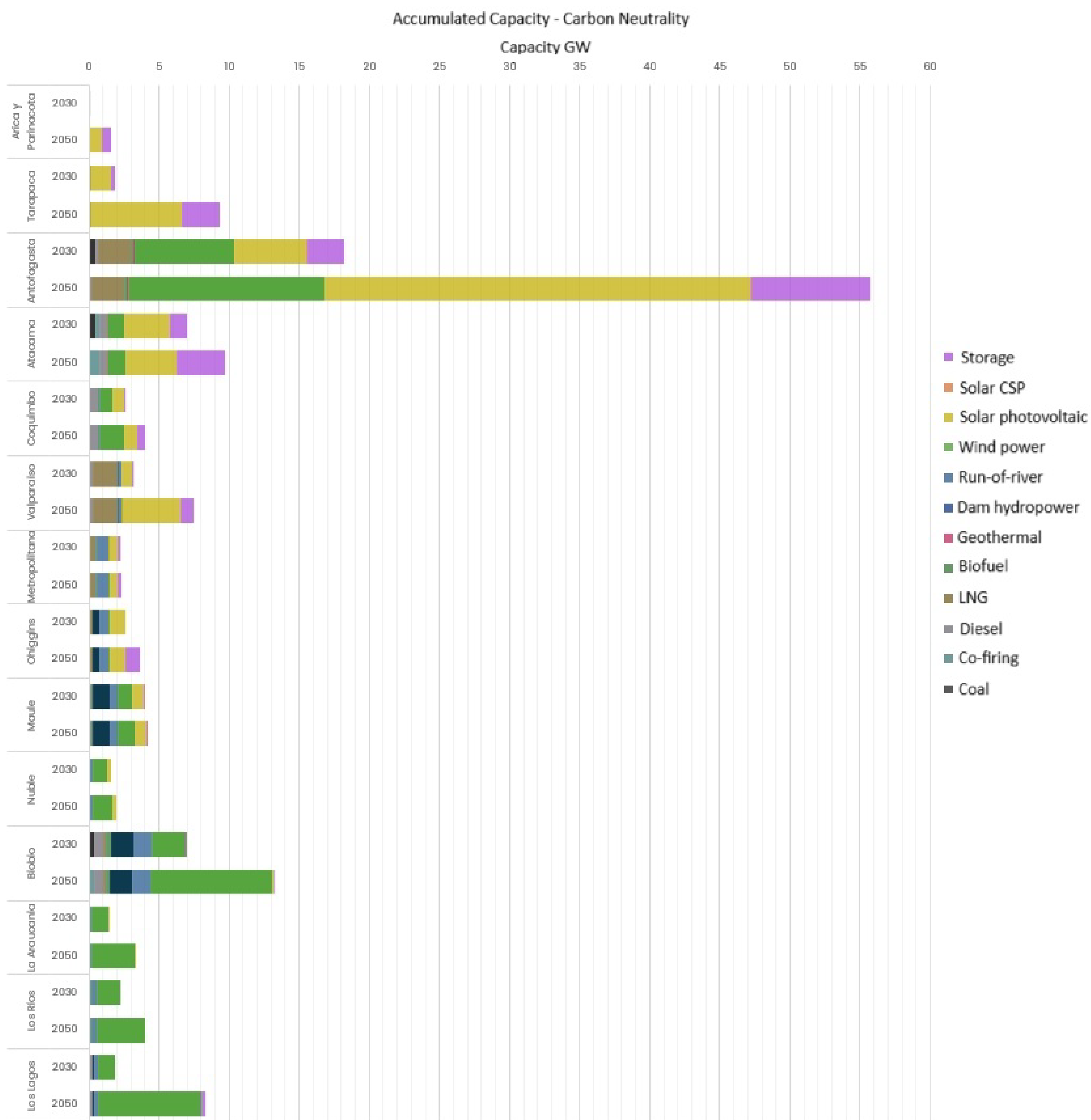


Figure 30: Regional distribution of cumulative installed capacity of the NES under the Carbon Neutrality scenario for the years 2030 and 2050.

The Antofagasta Region maintains its role as the region with the greatest development of investment in electric generation, reaching the installation of 45 GW of generation by 2050, within which are areas identified as Electric Generation Development Poles.

Electric Generation

The trajectories of electric generation by technology, both in absolute terms and in terms of percentage participation, are shown in Figure 31 to Figure 33 . It should be noted that, in all three scenarios, the generation mix exceeds 96% of generation from renewable sources by 2050.

In direct relation to what was presented for the development of new generation infrastructure, in the three scenarios, the generation mix in 2050 is mainly composed of wind and solar photovoltaic energy, with the exception of the Accelerated Transition scenario, which additionally introduces CSP solar technology. In this opportunity, storage was also included (only in discharge mode) to illustrate its magnitude in these graphs, not being discounted when it is loaded.

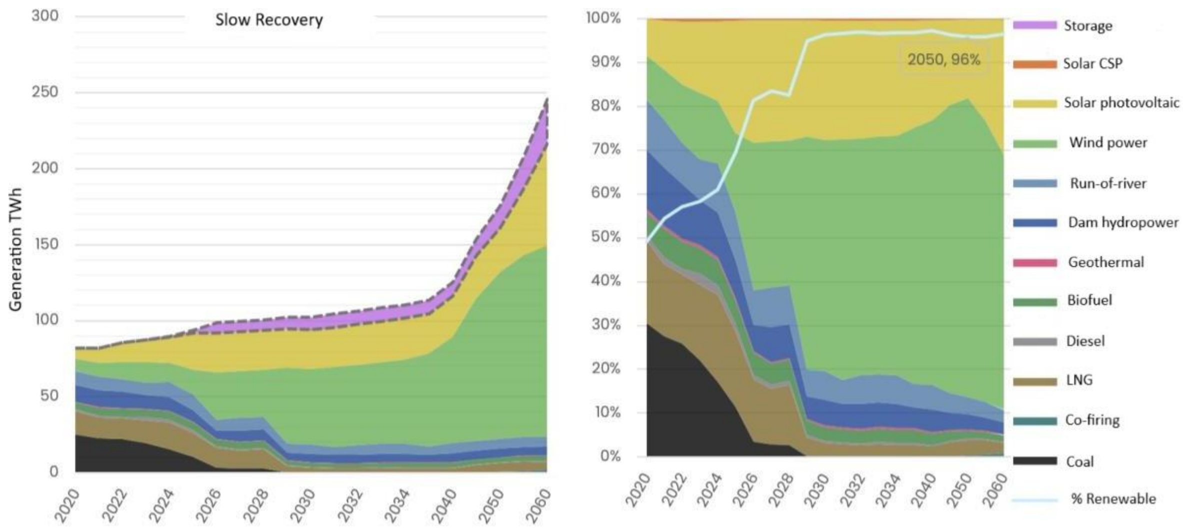


Figure 31: Electric generation and storage (left) and generation mix composition (right) under the Slow Recovery scenario.

Mediated by its operating cost and the emissions tax, LNG undergoes a progression from being dispatched during a large part of the hourly blocks to being dispatched mainly in night blocks. This effect substantially reduces its share in the generation mix as it transitions to more cost-effective sources. For the same reasons, coal-fired plants that have not been reconverted or retired by the end of the decade will not participate in the generation mix as of 2029. Finally, in the case of hydroelectric power plants, their participation in the generation mix is reduced due to the variation induced by climate change, which translates into a progressive decrease of their inflow[54] , and, therefore, of their available energy.

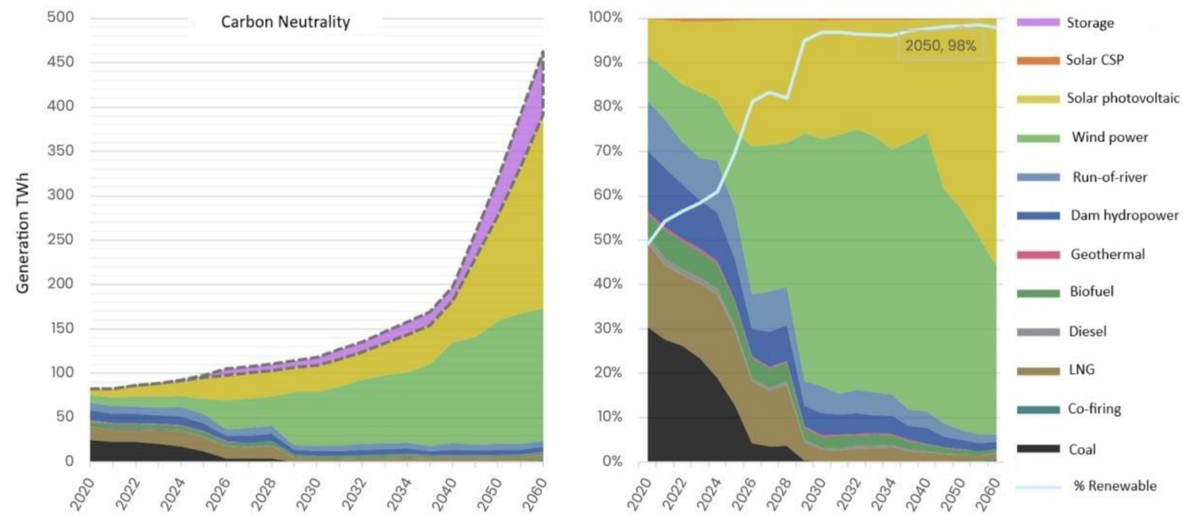


Figure 32: Electric generation and storage (left) and generation mix composition (right) under the Carbon Neutrality scenario.

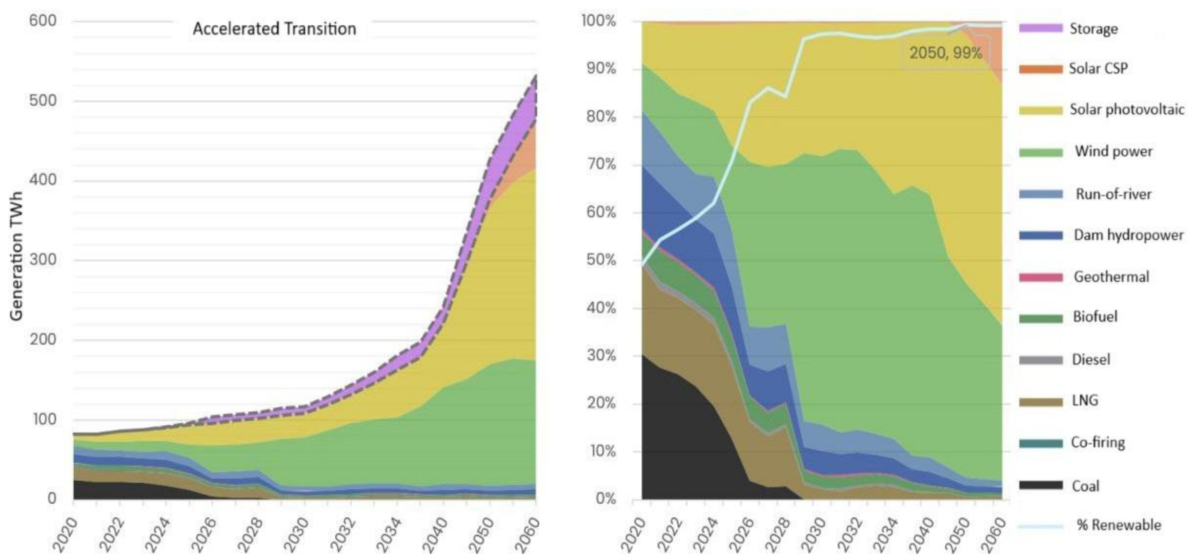


Figure 33: Electric generation and storage (left) and generation mix composition (right) under the Accelerated Transition scenario.

[54] Although a significant decrease in the inflow is projected for several plants in the country, in some plants a smaller decrease is projected, as in the case of Canutillar. In addition to the decrease, changes in seasonality are projected. For more details: https://www.cne.cl/wp-content/uploads/2020/12/Estudio-An%C3%A1lisis-de-la-Estad%C3%ADstica-Hidrol%C3%B3gica.pdf

Daily demand and generation curves

The daily operation curves of the generation and storage infrastructure are presented in Figure 34 to Figure 40 for four representative months of the years 2025, 2030 and 2050, for the three scenarios. In addition, the hourly profile of electric demand separated by its components is presented, which allows understanding which technologies are triggered according to the types of demand.

In Figure 34 shows the operation of the year 2025 under the Carbon Neutrality scenario, in order to present a basis for comparison with the present time. There is a seasonality in the generation profiles marked by the variation of solar photovoltaic energy, which is substantially reduced towards the months of lower irradiance (April and July) in the Figure 34 , being able to be of the order of 4.1 GW lower between these months (approximately 48%). This decrease is compensated by an increase during the daytime blocks of thermal generation in those months, mainly LNG.

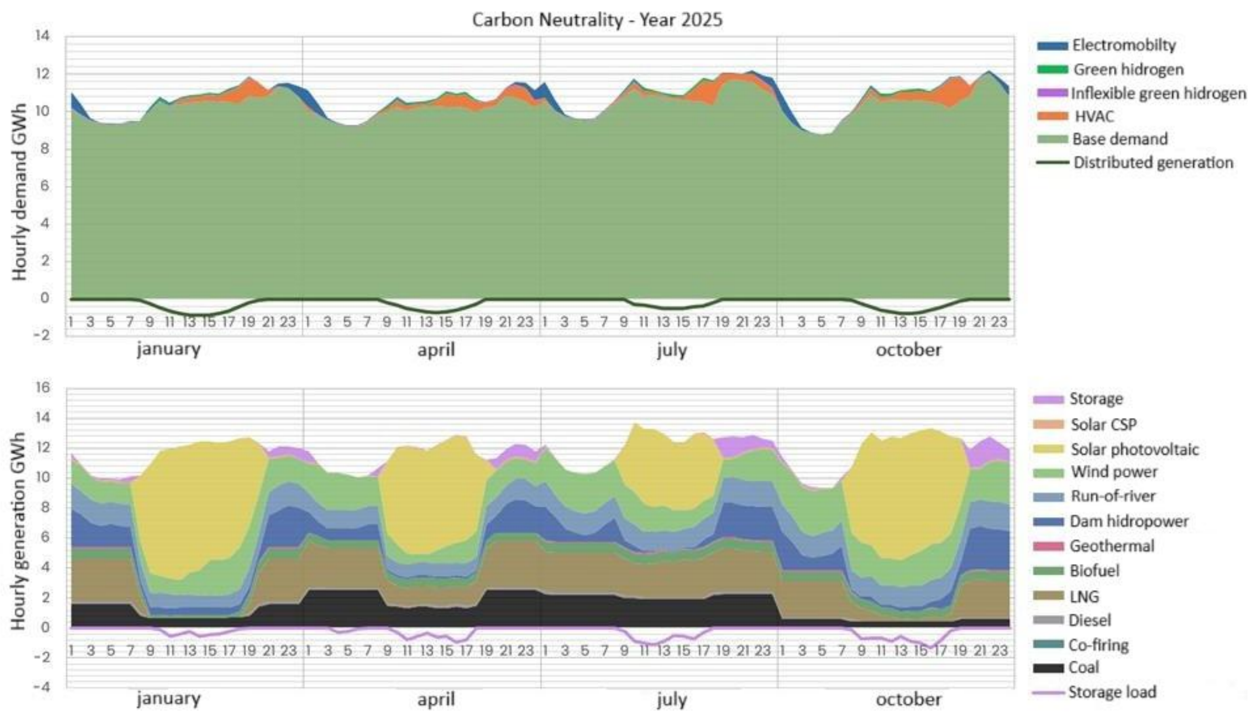


Figure 34: Hourly demand (top) and hourly generation (bottom) for four representative months of 2025 under the Carbon Neutral scenario.

Observing the behavior of storage for that year and scenario, it can be seen in Figure 34 that storage is discharged mainly in the blocks between 20:00 and 01:00, contributing to supply the demand during peak hours, and that its load is carried out mainly during 10:00 and 17:00, when energy is of lower cost during the day due to the operation of solar photovoltaic power plants. This behavior reveals the complementarity of solar PV technology with energy storage, which is also observed in the Figure 34, where a high correlation of storage installation is seen in those areas with higher solar PV generation capacity.

It is worth mentioning that distributed generation has been included in this model by discounting demand on an hourly basis, so that, in the face of a lower incorporation of distributed generation, demand would be higher in daytime blocks, increasing generation with available sources in those blocks, with the possibility of triggering a higher installation of solar photovoltaic energy.

The results of the operation towards the year 2030, presented in Figure 35,Figure 36 and Figure 37, indicate a progressive behavior among the scenarios, where when moving from the Slow Recovery scenario, to the Carbon Neutrality scenario, and finally to the Accelerated Transition scenario, the generation with renewable sources intensifies. This progression is related to the intensification of emerging consumption such as electromobility and green hydrogen.

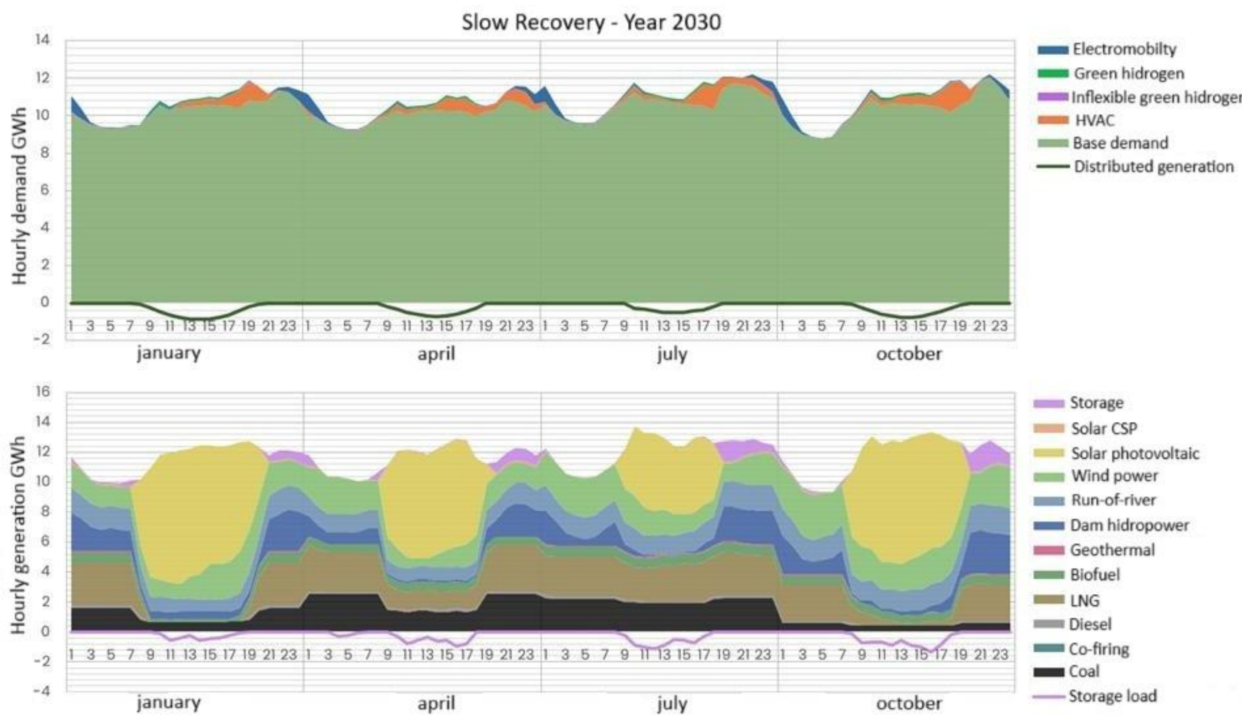


Figure 35: Hourly demand (top) and hourly generation (bottom) for four representative months in 2030 under the Slow Recovery scenario.

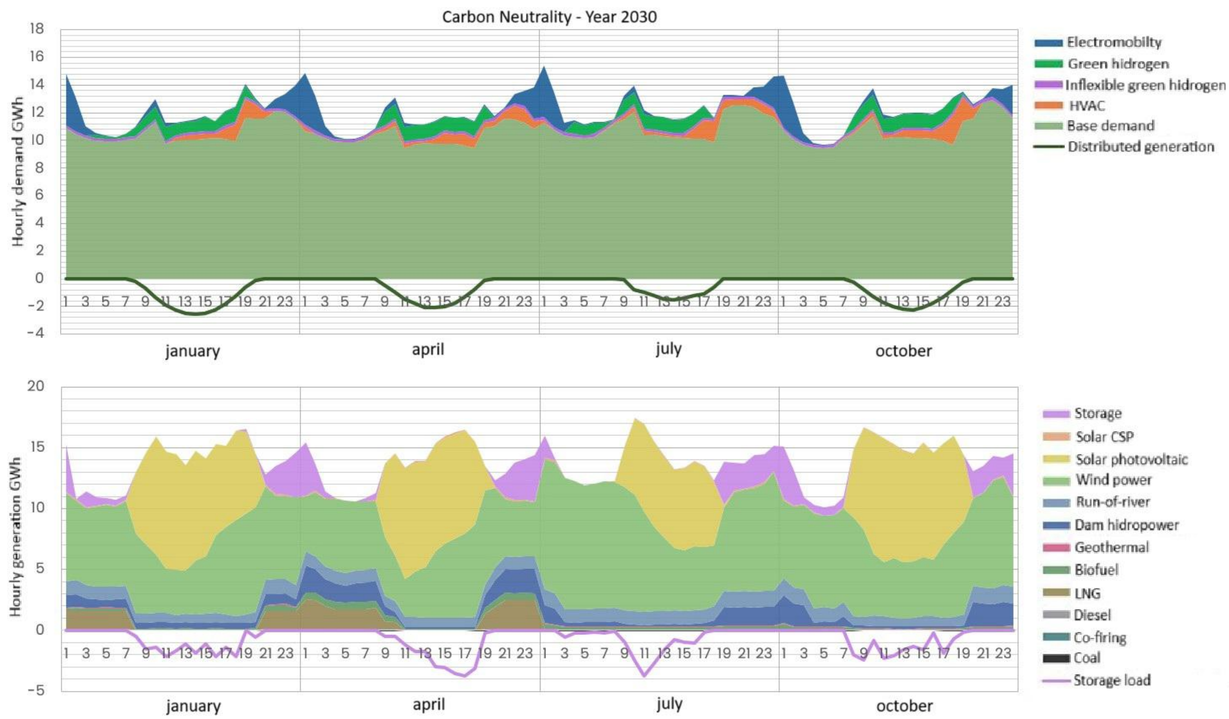


Figure 36: Hourly demand (top) and hourly generation (bottom) for four representative months in 2030 under the Carbon Neutral scenario.

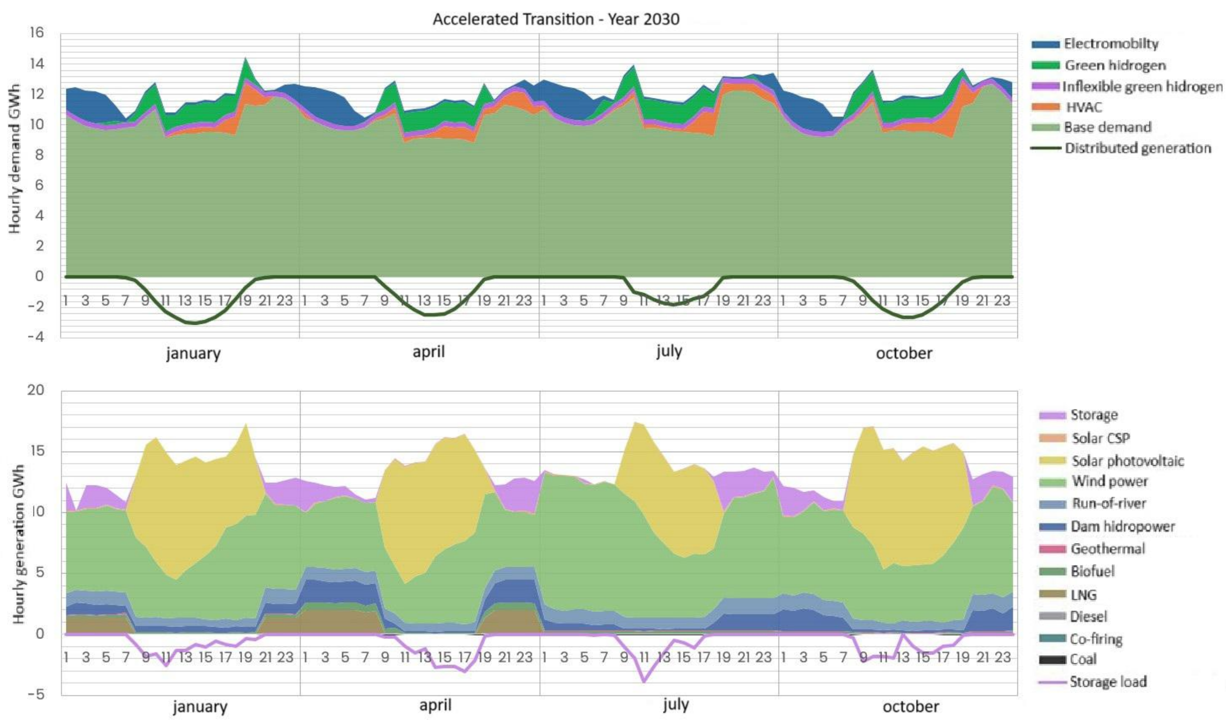


Figure 37: Hourly demand (top) and hourly generation (bottom) for four representative months in 2030 under the Accelerated Transition scenario.

Similar to what was observed for the year 2025, there is a seasonality that reduces solar PV generation in winter months. However, unlike the case seen for 2025 (Figure 34), in 2030 this seasonal reduction is compensated by wind energy, limiting the role of fossil fuel generation to nighttime generation when wind generation decreases seasonally. Such fossil fuel generation is economically provided by LNG, so that coal is economically displaced from the electric matrix by 2030.

The results of the operation towards the year 2050, presented in the Figure 38,Figure 39 and Figure 40, present a regime difference between the scenarios, where the emerging consumptions change the dynamics of the intraday operation. In particular, it is observed that in the Carbon Neutrality and Accelerated Transition scenarios there is a strong correlation of flexible hydrogen production with solar PV generation, while in all three scenarios there is a high correlation between storage discharge and electromobility consumption in the night blocks. In turn, storage charging behavior is exacerbated during daytime blocks. However, in the Slow Recovery scenario, storage is also charged during night blocks by wind energy.

Finally, by the year 2050, as we progress from the Slow Recovery scenario to the Carbon Neutral scenario, and finally to the Accelerated Transition scenario, we observe a progressive reduction of fossil-based generation, which by that time is very minor and mainly supportive when renewable sources decrease their contribution. Additionally, this progression shows a marked development of solar photovoltaic contribution, which accelerates during the 2040s onwards, as shown in Figure 38 to Figure 40.

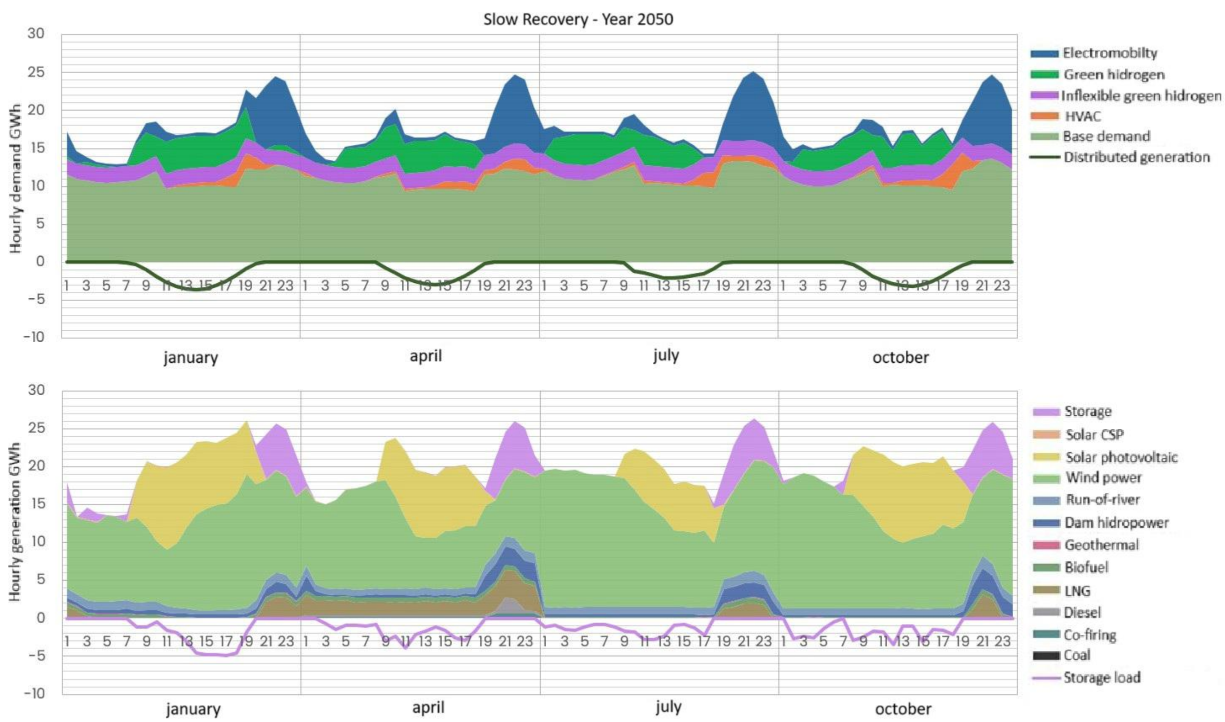


Figure 38: Hourly demand (top) and hourly generation (bottom) for four representative months in 2050 under the Slow Recovery scenario.

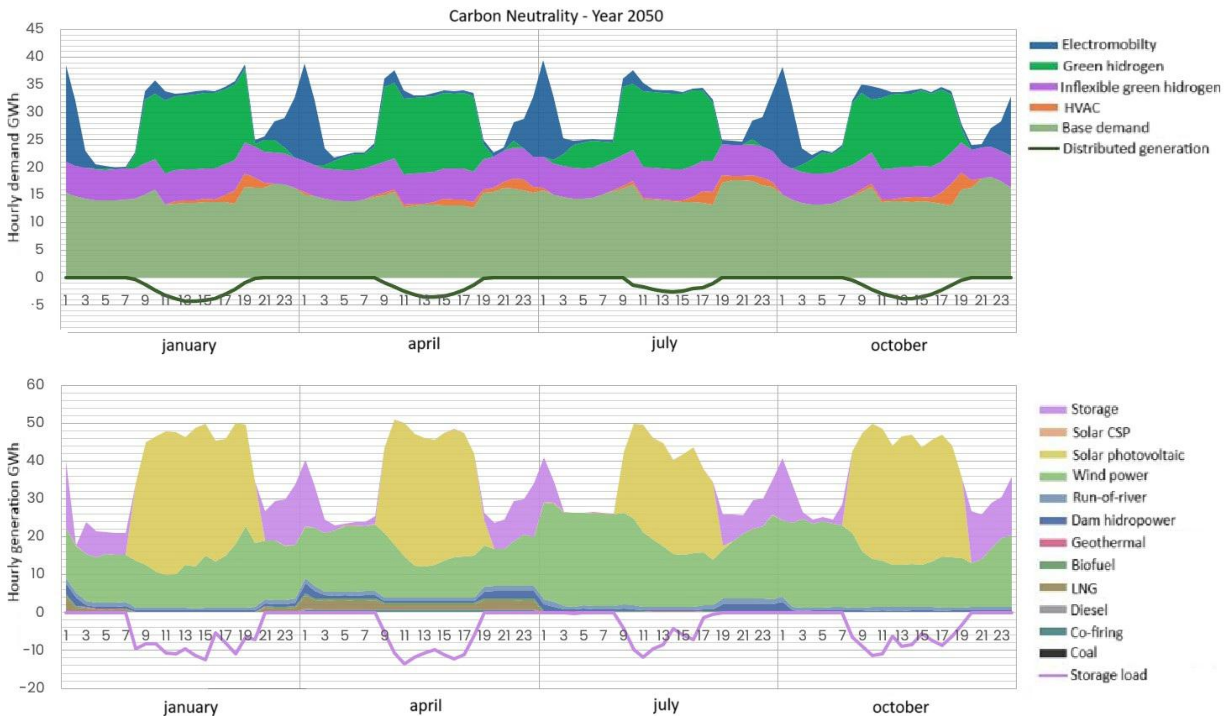


Figure 39: Hourly demand (top) and hourly generation (bottom) for four representative months in 2050 under the Carbon Neutral scenario.

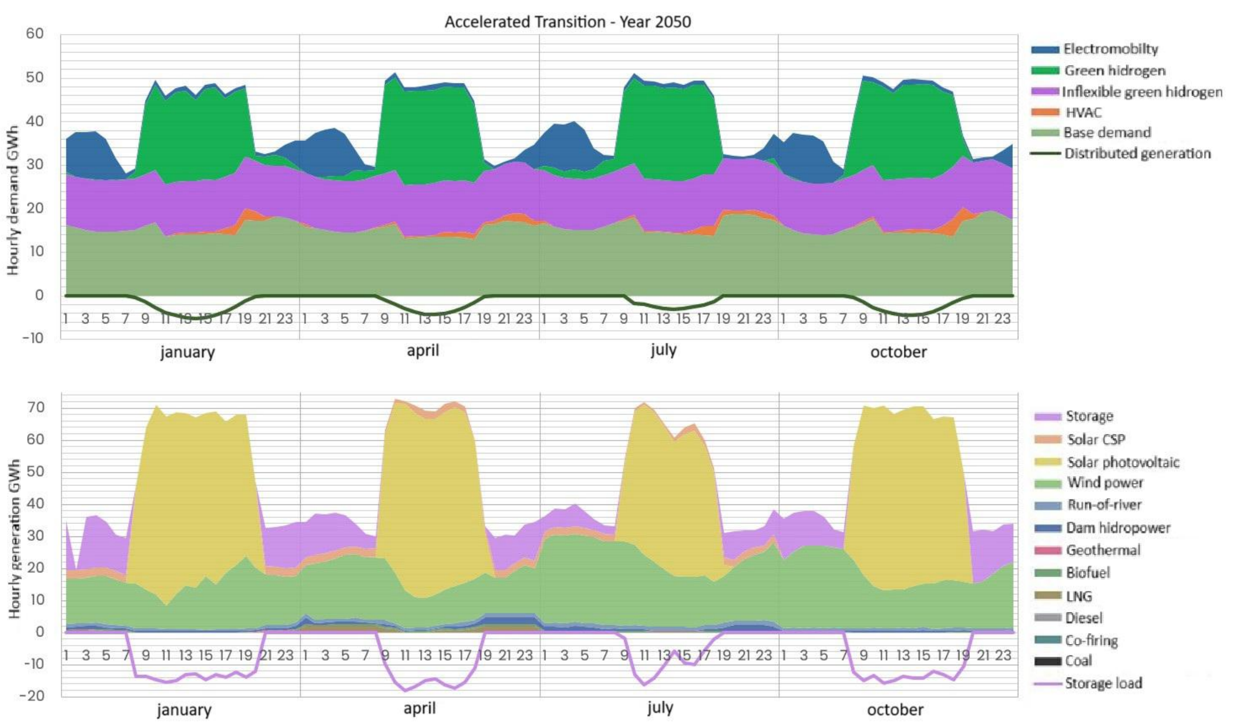


Figure 40: Hourly demand (top) and hourly generation (bottom) for four representative months of the year 2050 under the Accelerated Transition scenario.

From the analysis of daily operation under the three scenarios, the following conclusions are obtained:

- There is a high degree of complementarity between storage and solar photovoltaic technology, which will make it possible to mobilize low-cost energy at peak demand times. This complementarity will make it possible to supply two types of consumption that would define the peaks of the system: green hydrogen in daytime blocks, and electromobility in nighttime blocks.
- Fossil fuel-based generation is economically displaced by renewable generation sources. Thus, coal-based generation is displaced by the year 2029, while natural gas generation is greatly reduced and displaced to night blocks to supply variations in renewable generation profiles mainly during peaks.
- The proper determination of emerging demand profiles is key to understanding the expansion of generation and storage capacity, particularly given the large amounts of demand that are projected in the long-term. In this sense, we conclude that it is relevant to periodically validate the assumptions behind such demand profiles. As an example, in the Accelerated Transition scenario, an intelligent management of the hourly consumption of electromobility is contemplated, which distributes the demand requirement in the night blocks, unlike the Carbon Neutrality and Slow Recovery scenario. Also, a fixed operation of electrolyzers could lead to a lower installation of solar photovoltaic energy.

Transmission Development

Transmission expansion was determined by a joint optimization of transmission expansion as well as generation and storage infrastructure. The resulting transmission expansion is presented in Figure 41 for the three scenarios simulated to the year 2050, leaving only those transmission solutions whose cumulative capacity is 1000 MW or greater. In this figure the transmission lines that are developed are identified by connecting the legend to the X-axis of the graph. For example, in the Slow Recovery scenario, in the X axis, for the Alto Jahuel 500 node, there is a brown column, for 1744 MW, corresponding to the legend of Polpaico 500. This means that a line is developed between Polpaico 500 and Alto Jahuel 500 for 1744 accumulated at the year 2050 in the Slow Recovery scenario.

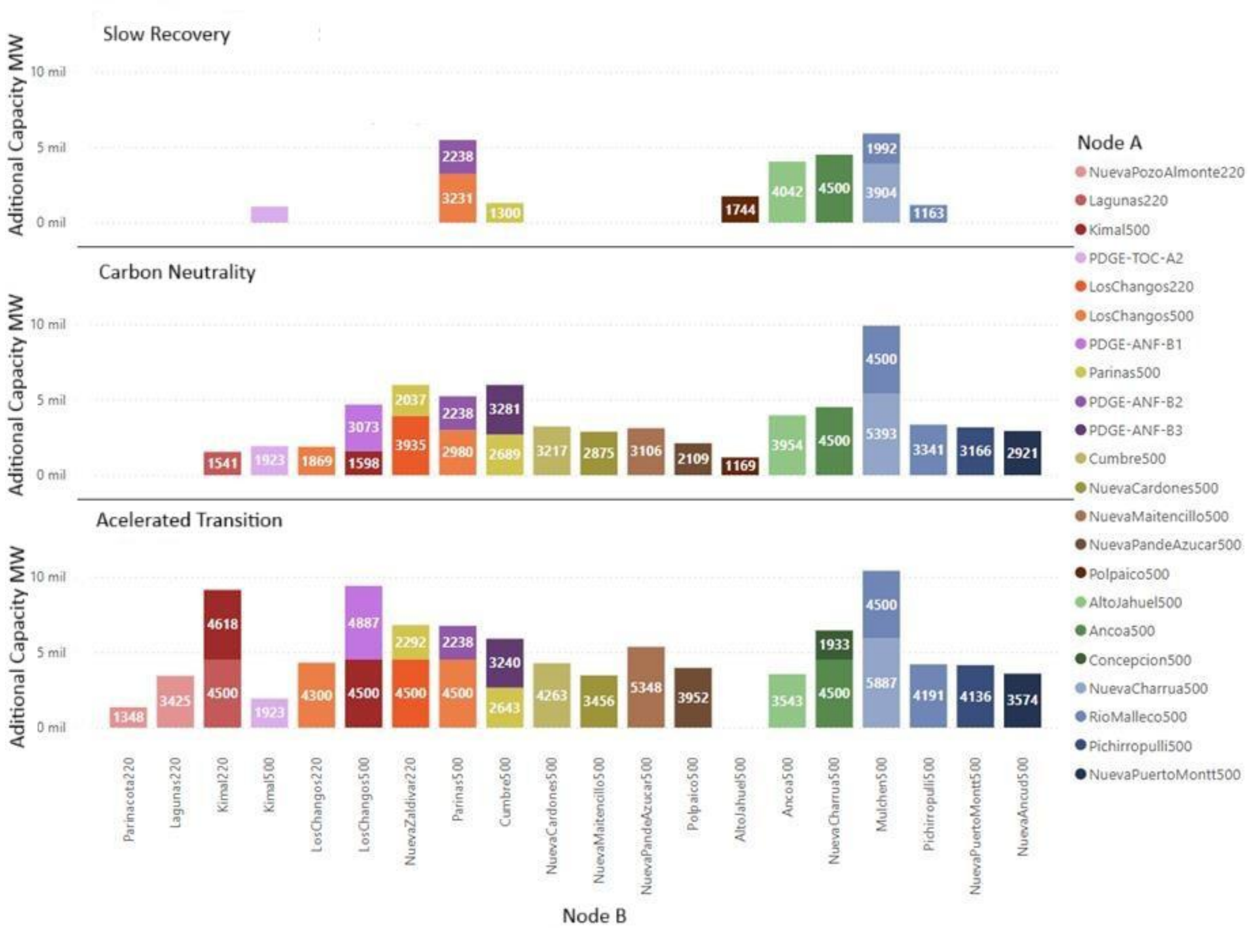


Figure 41: Cumulative NES transmission expansion to 2050 for the three simulated scenarios.

Thus, when analyzing the transmission expansion in Figure 41 , it is observed that there are two important developments that are constant throughout the scenarios. On the one hand, transmission is developed between Parinas 500 and Los Changos 500 for at least 2980 MW, as well as between Parinas 500 and the Wind Power Generation Development Pole located in Taltal (PDGE-ANF-B2) for 2238 MW. This is related to the fact that Parinas is an exporter node of wind energy to the demand of the North and the Center. On the other hand, there is also an important transmission development between the Alto Jahuel 500 and Río Malleco 500 nodes for amounts close to 3500 to 4000 MW by 2050. When looking at this section for the next 20 years, the required capacity in the three scenarios is at least 3,000 MW between Alto Jahuel 500 and Mulchén 500, and 2,000 MW between Mulchén 500 and Pichirropulli 500.

This connection is related to the development of wind energy in the south, which is growing steadily since 2029 in this area. Additionally, this transmission development is related to what is proposed by the National Energy Commission in its Annual Transmission Expansion Plan 2024[55] , where an HVDC transmission project is presented to connect the Lo Aguirre substations with Entre Ríos (Nueva Charrúa 500 in our model) with a capacity of 3000 MW. In this way, this HVDC transmission project could cover the first section of the complete corridor identified in the PELP 2023-2027 that should be expanded.

This transmission development is intensified in the Carbon Neutral scenario with respect to the Slow Recovery scenario, increasing the capacity of the selected lines, and extending the transmission development so that the expansion covers from Lagunas 200 to Nueva Ancud 500. In both cases the transmission is in line with the development of new wind generation capacity, connecting these resources distributed in the South zone and in the Parinas zone, with the demand centers of the Center. In the Accelerated Transition scenario, in addition to intensifying this dynamic of supplying the demand centers, the need to expand the transmission system also increases, covering all the grid nodes. In this scenario, the development of transmission in nodes that connect with Los Changos 500 is also intensified due to the demand for the production of green hydrogen located in this area, which is mainly supplied with photovoltaic solar generation that comes from neighboring nodes such as Kimal 500 and Nueva Zaldívar 220 (through Kimal 220).

In addition to the definition of long-term transmission, the following considerations that would support the adequate development of the transmission grid are highlighted:

1. Definition of system sections that can increase their capacity through reinforcement solutions, and those sections that are limited for other reasons, such as system stability or others. These solutions would support structural transmission works, such as those identified in Figure 41.
2. Review of network requirements at the zonal transmission level, and their consistency with increases in electric consumption at the level of consumers connected to the distribution network, mainly driven by air conditioning and electromobility.

The development of this transmission expansion enables the optimal development of generation identified in the preceding sections, allowing an optimal location of these resources.

International energy interconnections

International interconnections allow strengthening the security of electric and fuel supply between countries, promoting the efficient and synergic use of available resources, through a bidirectional exchange under an environment of

[55] Final Technical Report Annual Transmission Expansion Plan 2024, available at https://www.cne.cl/wp-content/uploads/2025/04/ITF-Plan-de-Expansion-de-la-Transmision-2024_.pdf.

cooperation and integration, thinking in the public and private good of the countries involved. These energy exchanges allow cost savings, develop energy complementarity and strengthen international relations with neighboring countries.

In this context, the Ministry of Energy is continuously working to advance in this objective with short, medium and long-term actions and measures, in coherence with the GLES regarding the responsibility of the PELP to review and incorporate this aspect within its analysis.

1. Electrical interconnections

Chile, through the Ministry of Energy, participates in different initiatives that promote regional electrical integration, such as the Andean Electrical Interconnection System (SINEA) and the Energy Integration System of the Southern Cone Countries (SIESUR). Within the framework of these initiatives, several studies have been carried out to advance the electrical integration of its member countries. In the case of Chile, a first study was carried out in 2013, financed by the Inter-American Development Bank (IDB), to evaluate interconnection options with Peru. Said study evaluated two alternatives with economic benefits of interconnection between both countries, one at 500kV and the other at 220kV. Subsequently, two updates of the study were carried out, in 2015 and 2019, deepening in the 220kV line between Tacna and Arica, which again showed economic benefits.

On the other hand, in 2023 a first phase of the study that evaluates interconnection alternatives between Chile and Bolivia was completed and is expected to be resumed in 2025.

Given the conclusions of the different analyses and, in order to advance in the necessary authorizations to materialize electric interconnection projects, Chile formally initiated in 2024 a process to advance in the regulatory harmonization with the SINEA, seeking operational and commercial compatibility with Peru and other countries of the initiative. Along these lines, it is currently in the process of talks with the Andean Community (CAN) in order to advance in the negotiation of a bilateral instrument that will allow the adoption of Decision 816 and its respective regulations, which define the regulatory framework for the sub-regional interconnection of electric systems and intra-community exchange of electricity of the member countries. At the same time, a study is being completed, financed by the IDB, to address the aspects of Chilean regulations that should be modified to make them consistent with the CAN Decision, as well as recommendations to facilitate international electric exchanges.

As a result of the advances in regulatory matters, it was also decided, in conjunction with Peru, to begin updating the energy-economic studies for the Tacna-Arica interconnection at 220kV in 2024, work that is being carried out by the IDB. Subsequently, the electrical studies will be updated, and a socio-environmental study will be carried out.

Regarding operational projects, Chile currently has an active electrical interconnection, which links the Andes (Chile) and Cobos (Argentina) substations through a 409 km line energized at 345 Kv. The electric exchange modality is by means of surpluses when there is an economic opportunity. The line is operated in island mode, so that the electrical systems are kept isolated while the exchange takes place. The flow capacity was technically defined in such a way that, during the day, the exchange is made from Chile to Argentina with a maximum capacity of 80 MW, while, during the night, the flow is from Argentina to Chile with a capacity of 200 MW. This configuration has allowed Chile to be able to export the solar surpluses from the northern zone to Argentina, which otherwise would have been dumped.

Notwithstanding the above, there are several initiatives both exploratory and of declared interest by different private companies, which are evaluating interconnection projects with Peru, Bolivia and Argentina.

- Peru - Chile interconnection: Interconnection studies, financed by the Inter-American Development Bank (IDB), within the framework of the Andean Electrical Interconnection System (SINEA), working table between the technical delegations of both countries (coordinated by IDB) and in the process of updating studies for the Tacna - Arica interconnection, and finalizing the study that identifies the aspects that need to be addressed for regulatory harmonization with CAN.
- Bolivia - Chile Interconnection: Studies have been carried out, financed by the IDB, to analyze possible interconnection alternatives. The start of a second part of the study will begin in the first half of 2025, which will focus on identifying new possible routes and updating energy complementarity.
- Argentina - Chile Interconnection: Andes - Cobo (AES Andes) is the only operational electrical interconnection in Chile, extending 409 km at 345 kV, in operation since the 1990s. Exchanges were stopped between 2015 and 2017 due to security requirements (SING and SIC interconnection), returning to operation in 2022. The electric exchange modality is through surpluses when there is an economic opportunity. The operation of the line is carried out in island mode, so that the electrical systems are kept isolated while the exchange is carried out. On the other hand, there is another private interconnection initiative, Ancoa - Rio Diamantes (ENEL), which contemplates a 314 km line in 500 kV with a capacity of 735 MW, where meetings have been held between the company, the CNE and the Ministry of Energy to provide feedback on studies and next steps.

2. Natural gas interconnections

In terms of gas interconnections, during the first half of the 90's, Argentine gas had become an attractive alternative for electric generation and the industrial sector. The signing of the gas integration protocol with Argentina in 1995 brought with it a series of international pipelines and initiated Chile's dependence on imported natural gas.

However, in 2004, Chile suffered the so-called "gas crisis", as Argentina began to restrict the supply of natural gas to Chile, with the aim of prioritizing the supply of the Argentine domestic market in view of the insufficient gas supply in that country, to which was added that Argentina began to apply significant taxes on the export of gas that did reach Chile. As a result, between 2005 and 2007, the supply to Chile was reduced to a minimum, which created a major problem for both power plants that had scheduled their electric production considering the imports of Argentine gas, in addition to the supply restrictions for the residential, commercial and industrial segments.

In view of this, several Chilean companies (both public and private) began to work together to build maritime terminals for regasification of liquefied natural gas (LNG) in order to avoid dependence on Argentine gas and, thus, to be able to import natural gas from other countries.

Notwithstanding the above, there are currently 7 gas pipelines enabled between Chile and Argentina, which began their imports in 1997, generating a peak in 2004. The regions that have connections are Antofagasta, Metropolitan, Biobío and Magallanes, however, many of them are not being used on a permanent basis.

In June 2022, Chile and Argentina agreed to exchange gas energy until September 2023, with Argentina agreeing to export natural gas to Chile, supplying the Pacific Gas Pipeline that covers the regions of Ñuble and Biobío, covering the cities of Chillán and Concepción. This would translate into 300,000 cubic meters of natural gas entering daily during that period of time. Along with the above, a tender was launched for Argentine companies to supply 4 million cubic meters of natural gas per day from the Neuquén basin to Chile.

During 2023, the Hydrocarbons Working Groups with Argentina were resumed, in which, among other issues, transportation capacity, infrastructure, regulatory homologation, knowledge transfer and gas exchanges were discussed, while in 2024 two meetings were held. For the year 2025, the first meeting of the Technical Committee has already been scheduled. At the working tables it was agreed to continue with the proposed agenda between both countries, mainly regarding gas exchanges through natural gas exports from Argentina to Chile, the prospects for infrastructure development in Argentina, the change of natural gas specifications in both countries, and other integration fronts. Regarding the change in Argentine technical specifications, Chile is already updating the technical standard with the National Standards Institute.

In terms of regional cooperation, the work being carried out within the framework of MERCOSUR, Bolivia and Chile, the Latin American Energy Organization (OLADE) and the Development Bank of Latin America (CAF), where a study was carried out to expand and optimize the natural gas transportation infrastructure at regional level[56].

[56] Available at: https://www.olade.org/publicaciones/integracion-gasifera-argentina-chile/

5.9 RESILIENCE ANALYSIS

Resilience framework and concept

Energy systems are complex systems subject to vulnerabilities of different origin and magnitude. In recent times, phenomena such as climate change have broadened the scope with which the vulnerability of energy systems, and in particular of electric systems, was typically analyzed, moving from an approach based on safety and reliability to an approach that also analyzes the resilience of these systems. Thus, the focus has shifted from studying mainly high probability and low impact hazards to also include low probability and high impact hazards. Among the latter we can find natural hazards, such as earthquakes and wind gusts, which can be exacerbated by climate change, as well as anthropogenic hazards such as accidents or cyber-attacks.

Given the scope and relevance of the concept of resilience to long-term infrastructure planning, the concept of resilience has been studied by bodies that inform decision makers, such as the Intergovernmental Panel on Climate Change (IPCC) which defines resilience as the "capacity of social, economic and environmental systems to cope with a hazardous event, trend or disturbance by responding or reorganizing themselves in ways that maintain their essential function, identity and structure, while retaining the ability to adapt, learn and transform." This definition is compatible with the definition adopted in the Framework Law on Climate Change, which defines "climate resilience" as the "capacity of a system or its components to anticipate, absorb, adapt to or recover from the adverse effects of climate change, maintaining its essential function, while retaining the capacity to adapt, learn and transform".

However, the study of the impact of low probability and high impact phenomena in electrical systems requires definitions that are more limited to the operation of these systems. This is why in the PELP the concept of resilience used corresponds to that defined by a *Task Force* of the PES branch of the IEEE[57] for the resilience of electrical systems, understanding this as the *"capacity to limit the extent, systemic impact and duration of degradation with a view to maintaining critical services after an extraordinary event. Key enablers of a resilient response include the ability to anticipate, absorb, recover quickly from, adapt to, and learn from such an event. Extraordinary events for a power system can be caused by natural hazards, accidents, equipment failure, deliberate physical attacks, and cyber-attacks*." This definition of resilience highlights not only how hazards can cause degradation of the infrastructure, but also degradation of the service provided by that infrastructure.

This section addresses the resilience of the infrastructure proposed by the PELP electric model. In this sense, the solutions found by the expansion model of

[57] A. M. Stanković et al, "Methods for Analysis and Quantification of Power System Resilience," in IEEE Transactions on Power Systems, vol. 38, no. 5, pp. 4774-4787, Sept. 2023. Available at https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9913670.

the electric system, in addition to being optimal from the techno-economic point of view, must be resilient to variations in the modeled variables. Then, and following the definition of resilience provided by the IEEE, this section studies approaches to address the ability of PELP power model expansions to limit the extent, systemic impact, and duration of operational degradation in the face of variations in renewable inputs, particularly wind energy and hydrology profiles.

For this purpose, a *Unit Commitment* model is developed to obtain the operation of the electric system, considering as given the investments in generation, transmission and storage determined by means of the long-term model. Thus, the operation is analyzed for a representative year in the medium term (year 2030), varying the wind profiles or hydrological affluents and analyzing the system's available slack under these circumstances. It is worth mentioning that these analyses are not exhaustive in terms of all the possible variations in the input parameters that would allow studying the resilient response of the system, but they constitute a first approximation to the study of this response.

Short-term case: Slack under a wind reduction in the north

The variations in the wind profiles were simulated locally for the most critical nodes. For this purpose, an indicator was defined to identify nodes with a high concentration of variable renewable energy in relation to system demand. Thus, the generation concentration indicator is defined as the quotient between the generation of a certain technology in a certain node and the total system demand, at an hourly level. When applying this indicator to the results of the long-term model (NES expansion model) it is found that, in 2030, the Parinas 500 node and the PDGE-ANF-B2 Electric Generation Development Pole (both located in the Taltal district), are the nodes with the highest value of this indicator: Parinas 500 comes to supply a quarter of the hourly demand of the NES with its wind capacity, with an average of 10%, while PDGE-ANF-B2 supplies comes to supply a fifth of the hourly demand of the NES with its wind capacity, with an average of 7.4%. This is due to the high wind power generation capacity of these nodes in 2030 (5476 MW in the Carbon Neutral scenario adding both nodes) given the good wind conditions in the area.

In order to study the system's flexibility in the face of possible variations, the effect of a reduction in wind power inflows at these two nodes was studied, going from 30% to 50% reduction in 5% intervals. For the choice of the month in which to apply this reduction, the criterion was to apply it in a month with the lowest availability of hydrological inflows, which for the year 2030 corresponds to the month of August. For the choice of the hourly blocks in which to apply this reduction, the criterion used was that they should be blocks with low storage availability; therefore, early morning blocks were used, where the batteries for intraday storage would have already been discharged during the peak hours of the previous day. Thus, wind inflow curtailment was applied in the first seven early morning blocks of a representative day in August 2030.

At the system level, the proposed 2030 infrastructure is capable of accommodating the wind inflow reduction in terms of sufficiency. This is presented in Figure 42 , where the main difference generated by the reduction in wind inflow is an increase in LNG generation as the level of wind inflow reduction increases, going from having a mix with no LNG generation in the base case to having an additional 1.3 GWh contribution per hourly block. Additionally, the reduction of wind inflow generates a slight increase in hydro generation from the reservoir, as well as a reduction in the contribution of storage.

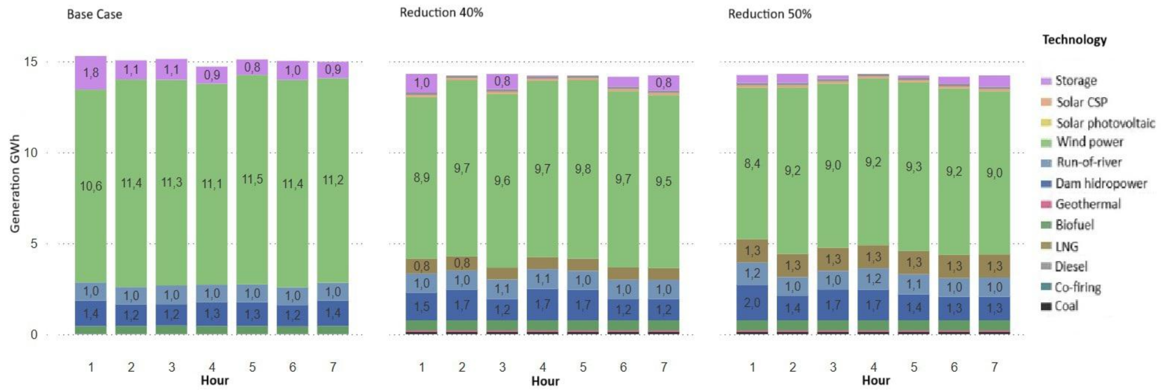


Figure 42: Hourly generation during blocks with reduced wind profiles in the Taltal area. Left: base case. Center: 40% reduction. Right: 50% reduction. Carbon Neutrality Scenario.

When analyzing the difference by nodes, a redistribution of generation can be seen as shown in Figure 43 for the hourly block between 01:00 and 02:00 on August 2, 2030, for the base case and the case with 50% reduction of wind power inflow, under the Carbon Neutrality scenario.

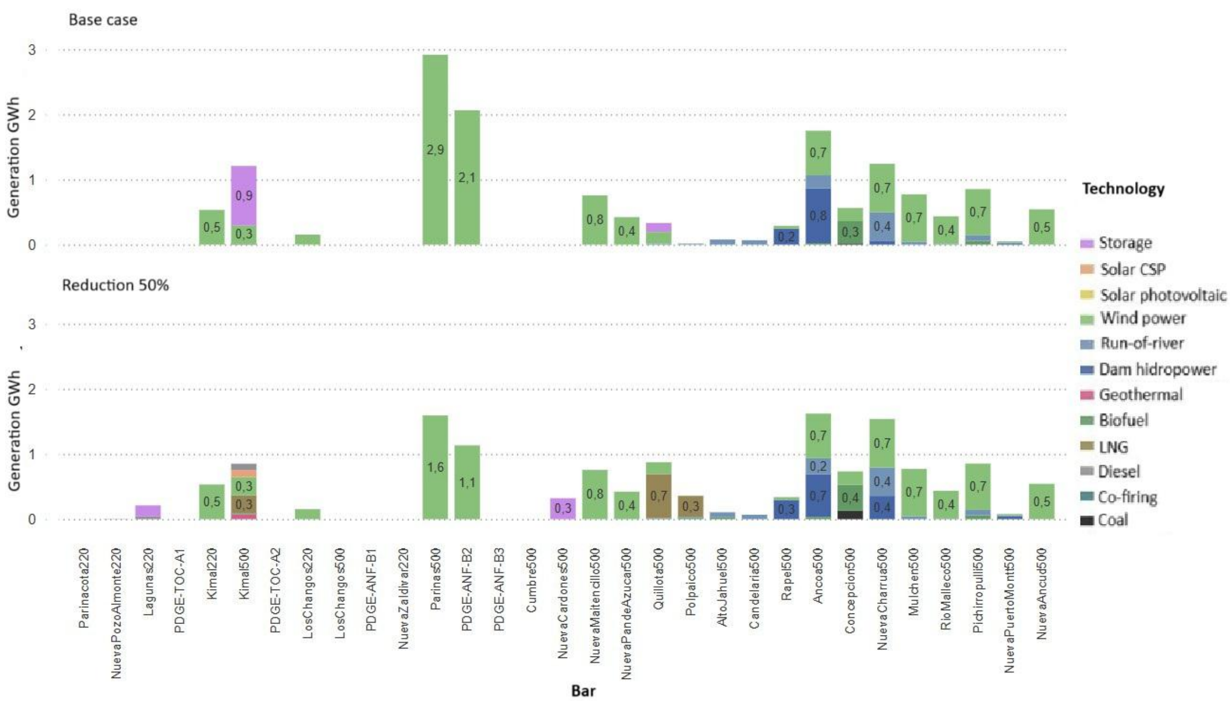


Figure 43: Distribution of hourly generation between 01:00 and 02:00 AM on 2/8/2030. Top: Base case. Bottom: 50% reduction of wind power inflow at Parinas 500 and PDGE-ANF-B2. Carbon Neutral Scenario.

Figure 43 shows that the system uses LNG generation available in the Central zone (Quillota 500 and Polpaico 500 nodes) and North zone (Kimal 500 node) to compensate for the 50% reduction in renewable inflow at the Parinas 500 and PDGE-ANF-B2 nodes.

Additionally, the system increases the generation from some reservoir hydroelectric power plants coming from the Biobío. This rearrangement also occurs in the Slow Recovery scenario, but not in the Accelerated Transition scenario, where the cost of fuel, as well as the tax on emissions, cause the drop in wind generation to be compensated with reservoir hydro generation, mainly.

Considering that the system has the capacity to accommodate important changes in the generation profile in the most critical nodes of the system, which exceed the magnitude of the contingencies typically studied, such as the disconnection of a large unit, it is considered that the expansion of the system is not vulnerable to wind inflow reduction events, in contingencies such as the one studied.

This change in generation is possible to the extent that there are no congestions that prevent the rearrangement of generation in the Central-South and North zone, thus highlighting the importance of having a transmission system that allows for operational slack to supply contingencies due to the variability of the renewable profiles and the concentration of generation. Likewise, this analysis will become more important to the extent that a greater concentration of variable renewable energy is considered and the greater this contribution is.

Short-term case: Inertia levels in the face of climate change hydrology

The hydrology used in the long-term model for NES expansion considers the effect of climate change through the use of a global general circulation model (MIROC-ESM CHEM model under a RCP 8.5 scenario). However, there are 34 hydrological series generated with different global general circulation models under a RCP 8.5 scenario, whose effects may have different implications in the operation of the NES.

One of the variables of interest to be studied is the inertia of the system, given that the economic operation of the system, studied in previous sections, is based on solar photovoltaic and wind generation, which currently do not provide inertia. However, despite the fact that thermal power plants are economically displaced from the generation mix, run-of-river and reservoir hydroelectric generation will continue to contribute inertia to the system, but with a generation that varies according to the climate change series used, among the 34 series available.

For this reason, the operation of the NES to the year 2030 was simulated for the 34 available series and the response of the system inertia was compared between these series, having as a point of comparison the series used for the NES expansion model (MIROC-ESM CHEM r1i1p1 series). For the selection of the month to be evaluated, the month with the least contribution of hydroelectric generation in the year 2030 was considered. As reported in the long-term model, this corresponds to the month of August. Thus, the inertia contribution of synchronous generators was evaluated by means of a short-term operation model, with *Unit Commitment* restrictions, analogous to the model used to analyze wind variability. In this modeling, an inertia constraint was not imposed on the system either, but the amounts of reserves for primary and secondary frequency control, detailed in Table 5 , were maintained.

The system inertia, obtained for the three scenarios using the hydrological series of the expansion model, is presented in a bar chart in Figure 44, separated by the different technologies that contribute to this attribute. Additionally, the figure presents, in segmented lines, the maximum and minimum values of inertia generated by the 34 hydrologic series with climate change available. It is found that system inertia is mainly contributed by reservoir and run-of-river hydro generation, and that the contribution of LNG to system inertia occurs only in the Slow Recovery scenario, since in the Carbon Neutrality and Accelerated Transition scenarios there are other lower cost technological options to supply the demand, such as solar photovoltaic, wind and storage.

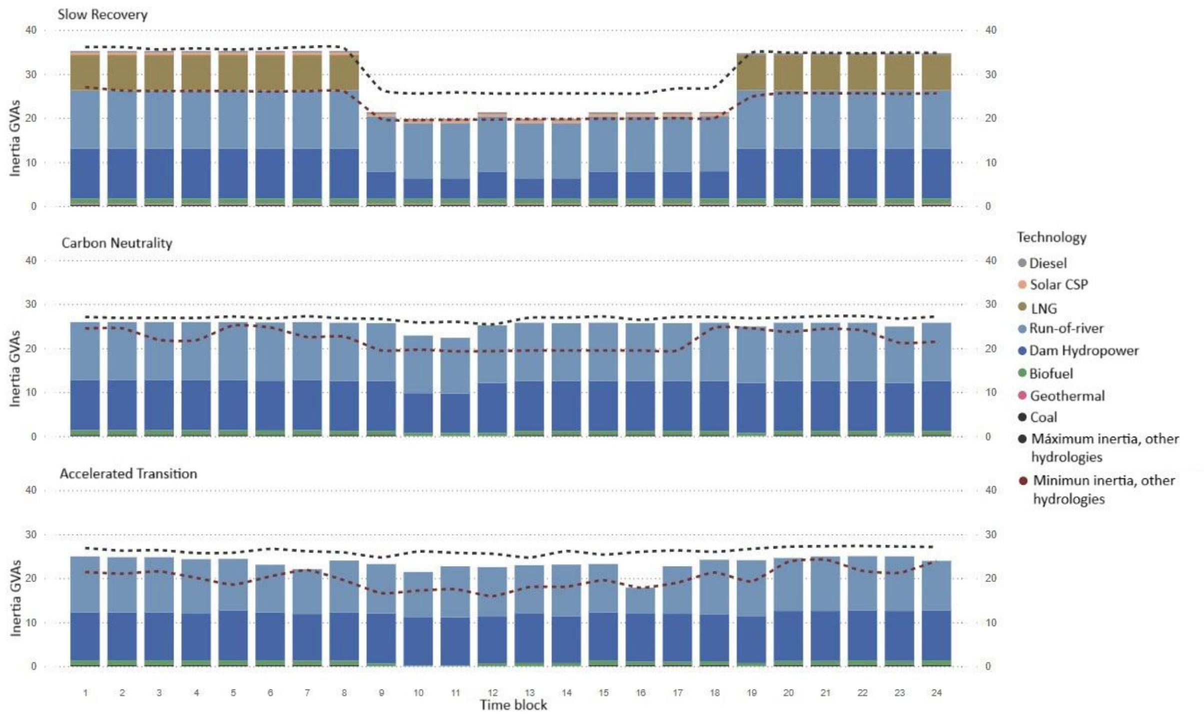


Figure 44: Range of inertias contributed to the system under different hydrology's affected by climate change.

In general, the level of inertia, for the series used in the expansion model, is above 20 GVAs and below 35 GVAs, except for one hourly block in the Accelerated Transition scenario, which, in practice, would be adjustable in dispatch. For example, in the Carbon Neutral scenario, the minimum value is 22 GVAs with demand above 14 GW. These levels would be in line with the levels identified for the safe operation of the system[58] when considering that by 2030 there will already be synchronous condensers making inertia contributions to the system, whose entry into operation is projected for 2027 according to the last tender awarded.

The variation in the level of systemic inertia as the hydrologic series changes (segmented lines in Figure 44) indicate that the level of inertia contributed could decrease below the level of 20 GVAs in the Accelerated Transition scenario, which is the scenario with the highest demand. However, in the rest of the scenarios, the inertia levels would be within the range that could be considered safe by 2030. In this

[58] Supplemental Services Report 2025, available at https://www.coordinador.cl/wp-content/uploads/2024/12/2024.12.20-Informe_SSCC_2025.pdf.

way, it is considered that the solutions found in the expansion model are resilient to variations in hydrology, since they would allow to operate safely following the economic optimization of the operation, or adjust it slightly with the resources that would be available, such as LNG.

It is worth mentioning that this type of analysis should be complemented in the future with dynamic studies on the levels of inertia required for certain operating conditions. Likewise, the possible contribution of inverter-based technologies to fast frequency control should be considered in such studies. The above is part of the commitments that the Ministry of Energy has adopted in its Sectoral Plan for Climate Change Mitigation and Adaptation, in its adaptation axis, where it aims through the first measure to increase resilience and adaptation in the electric sub-sector, in line with the goal of being a resilient country by 2050 of the Framework Law on Climate Change.

6. TRANSMISSION STRENGTHENING: POLES FOR SUSTAINABLE DEVELOPMENT

6.1 DEFINITION OF ELECTRIC GENERATION DEVELOPMENT POLES (PDGE)

According to Article 83° of the General Law of Electric Services, the Electric Generation Development Poles are part of the Long-term Energy Planning and correspond to territorially identifiable areas in the country, located in regions where the National Electric System is located, where there are resources for the production of electricity from renewable energies, whose use, using a single transmission system, is of public interest for being economically efficient for electric supply, and must comply with environmental and land use planning legislation, as stated in Article 85° of the Law.

In addition, according to the provisions of article 75°, they have a Transmission System of Development Poles, which will be constituted by the electric lines and substations destined to transport the electric energy produced by means of generation located in the same development pole, towards the transmission system, making an efficient use of the national territory. Said system may correspond to dedicated lines and substations, new or existing, with the purpose of allowing their use by new generation projects, which the National Energy Commission may consider in the annual transmission expansion plan, detailed in Article 88°.

This transmission system, in turn, is subject to the Open Access regime, described in Article 79°, in that it may be used by third parties under technical and economic conditions that do not discriminate among all users, through the payment of the corresponding remuneration. Therefore, the PDGE do not produce binding effects for the development of energy generation projects, since they do not restrict access to the Transmission System of Development Poles, to facilities located outside the geographical area that they include and, likewise, the determination of the Development Poles of Electric Generation, does not condition or prohibit the location, in said geographical area, of other uses different from the generation of electric energy, since its determination only has a guiding character for the use of the territory for energetic purposes.

Finally, Article 17° of Decree 134, which approves the Long-term Energy Planning Regulation, states that for the identification of the area to be defined as an Electric Generation Development Pole, the Ministry may consider criteria such as the availability of resources for the production of electric energy from renewable energies, the technology of existing generation plants or future generation projects in such area, their location with respect to existing or future electric transmission facilities and the state of development of transmission or generation projects relevant to such area.

In summary, it can be pointed out that the Poles of Electric Generation Development are places prioritized by the Ministry of Energy, under a long-term view, to generate renewable energy, in harmony with the territory and the communities, also promoting local development, whose main characteristics are:

- The PDGE(s) are part of long-term energy planning.

- The PDGE(s) are part of a national scale energy planning, with provincial application.
- The PDGE(s) are an indicative and non-binding instrument.
- The PDGE(s) guide the use of the territory for energy generation with an impact on electric transmission planning.
- The location of the PDGE(s) is conditioned to the existence of resources for the production of electricity from renewable energies.
- The generation of energy from the PDGE(s) must be injected into the National Electric System, therefore, it is not for self-consumption of any particular activity.
- The design of the PDGE(s) is subject to a Strategic Environmental Assessment (SEA) in each province where the poles are located.

Likewise, from this definition, the following can be inferred as part of the general objectives of the instrument:

- Enable the CNE to plan a single transmission solution that evacuates the renewable energy generated in the PDGE(s).
- Incorporate the dimensions of sustainability in the identification of the PDGE(s), being able, in addition, to influence the sustainability of the future transmission solution planned by the CNE.
- Make an efficient use of the territory through a single transmission solution in an orderly and coordinated manner among future generators.
- Provide a location signal to the future transmission solution that guides the location of power generation projects in the area identified as PDGE, allowing its implementation, beyond its indicative nature.

6.2 RATIONALE IDENTIFICATION OF POTENTIAL PDGE PROVINCES

The Long-term Energy Planning (PELP) identifies candidate provinces for Generation Development Poles using criteria that respond to two dimensions: social-environmental-territorial and economic-technological.

The social-environmental-territorial dimension addresses those criteria that reflect the sensitivity of the territory in its different areas, for which two general criteria were used:

- Environmental and Territorial Variables: Through this criterion and with its consideration at different moments of the long-term energy planning, it is sought that the candidate provinces consider these variables and their degree of conditioning or incidence in the generation of energy based on renewable sources. Likewise, this is a criterion that will be further developed later in the framework of the planning of each one of the Electric Power Generation Development Poles.
- Territorial reconversion due to the closure of coal-fired power plants: This criterion considers the Ministry of Energy's Plan for the retirement and/or reconversion of coal-fired power plants, in order to prioritize those territories involved in the closure processes and where there are important challenges, but also great opportunities, among them, changes in the type of employment and training needs, development of new technologies, changes and diversification in the productive matrix of the territories, challenges in the competitiveness of the regions, among others. The communes considered in this Plan are Iquique, Tocopilla, Mejillones, Huasco, Puchuncaví

and Coronel, where the generation of renewable energies contributes to the economic development and local employability, being able to contribute to the mitigation of the externalities that the closing of a power plant could cause.

The economic-technological dimension addresses the effect and feasibility of the materialization of renewable projects in the different provinces of the country. For this purpose, three general criteria were used:

- Projection of energy supply and demand: This criterion considers the growth of renewable capacity so that the projected energy supply in the provinces should be relevant in a medium-term time horizon and the projected capacity levels should point to a development of multiple projects in the same area; and the probable development of projects, i.e., the projected growth in a territory should be contained in the totality of the PELP scenarios.
- Investment Trends: This criterion addresses, on the one hand, the fiscal lands tendered or to be tendered by the Ministry of National Assets as a base input, the projects approved by the Environmental Assessment Service with RCA in force as a signal from the investment, and new capacity needs and number of projects interested in connecting to the grid, integrated through information from the open access process of the National Electric Coordinator.
- Timing: This criterion refers to the temporal prioritization in the provinces that will be submitted to the Strategic Environmental Assessment (SEA) process for the definition of development poles, understanding that each five-year PELP process can establish and define potential development poles for analysis. The next PELP 2028-2032 process will begin no later than the end of 2025, as required by law.

In line with the above, the PELP Preliminary Report for the provinces of Antofagasta and Tocopilla concluded that:

- In the Antofagasta region, total solar and wind energy generation for the years 2030 and 2050 is estimated at 27 TWh and 95 TWh, respectively, and with very competitive renewable energy resources at the country level.
- In the province of Antofagasta, a sustained growth of renewable generation is projected, fluctuating in the modeled scenarios, between 2,000 MW to 11,821 MW by 2050, reaching 28% of the installed capacity of renewable generation in the country, projects that will be connected to the National Electric System to evacuate their energy to the grid.
- In the province of Tocopilla, a sustained growth of renewable generation is projected, fluctuating in the modeled scenarios, between 1,280 MW to 2,968 MW by 2050, reaching 11% of the installed capacity of renewable generation in the country, projects that will be connected to the National Electric System to evacuate their energy to the grid.
- The expansion of renewable energies for generation in both provinces is limited by the current transmission, with a high demand in the short term due to the use of positions in different existing substations, which confers a critical time urgency to seek transmission solutions with a long-term vision and that allow connecting the renewable generation that will be located in the area in an efficient way in terms of sustainability.

- Together with the quality of the resource for renewable generation and the regional context in energy matters, such as the closure of coal-fired power plants and the penetration of Green Hydrogen, there is at the same time a high interest on the part of renewable energy project developers, which gives both provinces a relevant role in increasing generation based on renewable sources.

Thus, the province of Antofagasta and the province of Tocopilla are identified mainly by the following findings:

- High projection of additional electric supply in this decade, and maintained until 2050.
- High request for Open Access connection.
- High number of public land bids.
- Closure of coal-fired power plants and Green Hydrogen potential.
- Signal location HVDC Kimal - Lo Aguirre.
- Reservation of cloths/positions for PDGE.

6.3 PDGE METHODOLOGY

Preliminary definitions

Considering that the PDGE are part of the Long-term Energy Planning, their design uses as reference the range of the projection of the expansion of energy generation in each province towards the year 2050 obtained during the Preliminary Report for the three scenarios of the PELP 2023-2027. This projection is estimated, for the Province of Antofagasta, between 1,366 MW and 2,968 MW of wind generation and between 6,799 MW and 9,822 MW of solar photovoltaic (PV) generation; and in the Province of Tocopilla between 1,280 MW and 2,968 MW with Concentrating Solar Power (CSP) technology.

As a premise, by virtue of the mandate of the Framework Law on Climate Change, it is established that the PDGE must comply at least with the projection of the "Carbon Neutrality" Scenario, in order to comply with the goals established in said legal framework.

On the other hand, the condition indicated in article 150° bis of the GLES for the identification of the PDGE, referred to "an amount of energy equivalent to 20% of the total affected withdrawals in each calendar year, has been injected to the electric system by means of non-conventional renewable generation", is already incorporated in the results of the PELP modeling that initiate this planning process.

The sizing of each PDGE will respond on the one hand to the capacity of a single transmission system, estimated in the range of 2000 MW, and on the other hand, to the grouping of areas with renewable energy potential, continuous or discontinuous, but close to each other, allowing the use of a single transmission solution.

Regarding the technologies to be considered, according to article 85° of the GLES, the PDGE must distinguish the type of generation source, which results in a design criterion of the PDGE and in an orientation for the projects to be located in it, for which all the renewable energy potentials available in the identified territory will also be reported, but a prioritization to one or more technologies will be indicated, according to the results of the planning process.

The formulation of the preliminary and final PDGE project will be based on the alternative or development option selected after the strategic environmental assessment of the effects or implications on the environment and sustainability of each of them, and constitute zones or areas with aptitude or vocation for energy development.

Stages of the process

The planning process distinguishes five (5) sequential stages, which also allow an approach to the territory from the provincial scope of application, defined by the GLES, to the local planning scope of the delimitation of the PDGE(s), integrated and synchronized with the application of the strategic environmental assessment (SEA). In this way, the stages correspond to:

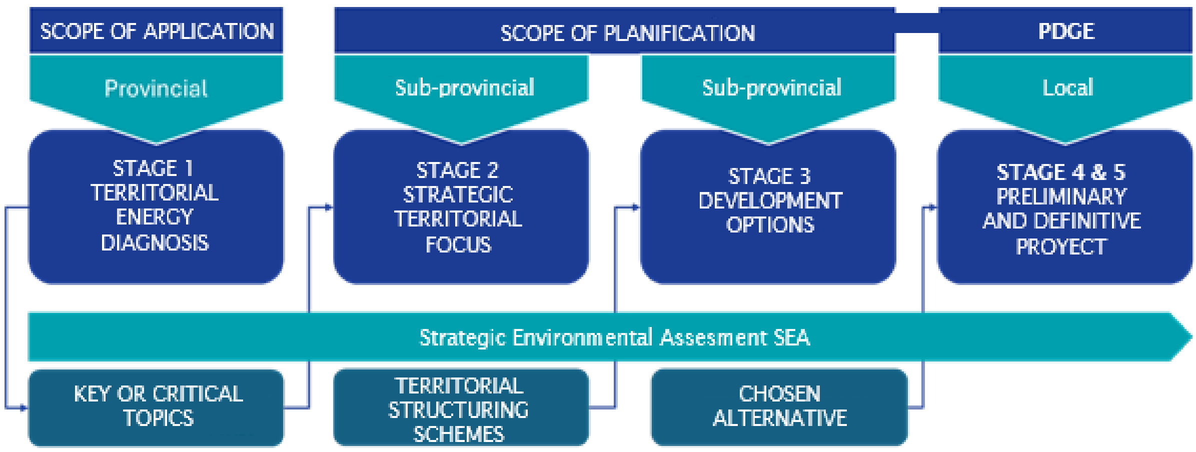


Figure 45: PDGE planning stages.

Stage 1: Territorial Energy Diagnosis, which addresses the scope of "application" of the instrument, which corresponds to the Province, and whose purpose is to know the territory to be planned, identifying those key issues that allow the identification of sustainability issues and define the main ideas that will guide the planning of the PDGE(s) and, consequently, result in a subsequent strategic and territorial focus.

In accordance with the nature of the PELP in which the definition and evaluation of the PDGE(s) is framed, it will be understood that the territorial scope of application of this instrument is the province of Antofagasta and Tocopilla respectively, in the Region of Antofagasta, without prejudice that the PELP and its Preliminary Report is of national level. This instrument is applied in its temporal scale while the conditions that triggered the need to determine the Electric Generation Development Pole or Poles remain in force, unless such conditions change or a transmission system that allows connecting the PDGE with the National Electric System does not materialize, in which case, the PDGE will be reevaluated in the following PELP process.

The Territorial Energy Diagnosis addresses the energy component of the province and is linked to the territory through the territorial systems defined by the National Land Use Planning Policy (PNOT), using information held by the Ministry of Energy, in collaboration with other State services, and existing studies at national, provincial and/or communal level, which allow delimiting one or more areas where there are the best conditions for the location of the potential PDGE or PDGEs.

Within the framework of the territorial systems, we worked with the consideration of what are called Environmental Variables[59] and Territorial[60] (EVT) in the framework of the identification of energy generation potentials based on renewable sources that serve as input for the delimitation of PDGE, identifying those VAT additional to those sensitized in the national energy planning that, without being restrictions, have an impact on the development of energy generation according to the provincial sensitization, valuing them according to the degree of conditioning or incidence, thus being called objects of territorial valuation (TVO), These are called provincial objects of territorial valuation (TVO), whose treatment is defined in the framework of the delimitation of the planning areas and the design of development options, according to the planning decisions in each of them.

Finally, this stage was accompanied with participatory spaces oriented to the State administration agencies, within the framework of the strategic environmental assessment, as well as to the general public, all through workshops, surveys, participatory mapping and bilateral meetings.

Stage 2: Strategic-Territorial Focusing, which addresses the sub-provincial "planning" area, and whose purpose is, to focus planning from the strategic point of view in terms of defining the territorial strategic guidelines (TEG) based on the conclusions of stage 1, which guided the definition of the PDGE(s), as well as the critical decision factors that were considered, based on the sustainability issues of stage 1, as determining and highly valued elements for the formulation of the preliminary project and, in sum, determined the focus from the territorial point of view in "planning areas" within the province.

The planning areas, according to the strategic definitions, are located in territories where the objects of territorial valuation present do not prevent or strongly condition their selection, and preferably where the PELP (in its Preliminary Report) had identified within the corresponding province, areas that, due to the characteristics of their renewable resources, constitute a potential for the development of such energies.

This stage concludes with a first preliminary proposal of territorial organization of potential PDGE within the defined planning area, called "Territorial Structuring Schemes", as a starting point for the elaboration of the development options to be evaluated.

This stage was accompanied by participatory spaces oriented to the State administration agencies, within the SEA framework, as well as to the general public, through workshops, surveys, participatory mapping and bilateral meetings.

Stage 3: Development Options, which addresses the sub-provincial "planning" area, and whose purpose is to define alternatives for territorial structuring of potential PDGE within the defined planning areas, based on the schemes elaborated in the

[59] Environmental variable shall be understood as the element of the environment in its different dimensions, natural or artificial, that is subject to probable or frequent changes, derived from the activities and/or power generation projects susceptible to generate effects on the baseline condition.

[60] Territorial variable shall be understood as that which has been established in a land use, planning or management instrument and which affects or conditions the location of the power generation.

previous stage , which were evaluated in light of the critical decision factors (CDF) previously identified and diagnosed. The development alternatives or options must comply with all the TEGs defined, but with different emphases. This stage concludes with the evaluation of the development options in terms of the effects or implications on the environment and sustainability and with the selection of an alternative or option for the formulation of the pre-project.

This stage was accompanied by participatory spaces oriented to State administration agencies, within the framework of the strategic environmental assessment, as well as to the general public, through workshops, surveys, participatory mapping and bilateral meetings.

Stage 4: Preliminary Project, which addresses the local "planning" area, and whose purpose is to develop the PDGE preliminary project, based on the selected alternative or development option that, after submission to Strategic Environmental Assessment, was exposed to Public Consultation between August 14 and September 29, 2023 and whose results are an integral part of the Undersecretary's Exempt Resolution No. 9[61] , dated January 16, 2024.

Stage 5 Final Project, which corresponds to the final design of the PDGE, having incorporated the results of the Public Consultation and which are included in this Report and in the Energy Planning Decree, in accordance with the provisions of Article 17° and 21° of Decree 134 that approves the Long-term Energy Planning Regulations of the Ministry of Energy. For further details of the process, review the background information provided in the PDGE Technical Reports.

6.4 PDGE TOCOPILLA PROVINCE

Territorial Energy Guidelines (TEG) PDGE for the Province of Tocopilla

For the Province of Tocopilla, the following Territorial Strategic Guidelines (TEG) are defined to guide the definition of the PDGE:

[61] https://energia.gob.cl/sites/default/files/20240116_res_esu_0009_2024_termino_ambos_polos_pagenumber.pdf

TEG 1 Support for a fair and sustainable energy transition as an opportunity for economic revitalization, generating value in terms of employment and local entrepreneurship.

TEG 2 Diversification of the productive matrix by promoting emerging activities and technologies in the province, both in the energy sector and in other sectors of the regional economy.

TEG 3 Prioritization of the use of public land for energy purposes.

TEG 4 Promotion of local energy development, by focusing government action on the territory prioritized by the PDGE.

TEG 5 Efficient use of land, through the use of existing infrastructure (structural roads, transmission, ports, etc.) and location advantages (available potential and logistical approach), together with the leveraging of new enabling infrastructure.

TEG 6 Harmonization of the location of PDGE with territorial conditions in terms of cultural, natural, and landscape heritage, with official protection or recognized by residents as part of their local identity.

Description and rationale of PDGE Tocopilla Province

Planning of an energy development that seeks to offset the power of the outgoing thermal generation in the commune of Tocopilla and be part of the green hydrogen value chain (H2V) within the framework of bioceanic integration.

In the Province of Tocopilla, 2 renewable energy generation zones are designed for an estimated total of 2,227 MW, one located in the commune of Tocopilla, Barriles sector (polygon A1), equivalent to 815 MW of photovoltaic power generation (PV) and the second zone located south of the commune of María Elena (polygon A2), equivalent to 1,412 MW of concentrated solar power (CSP) generation.

This option proposes a mixed composition of the energy matrix, based on photovoltaic (PV) and Concentrated Solar Power (CSP) generation (according to TEG 1).

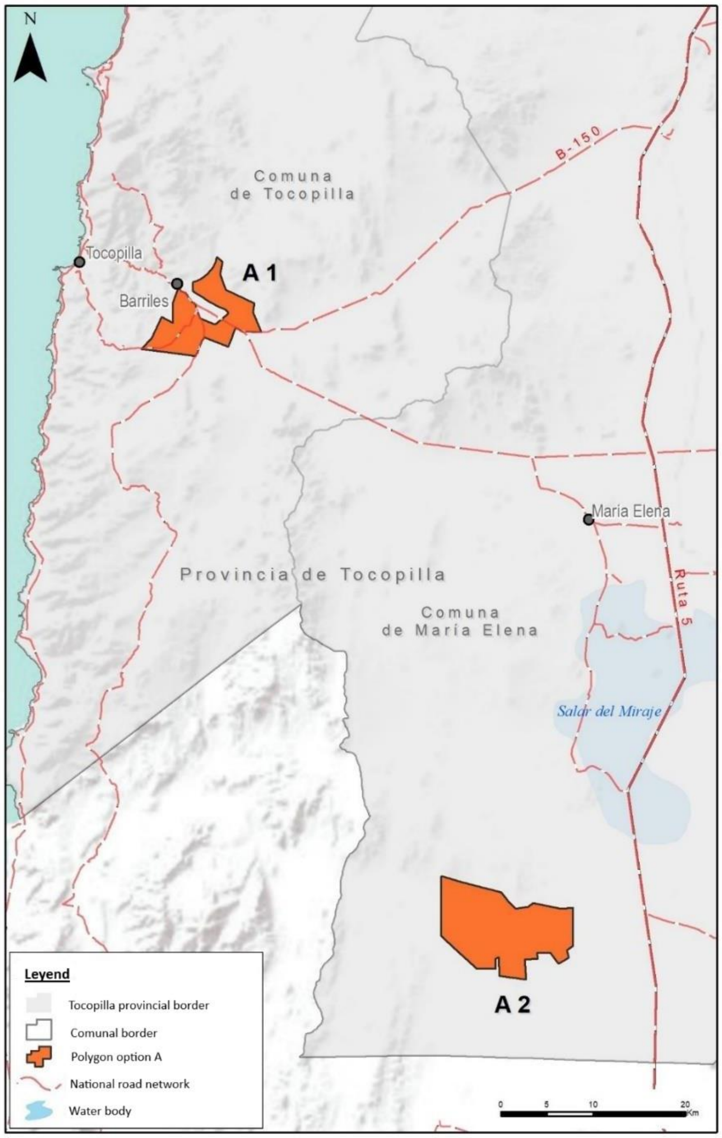


Figure 46: PDGE Tocopilla Province.

The Barriles sector of the commune of Tocopilla (polygon A1) is enhanced, with mixed use, to compensate for the 721 MW of coal-fired power plants that are leaving the area due to the Closure Plan, on public lands, in coherence with the existing and developing territorial planning (PRIBCA), which could leverage the development of the H2V industry, both for internal and external demand, as well as the consolidation of this node as part of the bioceanic integration; and CSP generation to the south of the commune of María Elena (polygon A2) (according to TEG 1, 2, 3 and 5).

The location of the polygons takes advantage of the existing transmission infrastructure (polygon A1 and A2), minimizing the need for new areas for this purpose and taking advantage of the proximity to the bay of Tocopilla (polygon A1), leveraging future port development, along with the accessibility of structuring roads (in accordance with TEG 2 and 5).

Sites with high archeological and paleontological potential, caravan routes, saltpeter heritage and bird nesting sites are Avoided. Distance is taken from the ancestral demand of Quillagua, areas with tourist attractions in María Elena, rural settlements, Miraje salt flat and "astronomical" tourism potential reported in citizen participation (in accordance with TEG 6).

It is proposed to develop a Local Energy Strategy (EEL)[62] in the communes of Tocopilla and María Elena, adapting the planning scale, with an Action Plan that identifies projects to prioritize programs of the Ministry of Energy in these communes, with emphasis on moving towards access to regulated electric supply of the coastal edge of the commune of Tocopilla and isolated sectors of the commune of María Elena (in accordance with TEG 4).

Regarding compliance with PELP's power generation expansion projections, the required capacity in the Carbon Neutral scenario is met.

PDGE Tocopilla - Polygon 1[63]

Technical Information

- Polygon surface area: 5,576 ha

Available Potential

- Photovoltaic (PV) potential of 815 MW equivalent to an area of 3,261 ha.

Potential prioritized by PELP

- Technology: Photovoltaic
- Potential area: 3,261 ha
- Potential MW: 815

[62] A Local Energy Strategy (EEL) is a tool designed for municipalities to analyze the energy scenario and estimate the renewable energy and energy efficiency potential that can be exploited in their territory, defining an energy vision and actively involving the community in the energy development of the commune. In this framework, goals are defined that can be reported, measured and verified in order to comply with the vision and strategic objectives set out in the energy strategy, and a list of key projects to achieve the proposed goals, validated with the actors of the public - private sector plus the local authority of the chosen territory. (Methodological guide for the development of local energy strategies, Ministry of Energy, 2015). Available at: https://energia.gob.cl/sites/default/files/documentos/guia_eel.pdf

[63] https://energia.gob.cl/sites/default/files/tocopilla_pdge_-_poligono_1_2.pdf

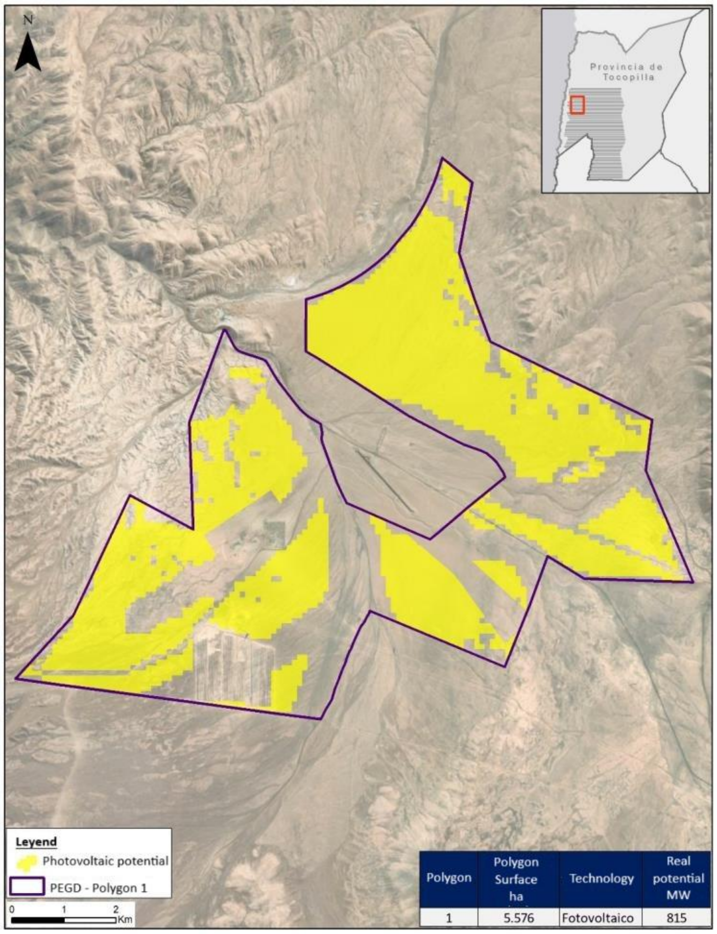


Figure 47: PDGE Tocopilla - Polygon 1.

PDGE Tocopilla - Polygon 2[64]

Technical Information

- Area of the polygon: 10,182 ha

Available Potential

- Concentrated Solar Power (CSP) potential of 1,412 MW equivalent to an area of 9,883 ha.
- Photovoltaic (PV) potential of 2,459 MW equivalent to an area of 9,835 ha.

Potential prioritized by PELP

- Technology: CSP
- Potential area: 9,883 ha
- Potential MW: 1,412

[64] https://energia.gob.cl/sites/default/files/tocopilla_pdge_-_poligono_2_2.pdf

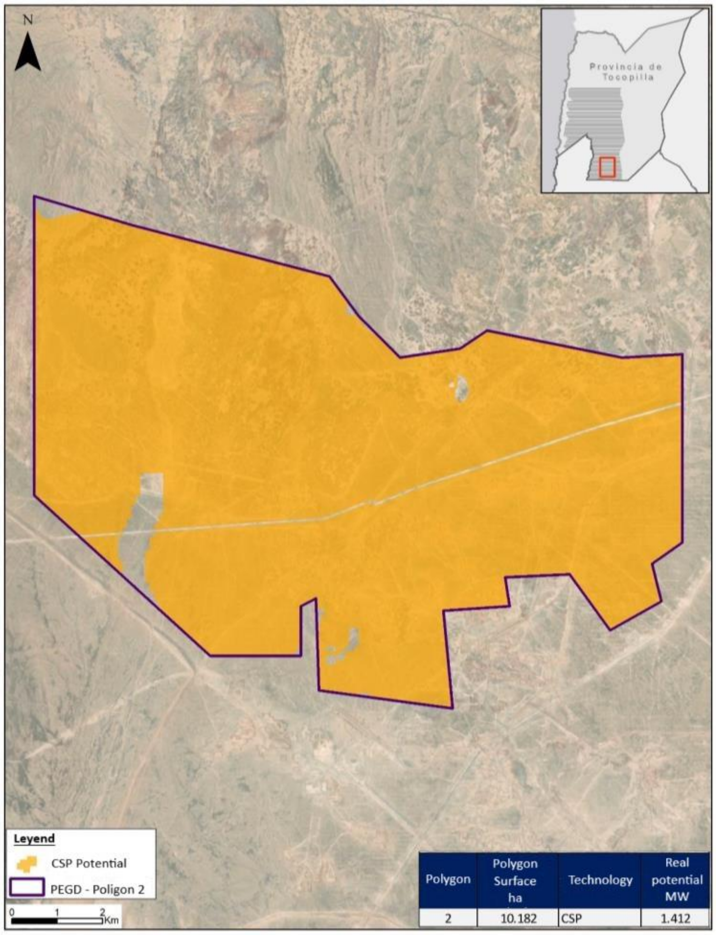


Figure 48: PDGE Tocopilla - Polygon 2.

6.5 PDGE PROVINCE OF ANTOFAGASTA

Territorial Energy Guidelines (TEG) PDGE Antofagasta Province

For the Province of Antofagasta, the following Territorial Energy Guidelines (TEG) are defined to guide the definition of the PDGE:

TEG 1 Promoting a sustainable energy transition in the province, taking advantage of its “site-specific” energy potential.

TEG 2 Production chains, through the promotion of established and emerging activities in the province, generating value in terms of employment and local entrepreneurship.

TEG 3 Guidance on the use of public land for projected long-term energy demand

TEG 4 Promotion of local energy development by focusing government action on the territory prioritized by the PDGE.

TEG 5 Promotion of alternative territories to existing energy development, in harmony with territorial conditions in terms of cultural and natural heritage and landscape, with official protection or recognized by inhabitants as part of their local identity..

Description and rationale of PDGE Antofagasta Province

Energy development planning that prioritizes new territories with "site-specific" energy potentials such as wind and Concentrated Solar Power (CSP).

In the Province of Antofagasta, 3 zones are designed that propose a mixed composition of the energy matrix, one located in the commune of Sierra Gorda (polygon B1), equivalent to 2,709 MW of photovoltaic (PV) and Concentrated Solar Power (CSP) generation, and 2 zones in the commune of Taltal, equivalent to 2,289 MW of Concentrated Solar Power (CSP) generation, and 2 zones in the commune of Taltal, equivalent to 2,289 MW of photovoltaic (PV) and Concentrated Solar Power (CSP) generation.289 MW of wind energy generation (polygon B2) and 3,220 MW of photovoltaic (PV) and Concentrated Solar Power (CSP) generation (polygon B3) (according to TEG 1):

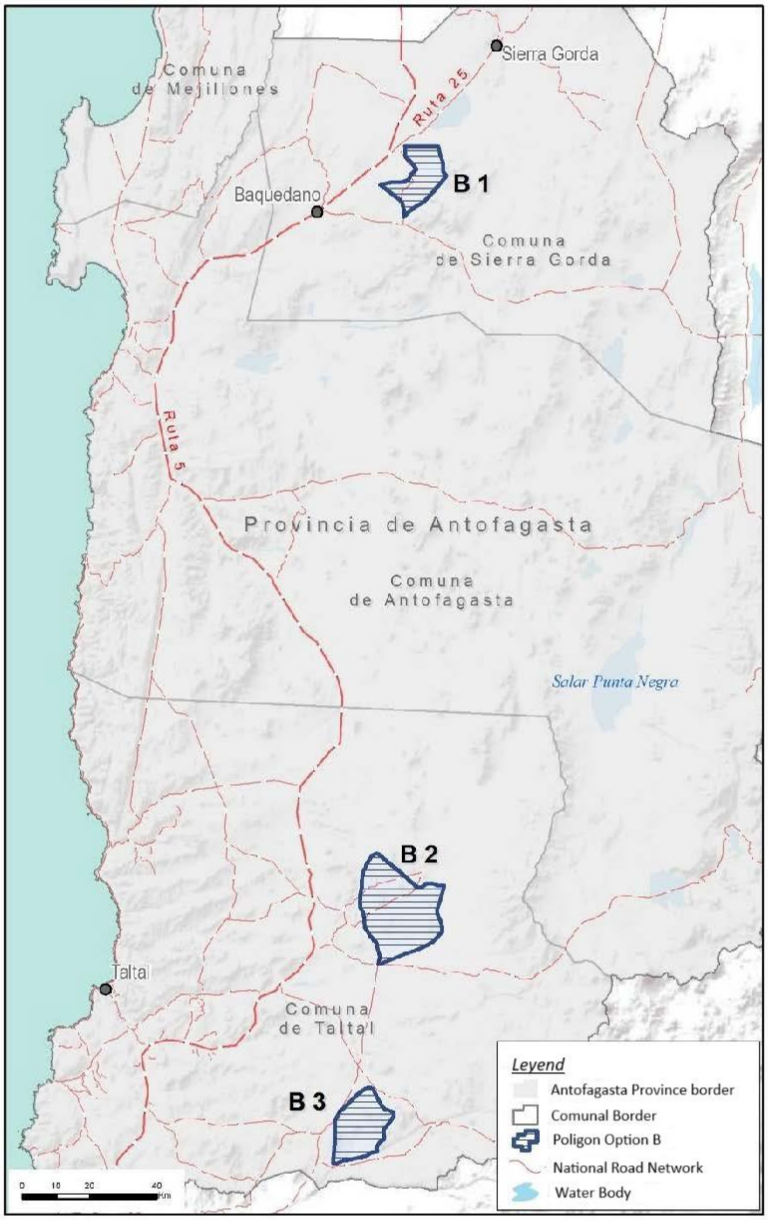


Figure 49: Development option Antofagasta Province.

New energy generation territories are proposed, a zone mainly CSP in the commune of Sierra Gorda (polygon B1) to supply the regional demand of industry and mining connected to the National Electric System (NES) in terms of energy consumption for their processes, among which energy sources such as H2V could be developed; a wind zone (polygon B2) and mainly CSP (polygon B3) in the commune of Taltal. The CSP technology seeks to compensate the photovoltaic requirement of PELP for the province (according to TEG 2, 3 and 5).

Sites with high archeological and paleontological potential are avoided. Distance is taken from Llullaillaco National Park, bird nesting sites and sites of astronomical interest, tourist destinations and attractions, and mining operations. For its part, the

CSP technology considers the landscape, distancing itself from rural human settlements and populated areas in general (in accordance with TEG 5).

It is proposed to develop a Local Energy Strategy (LES)[65] in the communes of Sierra Gorda and Taltal, adapting the planning scale and generating an Action Plan that identifies projects to prioritize programs of the Ministry of Energy in these communes, with emphasis on moving towards access to regulated electric supply of the coastal edge of the commune of Taltal (in accordance with TEG 4).

Regarding the fulfillment of PELP's power generation expansion projections, it complies with the Carbon Neutrality scenario .

PDGE Antofagasta - Polygon 1[66]

Technical Information

- Area of the polygon: 18,965 ha

Available Potential

- Concentrated Solar Power (CSP) potential of 2,046 MW equivalent to an area of 14,320 ha.
- Photovoltaic (PV) potential of 4,171 MW equivalent to an area of 16,684 ha.

Potential prioritized by PELP

- Technology: CSP - Photovoltaic (PV)
- Potential area: 16,937 ha [14,234 CSP - 2,703 PV].
- Potential MW: 2,709 [2,033 CSP - 676 PV].

[65] A Local Energy Strategy (LES) is a tool designed for municipalities to analyze the energy scenario and estimate the renewable energy and energy efficiency potential that can be exploited in their territory, defining an energy vision and actively involving the community in the energy development of the commune. In this framework, goals are defined that can be reported, measured and verified in order to comply with the vision and strategic objectives set out in the energy strategy, and a list of key projects to achieve the proposed goals, validated with the actors of the public - private sector plus the local authority of the chosen territory. (Methodological guide for the development of local energy strategies, Ministry of Energy, 2015). Available at: https://energia.gob.cl/sites/default/files/documentos/guia_eel.pdf

[66] https://energia.gob.cl/sites/default/files/antofagasta_pdge_-_poligono_1_2.pdf

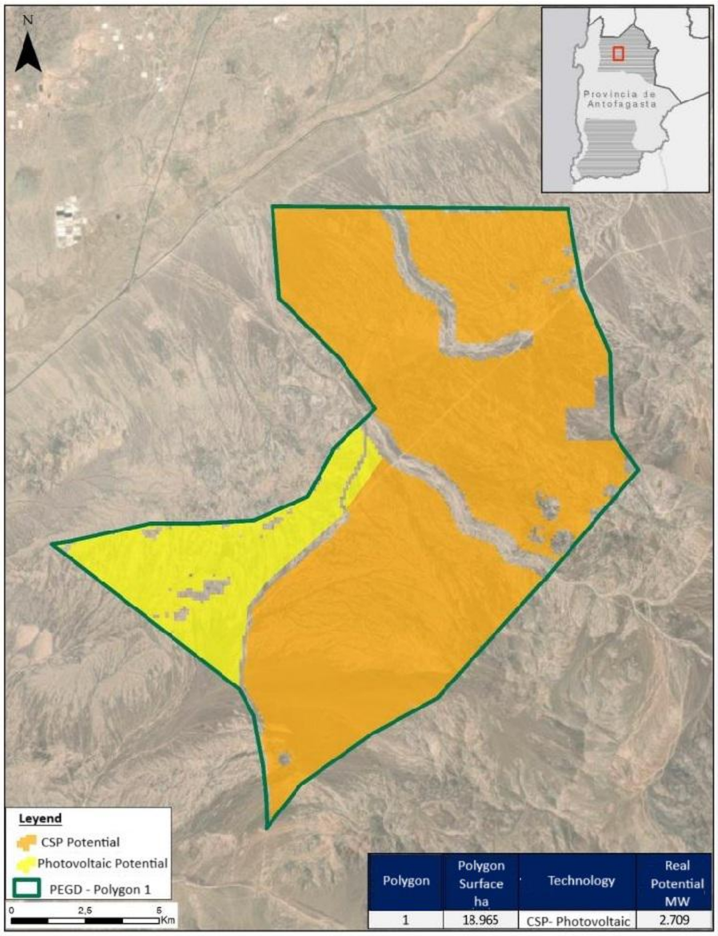


Figure 50: PDGE Antofagasta - Polygon 1.

PDGE Antofagasta - Polygon 2[67]

Technical Information

- Polygon surface area: 52,190 ha

Available Potential

- Wind Power Potential of 2,289 MW equivalent to an area of 45,786 ha.
- Photovoltaic (PV) potential of 8,395 MW equivalent to an area of 33,578 ha.

Potential prioritized by PELP

- Technology: Wind
- Potential area: 45,786 ha
- MW potential: 2,289

[67] https://energia.gob.cl/sites/default/files/antofagasta_pdge_-_poligono_2_3.pdf

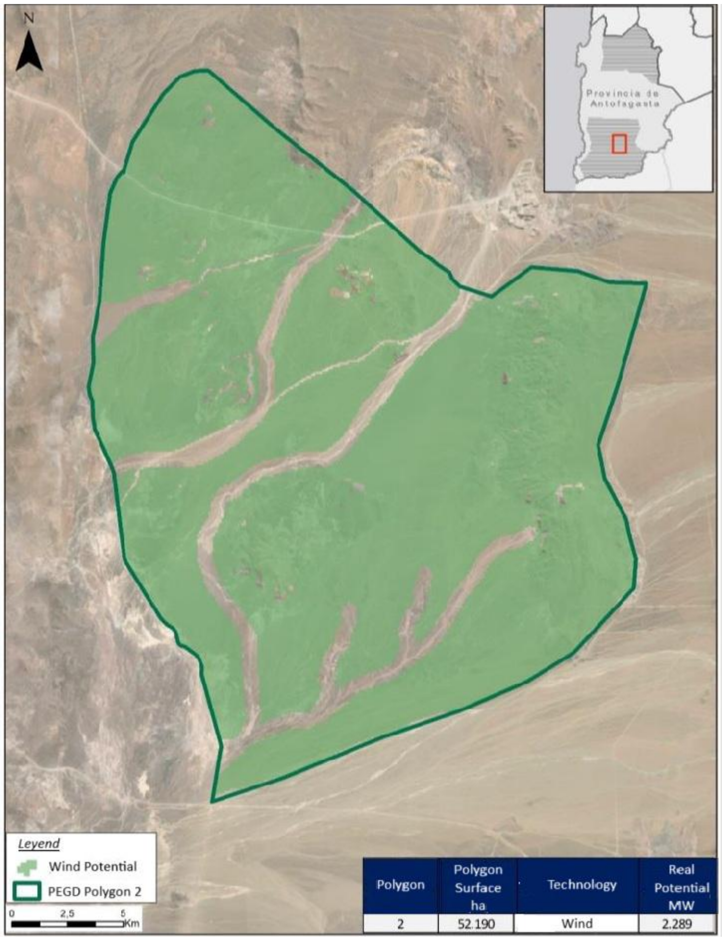


Figure 51: PDGE Antofagasta - Polygon 2.

PDGE-Polygon 3[68]

Technical Information

- Polygon surface area: 25,527 ha

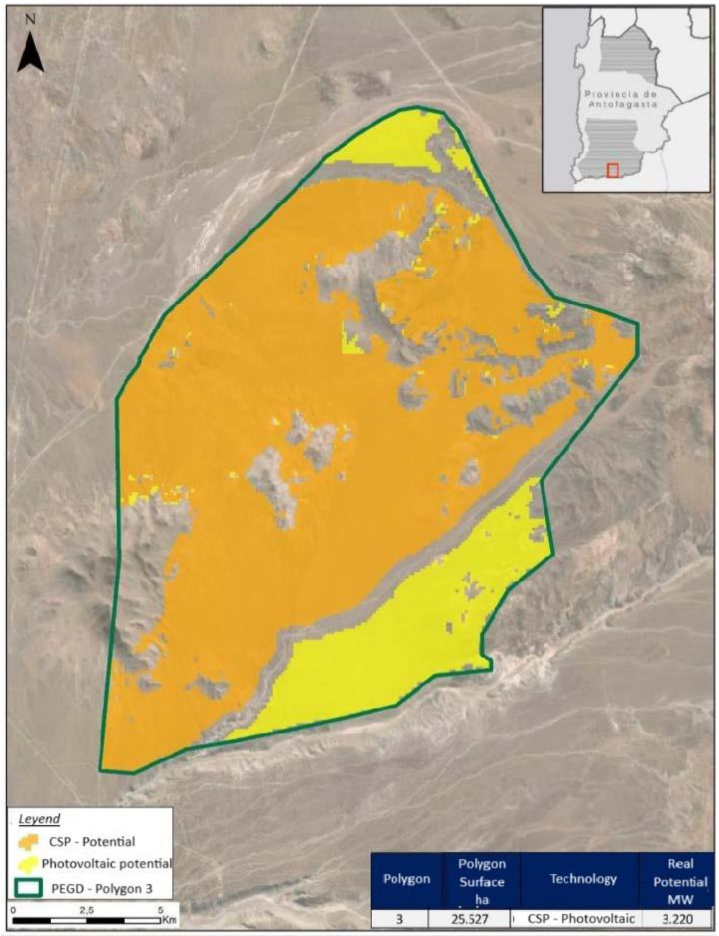
Available Potential

- Concentrated Solar Power (CSP) potential of 2,281 MW equivalent to an area of 15,965 ha.
- Photovoltaic (PV) potential of 4,105 MW equivalent to an area of 16,421 ha.

Potential prioritized by PELP

- Technology: CSP - Photovoltaic (PV)
- Potential area: 19,722 ha [15,965 CSP - 3,757 PV].
- MW potential: 3,220 [2,281 CSP - 939 PV].

[68] o_3_2 n https://energia.gob.cl/sites/default/files/antofagasta_pdge_-_poligo.pdf



Polygon	Polygon Surface ha	Technology	Real Potential MW
3	25.527	CSP - Photovoltaic	3.220

Figure 52: PDGE Antofagasta - Polygon 3.

7. CONCLUSIONS, AREAS FOR IMPROVEMENT AND FUTURE WORK

7.1 CONCLUSIONS

Through extensive participation, modeling, and analysis, the PELP 2023-2027 allows identifying the electric supply projection that will supply the country's electric demand in a long-term horizon under three scenarios: Slow Recovery, Carbon Neutrality, and Accelerated Transition. This electric supply projection is built on the basis of the transition that the energy demand will undergo, moving towards the electrification of various sectors of the economy, such as air conditioning and transportation. This electric supply projection is made through a joint optimization of the expansion of generation, transmission and storage infrastructure in the NES, identifying for each scenario, the infrastructure that would allow supplying the demand in an optimal way.

In this way, the PELP 2023-2027 identifies that the form of supplying electric demand is through renewable sources, mainly wind and solar photovoltaic, in direct relation to the transition that has been observed in recent years. The composition of the projected generation development varies according to the analysis horizon. For example, up to the year 2030, in the three scenarios, the need to expand wind generation capacity predominates, mainly in the Taltal area (Antofagasta) in the first instance, and then with greater relevance from Maule to Los Lagos towards the end of the decade. This decade also projects the need for at least 2 GW of storage in addition to those under development, and for solar photovoltaic development distributed throughout the NES. Development trajectories vary depending on the scenario towards 2050, partly influenced by large consumptions, such as green hydrogen. Thus, the Slow Recovery scenario bases its generation on a mix with the presence of wind energy, while the Carbon Neutral scenario considers a mix with a greater development of solar photovoltaic generation in the north, leveraged by storage, and the Accelerated Transition scenario exacerbates the behavior of Carbon Neutrality and considers CSP towards the end of the evaluation horizon.

Just as there are differences in how the generation mix develops by scenario, the development of transmission infrastructure also varies significantly by scenario. However, all three scenarios suggest, within the next 20 years, an expansion to evacuate wind generation capacity from Parinas to the Cumbre and Los Changos substations, as well as the expansion of the system between the Alto Jahuel substation and Río Malleco, by at least 3,000 MW in a large part of the section, also to evacuate wind generation between these substations. This last expansion is related to that identified by other planning exercises, such as that proposed in the Annual Transmission Expansion Plan, developed by the National Energy Commission, which proposes a HVDC transmission project for 3,000 MW between the Lo Aguirre substation and Entre Ríos, which could correspond to a first stage of the transmission need identified in this PELP.

Part of the generation expansion identified corresponds to Electric Generation Development Poles, which are expansion candidates that were identified as areas with less territorial impact and great potential to supply electric demand. This PELP 2023-2027 introduces for the first time the figure of this type of generators, who would have a unified transmission solution, allowing them to access economies of scale of a larger transmission line, and a special pricing regime, as indicated in the General Law of Electric Services and its regulations.

On the other hand, it should be noted that, in its previous stages (Preliminary Report and Definitive report) the PELP and its energy and electric demand projections have allowed building other public policies, such as the climate commitments that resulted in the carbon neutrality goal by 2050, the sectoral carbon budget and the actions that allow the Ministry of Energy to comply with the required mitigation efforts, which are embodied in the Sectoral Plan for Mitigation and Adaptation to Climate Change in Energy or in national instruments such as the NDC and the ECLP[69]. In particular, the Carbon Neutrality and Accelerated Transition scenarios have pronounced emission reductions that would allow achieving sectoral climate commitments that, in turn, contribute to the national commitment.

7.2 AREAS FOR IMPROVEMENT

The Long-term Energy Planning, through its five-year process and annual updates, allows the rapid integration of the learning obtained in each of its stages and activities. In this sense, one of the main experiences provided by this second PELP process is related to the identification process of the potentials for PDGE and its subsequent Strategic Environmental Assessment for the preparation of the respective technical report. It is estimated that in the next PELP 2028-2032 the times for this stage could be reduced to less than one year, based on the creation of internal capacities in the Ministry of Energy.

In a similar perspective, it is a challenge to reduce the times of the process in general, allowing to reduce the time between the Preliminary Report (which must be issued eight months after the beginning of the process) and the Definitive Report, which in the current process was extended for almost three years and this has consequences in the operation of the process, as well as in the information itself that the instrument is able to deliver given possible changes in the different contexts that affect the PELP.

In addition, aspects for improvement have been identified within the modeling work in at least three priority areas for this year: firstly, technical work will be promoted for the development of new methodologies that allow incorporating resilience in the complete planning process, allowing incorporating a more exhaustive analysis of the resilience of the solutions found by the PELP than the one contained in this process. Secondly, it has been identified the need to make improvements to the distributed generation model that allow aligning the results obtained with the real application of the technology that, preliminarily, could condition the results of the model by decreasing the demand in solar blocks. Finally, the need to update the projections for hydrogen and ammonia production and exports has been identified, since this emerging demand is key for the expansion of the infrastructure in the long-term.

A challenge that needs to be addressed concretely in the following process is related to how the energy system as a whole is addressed and the necessary projection of the

[69] More information at: https://energia.gob.cl/sites/default/files/pagina-basica/informe_resumen_cn_2019_v07.pdf

decarbonization of the other consumption sectors that are not feasible or cost-efficient to electrify, finding alternatives through the use of new energy or quality biofuels, which are correctly incorporated in the models to focus future public policies and decisions around these segments that represent the largest final energetic consumption in the country.

7.3 FUTURE WORK

Finally, after the publication of this PELP 2023-2027 Definitive Report, the Ministry of Energy will issue the Energetic Planning Decree, period 2023-2027, as of July 2025.

The next PELP 2028-2032 process will start before December 31, 2025, through its respective resolution, to then give way to the participatory process, tentatively between January and April 2026. With this, between May and July 2026 the PELP 2028-2032 Preliminary Report will be prepared, which should be published in August of that year together with the PDGE candidates, whose process, including the Strategic Environmental Assessment, will be carried out from September 2026.

8. ANNEXES

8.1 CITIZEN PARTICIPATION

The participatory process is composed of several elements that, as a whole, incorporate a diversity of contributions in a context of collaborative and interdisciplinary work. The different work instances are the following: citizen input (open and voluntary registration), technical support group (academic-researcher and consultant) and a coordination group with public sector agencies. In this sense, the PELP process opens a space for convergence of views between citizen participation, science and institutions, so that - jointly and consensually - the routes for the country's energetic future can be shaped.

Citizen Participation Registry

On December 29, 2019, the new five-year process PELP 2023-2027 was launched, by opening registrations to participate in the workshops, public hearings and review of the various documents prepared, and which are shared to individuals and organizations registered in the Citizen Participation Registry PELP 2023-2027. Open for a period of three months, on March 3 the registrations close with a total of 706 registrations, among people and organizations of different nature; almost three times the participants of the previous PELP 2018-2022 process, where 262 registrations were reached.

Aware of the importance of diversity in the composition of the groups when discussing issues of general interest, special attention is given to an adequate representation of the national and diverse sectors. With this objective in mind, a broad dissemination campaign was carried out to incorporate actors from the public and private sectors, academia and civil society. Thus, of the total number of registrations, 84% were made as individuals and the remaining 16% as organizations, whether companies, associations, NGOs, universities or public agencies such as ministries or municipalities. As for the geographical distribution of the total number of participants, 60% came from the Metropolitan Region and 40% from the rest of the country's regions, among which Valparaíso stands out with 7%, followed by Biobío and Tarapacá with 5% each.

Academy Representation

Considering the technical challenges faced when making long-term energetic projections, as well as the wide variety of sources of information and knowledge available, representatives from academia, research centers and consulting firms were invited to form a PELP 2023-2027 Technical Support Group, whose main objective is to provide *ad honorem* expert technical advice, provide scientific evidence and ensure the consistency of the energetic scenarios and projections.

The formation of the Technical Accompanying Group was carried out at the invitation of the Ministry of Energy and was conducted under gender equity considerations. It had 21 participants, 11 of whom were prominent academics. In addition, the group is made up of people with recognized capabilities that are considered necessary to project the energetic future, highlighting the cross-cutting nature and breadth of disciplines contributed, divided into the following subgroups: mathematical modeling; energetic scenarios; medium and isolated systems; resilience and adaptation; environment and territory; and enabling technologies.

Figure 53: Members of the PELP 2023-2027 technical group[70].

Inter-institutional coordination

One of the main gaps detected in the public sector is the effective coordination between state institutions. In order to overcome this gap, a coordination group was created with sectoral agencies, which brings together all the services related to the energy planning process, such as: Ministry of Energy; Ministry of Mining; Ministry of Environment; Ministry of Housing and Urbanism; Ministry of National Assets; Ministry of Transport and Telecommunications; Ministry of Agriculture; Chilean Copper Commission (COCHILCO); Office of Agrarian Studies and Policies (ODEPA); National Service for Disaster Prevention and Response (SENAPRED); National Energy Commission (CNE); Superintendence of Electricity and Fuels (SEC); National Electric Coordinator (CEN); and Energy Sustainability Agency (ASE).

The main objective of this group is to ensure consistency with plans, programs and policies related to long-term energy planning. Together with them, a group called Electric Core Team is formed, which meets continuously with the objective of reviewing, supporting and analyzing improvements to the planning and operation processes of the national electric system, formed by professionals of the energy institutions (Ministry of Energy, CNE, SEC, CEN and ASE).

[70] The institutions of the representatives are as of 2021, in the framework of the Preliminary Report PELP 2023-2027 and may have changed by the date of publication of this report.

WORK SESSIONS

The process of building the PELP is based on participatory instances of dialogue and collective reflection with the citizenry on the opportunities and challenges of the sector for the next 30 years, addressing social, environmental, territorial, cultural and technological aspects. This is complemented with the expert and multidisciplinary contribution of academia, research and consulting, and with instances of collaboration and coordination between public service institutions related to the future of the energy sector, and with the challenge of achieving national environmental and climate goals.

The process begins with the opening of the registration registers, which in this opportunity is formed by a group of 706 people and organizations, with varied interests, experiences and motivations to share.

The work is structured around three blocks with thematic workshops and three public hearings. The purpose of the workshops is to debate and confront positions on issues of relevance to the long-term energy planning process. The public hearings, which are open to the public, have the role of presenting the progress of the process.

The work of the workshops and the respective public hearings is organized as follows:

- Public Hearing 1: General aspects of the energy planning process are presented. More than 450 people connected simultaneously participate.
- First block of workshops: Composed of 4 consecutive workshops. The objective is to build a proposal of energy scenarios, incorporating possible future situations that allow planning to adequately meet the transmission needs and optimize the country's energy development. A total of 682 people attended.
- Public hearing 2: The energy scenarios worked on in the first round of workshops are presented. More than 200 people connected simultaneously.
- Second block of workshops: Composed of two workshops. The objective is to generate an understanding of the concept of development poles and generate proposals of criteria to identify territories and provinces as potential candidates. A total of 138 people attended.
- Third block of workshops: Composed of one workshop, where the objective is to evaluate the coherence of the energy scenarios with the respective energy and electric projections. Attended by 95 people.
- Public Hearing 3: The general results of the new PELP 2023-2027 are presented and an agenda for the continuity of the process is proposed.
- Final Public Hearing: Presentation of the results of the energy scenarios with the updated technical, economic, environmental and social parameters, together with the results that include the candidates for electric generation development poles in the provinces of Antofagasta and Tocopilla.

In order to facilitate participation in the workshops, each workshop will be held on two similar days, one in the morning (09:00 to 11:00 hours in Chile Continental) and another in the afternoon (17:30 to 19:30 hours in Chile Continental), in order to ensure a transversal and diverse representation, according to the possibilities of participation of each person registered in the Citizen Participation Registry.

The working methodology, of the virtual type, is specifically designed for each of the workshops and hearings. It consists, in general terms, of a first section of expository type, where the main background information to be considered in the discussions is presented. The second section consists of work in subgroups, made up of approximately 15 people each, using virtual tools such as online surveys, voting and discussion with the support of notes on a virtual mural, to which everyone has access. Finally, a third plenary section, in which the main ideas discussed are shared, to end with the presentation of the next steps.

Once each of the workshops is completed, the citizen participation team systematizes the information and, using various qualitative and quantitative techniques, analyzes it, paying special attention to the territorial approach, together with the under and/or over representation of the different interest groups.

Subsequently, with the processed information, it is delivered to the technical team of the Ministry of Energy to incorporate it into the models and projections, in an iterative process of participatory co-construction.

Expert Input

The Technical Accompaniment Group meets for the first time before the first public hearing, in order to pre-validate the main elements to be worked on in the citizen workshops. In this first session, the working subgroups are organized by topics to be addressed, for subsequent specific calls for each identified topic.

The sessions, which have a periodicity of approximately two weeks, were held virtually during the process of preparing the PELP 2023-2027 Preliminary Report, and an expository and open discussion methodology was used. After the first report, meetings were held to present other advances.

Public coordination

In order to address the potential challenges of public coordination and to make the process more efficient, the different public institutions that have some degree of involvement in the definition and subsequent implementation of measures related to long-term energy planning were identified and convened.

To this end, two groups are convened, one related to the energy field and all its derivatives in terms of scope and productive sectors, and the other specific to the electric field, where institutions with direct dependence on the Ministry of Energy and the National Electric Coordinator predominate. Based on this, the groups known as Sectoral Bodies and the Electric Core Team are formed, respectively.

The sessions are held approximately every three weeks in virtual mode, with a methodology similar to the technical support group, that is, through presentations of the key background information to be discussed and then with an open discussion that allows identifying areas of coordination and collaboration.

8.2 CO-CONSTRUCTION OF THE PELP

The current five-year process centers its work methodology around the participatory process. On this occasion, a broad and diverse team is formed which, under the general coordination of the Energy Planning and Innovation team of the Ministry of Energy, integrates the teams of citizen participation, energy policy and various technical teams that contribute to the collaborative work.

As a general work methodology, an iterative and multi-stakeholder process is designed, which allows both expert participation and public sector coordination, always keeping citizen participation as the main axis.

The co-construction process begins with sessions of groups formed by academics with vast experience and by the different public institutions, to identify and validate the base information to be presented at the first public hearing, which focuses on transmitting basic elements to be worked on in the subsequent workshop sessions. Once the workshops have begun, the flow of information is reversed, so that the ideas and proposals raised by the public are taken and presented to the technical groups to challenge them to co-design the way in which they are incorporated into the energetic models and scenarios. To this end, assumptions, simplifications and the state of the art in related publications are discussed, allowing a validated work based on scientific evidence: the models and the technique, at the service of society.

Open and transparent communication

Constant and fluid communication, as well as transparency and availability of the material generated, is a fundamental part of the process, so different communication channels are available: PELP web platform, YouTube channel, satisfaction surveys and identification of new challenges and process email: pelp@minenergia.clThe email is open at all times to receive and respond to all queries and suggestions regarding the energy planning process on a permanent basis.

The main channel of communication and availability of relevant information for the process is the PELP website. This is constantly updated and is designed based on the following information axes:

- General information: It consists of general information about energy planning 2023-2027.
- Citizen education: A space for common questions and answers about the PELP and a glossary of related terms.
- Participatory process: Publication of minutes, minutes and videos of workshops and hearings of the 2021 participatory process.
- Energy future: Publication of energy and electric scenarios and projections resulting from the process.
- Climate change and air quality: Publication of relevant reports related to emissions and international commitments related to climate change, as well as publication of the results of emissions calculations for the energy sector.
- New technologies: Publication of reports related to enabling technologies and strategies, policies and roadmaps that consider medium and long-term actions.

- Territorial development: Publication of information related to development poles and territorial development concepts.
- Repository: Publication of the five-year process PELP 2018-2022, PELP 2023-2027 and annual background update reports.

The platform has been designed to be easy to navigate and simple to access and download information, highlighting its language with a gender perspective and access to people with limited visual capabilities.

As a complement to the topics and ideas shared in the citizen workshops, a massive survey plan is being carried out for the entire registry of participants, allowing for feedback on the user experience in each of the work sessions and to validate and identify sociocultural and technological challenges, to be incorporated into the work agenda for the continuity of the process after the publication of the final PELP 2023-2027 report.

Citizenship as a key element

Through the participatory process, the PELP 2023-2027 submitted to joint analysis and discussion several of the key decisions involved in the exercise of projecting the energy future of our country. Having different opinions, based on diverse experiences and knowledge, substantially strengthened the results through the consideration of potential benefits and impacts that would be associated with different decisions.

In the participatory process, priorities and interests in the different areas were worked on, and based on this information it was proposed how we should react as a society in certain circumstances. We worked on different possible futures considering -among others- different economic welfare, or different external contexts. Thus, based on the discussions, it was possible to define, for example, the importance of pushing and supporting from the State and in any economic context an energy transition from the use of firewood, based on the pollution that affects our cities and causes significant adverse effects on people's health.

For each of these long-term energy futures, energy demand projections were built, consisting basically of the quantification of energy needs (measured in terms of quantity or volume), required for the development and normal functioning of the country's economic activities, as well as the population. For this purpose, there are technological tools that allow the modeling of the national economy, where sectors are represented, such as copper mining, the paper and cellulose industry, the activity of land transportation of passengers and cargo, modeling even the residential sector from north to south of the country. Section 4 of this report will present a more detailed description of the modeling tools available to the Ministry of Energy. Each economic sector develops during the projection period according to the vision and story behind each energy scenario, development that will necessarily require a continuous supply of energy throughout the period. For example, for the copper mining sector, each scenario assumes an expected level of mineral production, consistent with the economic growth and the country's technological vision of that energy scenario, and such production level requires, as expected, volumes of energy for the operation of the different processes of the mining value chain, which are quantified by the modeling tool.

These energy projections were made considering a series of assumptions and parameters, built based on the opinions, experiences and preferences of the stakeholders who participated in the workshops. Actors and *stakeholders* from all sectors of society: academia, civil society, officials from other public institutions, citizens, and experts from different disciplines associated with the process of building energy scenarios).

Once the energy requirements of the demand are projected, the country's electric requirements will be taken into account, with which it will be possible to project the generation park that will be necessary to meet those requirements. This information is then submitted to the National Energy Commission (CNE), together with recommendations for transmission expansion and recommendations for provinces in areas that should be declared as development poles. Finally, the CNE is the body in charge of determining transmission expansions in annual processes.

The information gathered in the participatory process is a fundamental piece in the construction of the PELP, combined with a series of other inputs to build the model of electric requirements projections.

The participatory process was particularly key in defining collective preferences and potential decisions under different circumstances (scenarios). These preferences were combined with: (1) technical considerations defined in the transmission law or raised by the technical team, (2) baseline data and background information, (3) political-strategic decisions, and (4) social, environmental and territorial considerations, which also incorporated the concerns and issues raised during the participatory process.

8.3 ENERGY MODEL CONSIDERATIONS

Table 6: Activity levels considered for each economic activity. Source: Prepared based on Central Bank (2022)[71]

ECONOMIC ACTIVITY	LEVELS OF ACTIVITY CONSIDERED
Residential	Population
Copper	Copper concentrate production [t]
Iron	Iron production [t] Iron
Saltpeter	Nitrate production [t] Nitrate production [t
Various mines	Total mineral production [t] Paper and cellulose
Pulp and paper	Pulp production [t]. The projection considers surface restrictions due to new crops
Iron and steel industry	Steel production [t]. A distinction is made between BOF and EAF technologies.
Cement	Cement and clinker production [t].
Sugar	Sugar beet production [t].
Fishing	Extraction and cultivation [t]
Petrochemicals	Methanol and ethylene production

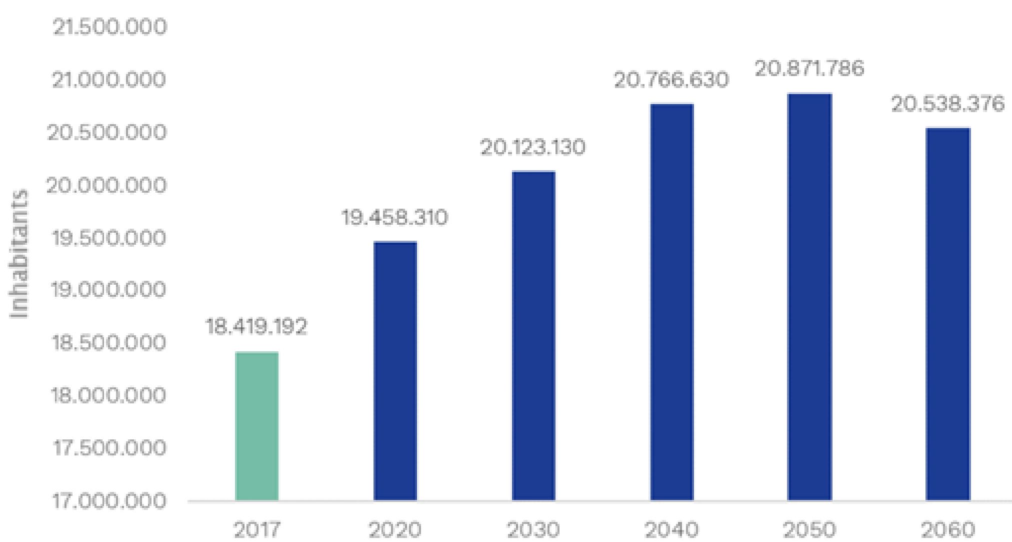


Figure 54: Population projection in the national territory. Source: United Nations (2022)[72].

[71] More information is available at: https://www.bcentral.cl/web/banco-central/w/2.3-agrupaciones-de-actividades

[72] United Nations Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022. The medium scenario was used.

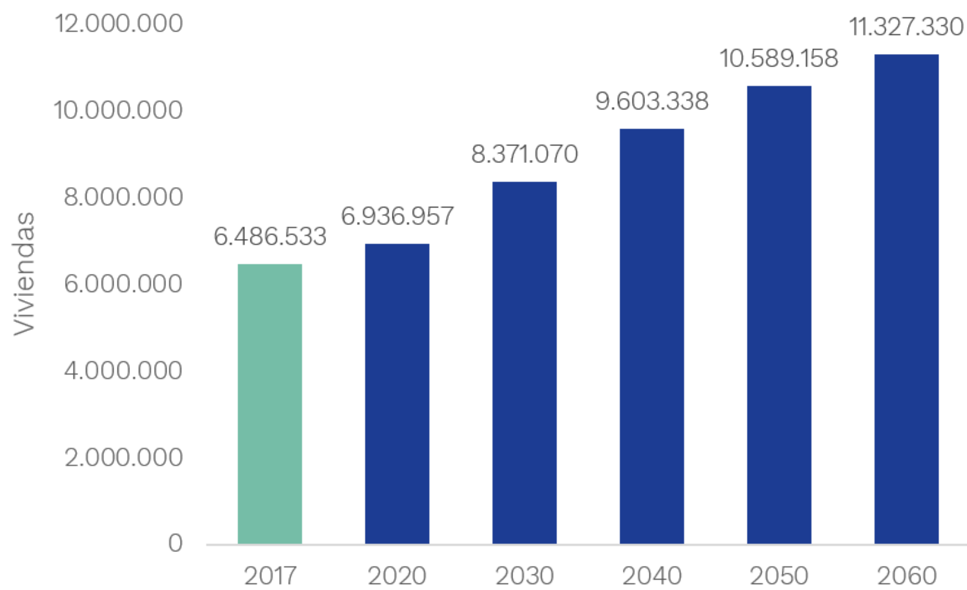


Figure 55: Housing projection 2017 - 2050. Source: Ministry of Energy, based on population and density projections.

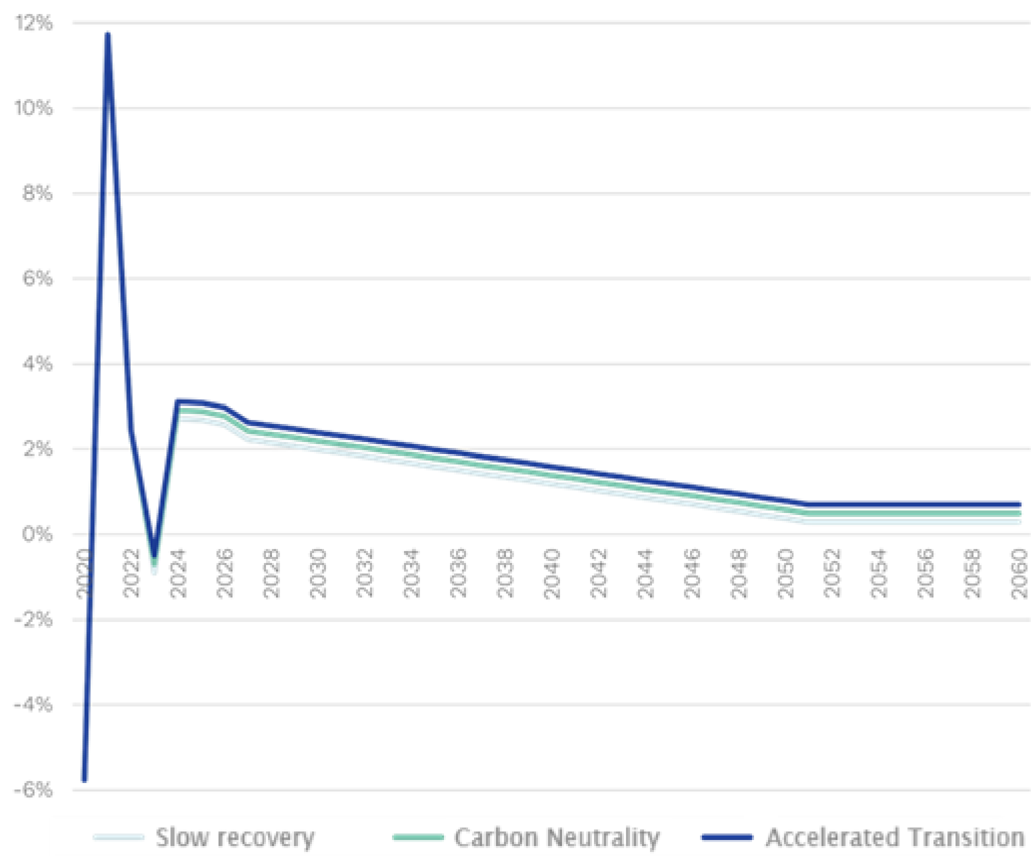


Figure 56: Projected Gross Domestic Product (GDP) growth rate to 2060. Source: Ministry of Finance.

8.4 ENERGY MODEL MEASURES

Below, from Table 7 to Table 10 , the measures included in the energy model are presented for the industry and mining, commercial and public, residential, and transportation sectors.

Table 7: Specification of modeled measures in the industry and mining sector.

<table>
<tr><th colspan="3">MEASURE</th><th>SLOW RECOVERY</th><th>CARBON NEUTRALITY</th><th>ACCELERATED TRANSITION</th></tr>
<tr><td colspan="3">Motor efficiency standards</td><td colspan="3">More stringent minimum energetic efficiency standards (MEPS) in 2025 and 2035.</td></tr>
<tr><td colspan="3">Energy management systems (EMS) in large consumers</td><td colspan="2">Annual savings per EMS:
1.9% the first 6 years of implementation, 1% between year 7 and year 20,
0.6% from year 21</td><td>Annual savings per EMS: 2.8% the first 6 years of implementation,
1% between year 7 and year 20, 0.6% from year 21 onwards.</td></tr>
<tr><td colspan="3">Renewable energy in thermal processes</td><td colspan="3">13% share of solar energy in thermal use in pulp and paper, various industries, cement, sugar, iron and steel, various mines by 2050. By 2060, a 19.8% share is reached.</td></tr>
<tr><td rowspan="4">Green hydrogen</td><td colspan="2">Thermal processes</td><td colspan="2">Up to 9% share in various industries by 2050 and 12.4% by 2060.</td><td>Up to 15% share in miscellaneous industries by 2050 and 29.7% by 2060</td></tr>
<tr><td rowspan="3">Driving Uses</td><td>Industry</td><td rowspan="2">N/A</td><td colspan="2">10% share by 2050</td></tr>
<tr><td>Copper Mining</td><td colspan="2">Reaches 44.3% share in 2035 in open pit mines and 10.4% in 2040 in subway mines.</td></tr>
<tr><td>Non-Copper Mining</td><td>N/A</td><td colspan="2">Diesel replacement reaches 92.47% by 2050</td></tr>
<tr><td rowspan="6">Electrification</td><td rowspan="3">Driving Uses</td><td>Industry</td><td>N/A</td><td colspan="2">Diesel to electricity replacement reaches 61% in Miscellaneous Industries sector</td></tr>
<tr><td>Mining Copper</td><td>N/A</td><td colspan="2">Reaches 55.7% in 2035 in open pit mines. In subway remains constant (only diesel is replaced by H2V).</td></tr>
<tr><td>Non-copper mining</td><td>N/A</td><td colspan="2">Replacement of diesel by electricity reaches 70% (of the balance not replaced by H2V) by 2060.</td></tr>
<tr><td rowspan="3">Thermal Uses</td><td>Industry</td><td>N/A</td><td colspan="2">Electricity in Industry Thermal Uses reaches 42.2% by 2060</td></tr>
<tr><td>Copper Mining</td><td>In smelting process reaches a share of 65% by 2060</td><td colspan="2">In smelting process reaches 85% share in 2060</td></tr>
<tr><td>Non-Copper Mining</td><td colspan="3">Electricity in Non-Copper Mining Thermal Uses reaches 28% by 2050</td></tr>
</table>

Table 8: Specification of modeled measures in commercial and public sector.

<table>
<tr><th>MEASURE</th><th>SLOW RECOVERY</th><th>CARBON NEUTRALITY</th><th>ACCELERATED TRANSITION</th></tr>
<tr><td>Energetic efficiency in public lighting</td><td colspan="2">8,000 luminaires replaced per year</td><td>18,000 luminaires replaced per year</td></tr>
<tr><td>Energetic efficiency Program for Public Buildings</td><td>5 public buildings are refurbished per year</td><td colspan="2">15 public buildings refurbished per year</td></tr>
<tr><td>Hospital Energetic efficiency Program</td><td colspan="2">5 hospitals are refurbished per year.</td><td>10 hospitals are retrofitted per year.</td></tr>
<tr><td>Electrification of heating in shopping centers</td><td>N/A</td><td colspan="2">100% use of electricity for heating by 2050</td></tr>
<tr><td>Electrification of motor uses in the commercial sector</td><td>40% share of driving uses by 2060</td><td>60% share of driving uses by 2060</td><td>80% share of driving uses by 2060</td></tr>
</table>

Table 9: Specification of modeled measures in residential sector[73].

<table>
<tr><th colspan="2">MEASURE</th><th>SLOW RECOVERY</th><th>CARBON NEUTRAL</th><th>ACCELERATED TRANSITION</th></tr>
<tr><td colspan="2">Solar thermal systems for domestic hot water</td><td>From 2023, 8,000 solar thermal systems will be incorporated each year.</td><td>From 2023 onwards, 12,000 solar thermal systems are incorporated each year</td><td>20,000 solar thermal systems are added each year after 2023</td></tr>
<tr><td colspan="2">Minimum standards for chillers</td><td colspan="3">85% efficiency is achieved by 2060, starting from 70% by 2022</td></tr>
<tr><td rowspan="3">Thermal envelope of dwellings</td><td>Regulation thermal regulation (RT)</td><td>RT1 starts in 2023. RT2 and RT3 not applicable (upgrades and improvements).</td><td colspan="2">RT1 starts in 2023 and RT2 in 2031. RT3 does not apply.
New RT in 2022.</td></tr>
<tr><td>Thermal retrofit</td><td>Subsidies: 10,000 dwellings per year from 2022 to 2050.</td><td>Subsidies: 20,000 dwellings per year from 2022 to 2050.

Credits: 10,000 dwellings per year through 2050</td><td>Subsidies: 30,000 housing units per year from 2022 to 2050

Credits: 30,000 dwellings per year through 2050</td></tr>
<tr><td>Energy qualification of new housing</td><td>From 2023, 1,000 homes are rated each year</td><td>From 2023, 2,000 dwellings are qualified each year</td><td>From 2023, 4,000 homes are rated each year</td></tr>
<tr><td colspan="2">Net Zero Buildings</td><td>N/A</td><td>450,000 homes are built to Net Zero standard between 2041-2050</td><td>900,000 homes are built to Net Zero standard between 2041-2050</td></tr>
<tr><td rowspan="3">Electrification of consumption</td><td>Heating</td><td>50% of homes with electric heating by 2060</td><td colspan="2">70% of homes electrically heated by 2060</td></tr>
<tr><td>Cooking</td><td>20% of dwellings with electric cooking by 2050</td><td>25% of houses and 60% of apartments with electric cooking by 2050.</td><td>55% of houses and 60% of apartments with electric cooking by 2050.</td></tr>
<tr><td>Sanitary Hot Water</td><td>20% of houses with electric cooking by 2050.</td><td>25% of houses and 60% of apartments with electric cook stove by 2050.</td><td>55% of houses and 60% of apartments with electric cooking by 2050.</td></tr>
</table>

[73] Participation percentages (%) have been approximated at around 5%.

Table 10: Specification of measures modeled in the transportation sector[74].

MEASURE		SLOW RECOVERY	CARBON NEUTRALITY	ACCELERATED TRANSITION
Electro-mobility	Urban public transport	100% electric buses by 2035 in the Metropolitan Region and by 2040 in other regions		
	Cabs	100% electric fleet by 2046	100% electric fleet by 2038	
	Light vehicles	40% share of electric vehicles by 2050	60% share of electric vehicles by 2050	80% share of electric vehicles by 2050
	Medium vehicles	75% share of electric vehicles by 2050		
	Conversion of light duty vehicles to EVs	Not applicable	Achieve annual light-duty vehicle conversion rate of 15% by 2035 (starting in 2023)	Achieve annual light-duty vehicle conversion rate of 20% by 2035 (starting 2023)
Energetic efficiency standards	Light-duty vehicles	Gasoline and diesel fuel efficiency increases at a rate of 1% per year, reaching 16.7 km/l and 23.7 km/l by 2060 respectively.		
	Medium vehicles	Gasoline and diesel fuel efficiency increases at an annual rate of 1%, reaching 16.6 km/l and 23.5 km/l by 2060, respectively.		
	Heavy-duty vehicles (tractor-trailers)	From 2025 onwards, the efficiency of tractor-trailers improves, reaching a 40% increase in efficiency by 2050.		
Green hydrogen	Heavy-duty vehicles (tractor-trailers)	50% of the fleet by 2050	85% of fleet hydrogen-powered by 2050 100% zero sales and low emissions by 2045	
Bicycle infrastructure		n/a	Linear increase in bicycle mode share to reach 5% of urban transport	Linear increase of bicycle mode share to reach 10% of urban transport

[74] The participation percentages (%) have been approximated at around 5%.

8.5 TERRITORIAL CONSIDERATIONS

Table 11: Technical factors for the identification of energy generation potentials based on renewable energy sources

<table>
<tr><th colspan="2">SOURCE</th><th>WIND</th><th>SOLAR PHOTOVOLTAIC</th><th>SOLAR CSP</th><th>HYDROELECTRIC</th><th>GEOTHERMAL</th></tr>
<tr><td rowspan="10">Technical Factors</td><td>DNI (Direct Normal Irradiation)</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Slope</td><td>< 15°</td><td>< 10° North facing and > 4° for all other orientations</td><td>< 7°</td><td>-</td><td>-</td></tr>
<tr><td>Altitude</td><td>< 3,000 masl for the whole country</td><td>< 4.000 masl for the whole country</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Percentage of cloud cover</td><td>-</td><td>-</td><td>< 20%</td><td>-</td><td>-</td></tr>
<tr><td>Percentage of hours with Wind Speed greater than 15 m/s at 5.5 m height</td><td>-</td><td>-</td><td>< 0,5%</td><td>-</td><td>-</td></tr>
<tr><td>PPO Project Areas</td><td>Exclusion zones by presence</td><td>Exclusion zones by presence</td><td rowspan="5">Exclusion zones by presence</td><td>-</td><td>-</td></tr>
<tr><td>Distributors' Bidding Project Areas</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>National Assets for Energy Purposes</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Taltal Reserve Area</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Wind Power Potential 2021</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">Standards</td><td>Plant factor</td><td>> 30%</td><td>> 21%</td><td>-</td><td>> 50%</td><td>-</td></tr>
<tr><td>Minimum continuous area</td><td>112 Ha between Arica and Coquimbo; 168 Ha between Valparaíso and Magallanes (equivalent to 5.6 MW)</td><td>12 ha (equivalent to 3 MW)</td><td>700 ha (equivalent to 100 MW)</td><td>Minimum of 3 MW</td><td>Not applicable</td></tr>
</table>

Table 12: Methodological treatment for Land Valuation Objects (OdVT).

VALUATION CRITERION	METHODOLOGICAL TREATMENT		
	NOT CONSIDERED	EXCLUDED	SENSITIVIZED
Normative	1. Virgin Region Reserve 2. Archaeological Site	National Parks (except in Geothermal) 2. 2. Natural Monuments (except in Hydro) 3. Ramsar Sites (except in Geothermal) 4. Historical Monument 5. World Heritage Site 6. Typical Zone	1. Indigenous Lands with recognized rights: Law Nº 19.253. Paleontological Site (Paleontological Fossil Potential)
Development		1. National Reserves (except in Hidro) 2. Forest Reserves (except in Hidro) 3. Native Forest (species with conservation problems)[75] 4. Sites of cultural significance 5. Soil classes I, II and III (CSP). Only for Wind, PV and CSP potential: 1. Salt Flats (300m) 2. Inventory of Water Bodies (300m) 3. Glaciers Inventory (300m) 4. Active Volcanoes 5. Urban Boundaries and Consolidated Urban Areas (1000m) 6. Inventory of Anthropized Water Bodies (300m) 7. Inventory of Rivers/Hydrographic Network (300m) 8. Road Network (60m) 9. Shoreline (100m) 10. Mining Tailings	Indigenous Development Area 2. Zones of Tourist Interest (ZOTI) (Eolic) 3. Soil Classes I, II and III (FV)

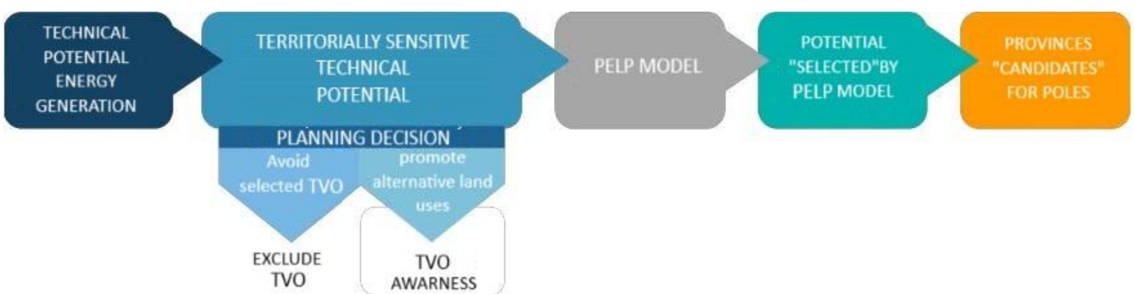


Figure 57: Diagram of the territorial sensitization process to define candidate provinces for PDGE.

[75] Species with conservation problems identified in the official MMA lists: Endangered, Critically Endangered and Vulnerable.

8.6 ELECTRIC DEMAND (HYDROGEN)

The production of green hydrogen comes from two sources: on the one hand, it is obtained from domestic consumption required to replace polluting energy sources in sectors such as cargo transportation, motor uses in mining, among others. On the other hand, H2V production is required for export in the form of *carriers*, such as ammonia or methanol, the former being one of the most prominent forms. The H2V production figures in the different scenarios are constructed based on the National Green Hydrogen Strategy (2020) .[76]

Projections of H2V production for domestic consumption and export in each energy scenario are presented in Figure 58 to Figure 60.

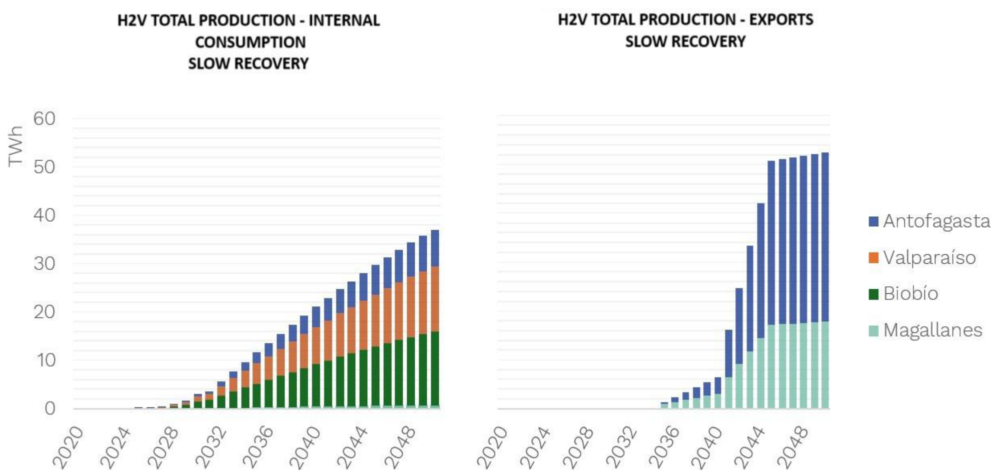


Figure 58: Total green hydrogen production for domestic consumption (left) and export (right) under the Slow Recovery scenario.

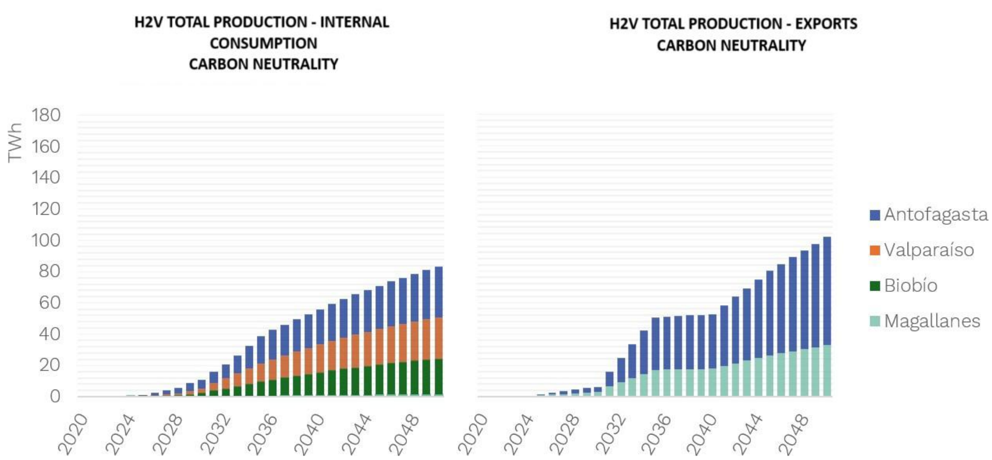


Figure 59: Total green hydrogen production for domestic consumption (left) and export (right) under the Carbon Neutral scenario.

[76] Available at: https://energia.gob.cl/sites/default/files/estrategia_nacional_de_hidrogeno_verde_-_chile.pdf

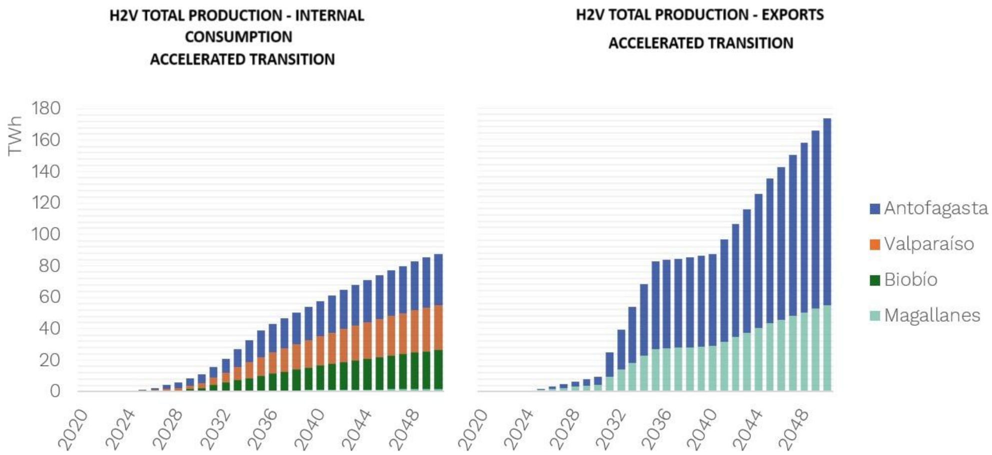


Figure 60: Total green hydrogen production for domestic consumption (left) and export (right) under the Accelerated Transition scenario.

Moreover, hydrogen and ammonia are projected to be produced by two types: *off-grid* (disconnected from the electric system) and *on-grid* (connected to the electric system). For the first type, a production level ranging from 50% to 90% is projected, depending on the scenario, as presented in Table 13 , below.

Table 13: Green hydrogen production factor in *on-grid* and *off-grid* form by scenario.

Scenario	Type	Year								
		2020	2025	2030	2035	2040	2045	2050	2055	2060
Slow Recovery	on-grid	59%	44%	30%	35%	40%	45%	50%	50%	70%
	off-grid	41%	56%	70%	65%	60%	55%	50%	50%	30%
Carbon Neutrality	on-grid	54%	47%	40%	45%	50%	60%	70%	70%	90%
	off-grid	46%	53%	60%	55%	50%	40%	30%	30%	10%
Accelerated Transition	on-grid	50%	50%	50%	60%	70%	80%	90%	90%	90%
	off-grid	50%	50%	50%	40%	30%	20%	10%	10%	10%
All Scenarios	on-grid Magallanes	0%	0%	0%	0%	0%	0%	0%	0%	0%
	off-grid Magallanes	100%	100%	100%	100%	100%	100%	100%	100%	100%

Additionally, green hydrogen production is categorized according to whether it is intended to be consumed as hydrogen or to supply ammonia synthesis. In the former case, hydrogen production can be carried out flexibly depending on incentives to use intraday production cost variations. Given the fast response rates of the electrolyzers, it is assumed that they can be adapted to this type of regime, assuming a lifetime commitment.

In the second case, the hydrogen will serve to supply the demand for ammonia synthesis through the Haber-Bosch process. Given the high temperatures and pressures at which the Haber-Bosch process operates, it has technical minimums for ammonia production, as well as hourly ramp restrictions, which make it inflexible. When the high cost of hydrogen storage is also considered, the buffer feeding the Haber-Bosch process will tend to be of low capacity, so that the hydrogen produced will be rapidly consumed for ammonia synthesis. Thus, the inflexibility of the Haber-Bosch process is transferred to the production of green hydrogen for this purpose, making it inflexible.

The annual demand for green hydrogen, produced on-grid, breaks down as follows:

- Demand for export: 90% of this demand will be produced in inflexible form, mainly to produce ammonia, while the rest will be produced in flexible form to produce mainly other *carriers*.
- Demand for local consumption: 90% of this demand will be produced in a flexible form, considering that the hydrogen produced will be consumed in this form, while the remaining 10% will be produced in an inflexible form, to supply possible consumption of ammonia demand.

8.7 DEVELOPMENT POLES COORDINATES

PDGE Tocopilla Province (Polygon 1)

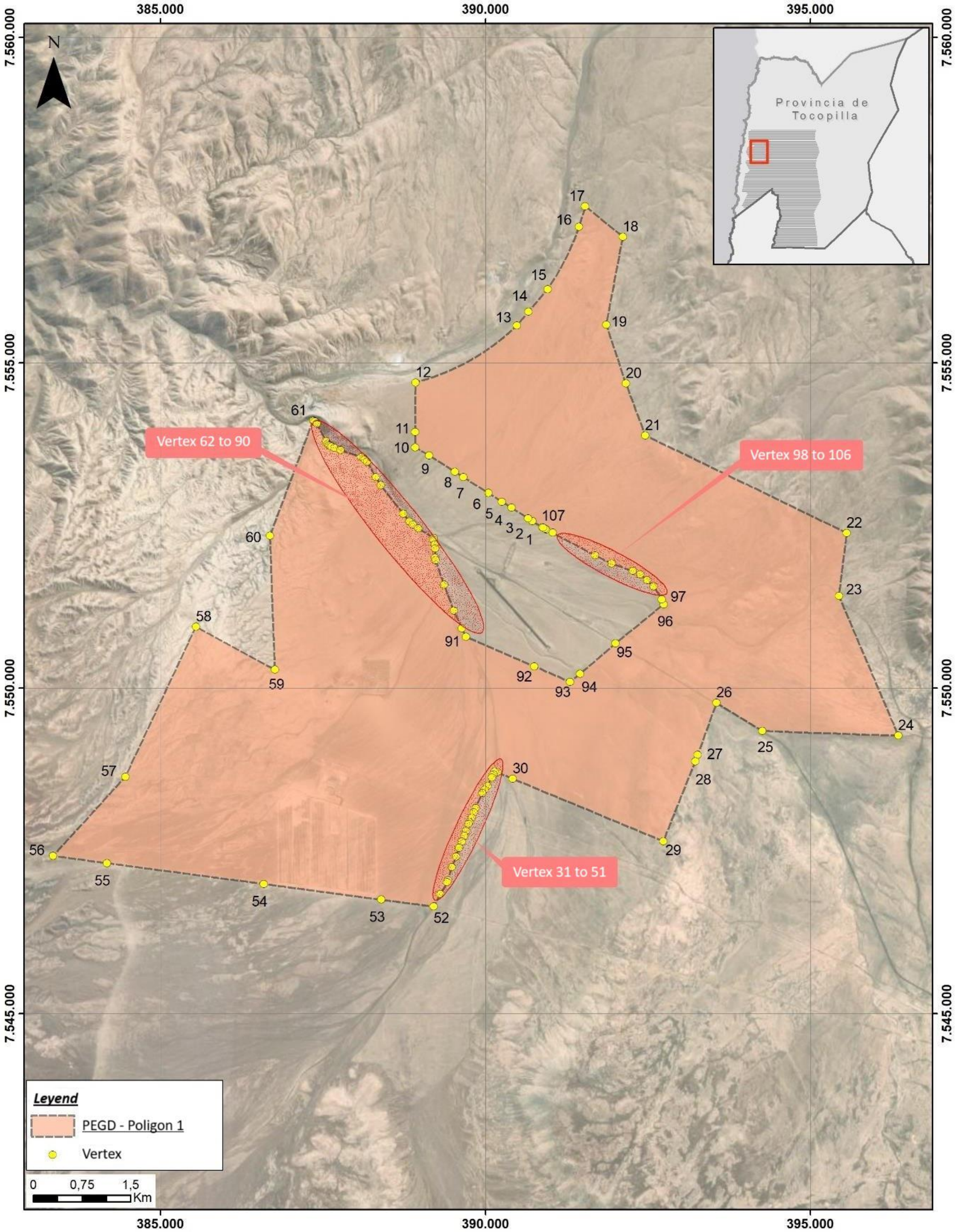


Figure 61: PDGE Tocopilla - Polygon 1.

Table 14: Polygon 1 vertex coordinates - Province of Tocopilla.

VERTEX	PROJECTED COORDINATES[77]		GEOGRAPHICAL COORDINATES[78]	
	EAST	NORTH	LONGITUDE	LATITUDE
1	390.871	7.552.473	-70,05815491	-22,12937891
2	390.717	7.552.571	-70,05964546	-22,12848266
3	390.653	7.552.612	-70,06026509	-22,12811009
4	390.397	7.552.774	-70,06273116	-22,12662721
5	390.253	7.552.866	-70,06411959	-22,12579231
6	390.042	7.553.000	-70,06615398	-22,12456893
7	389.656	7.553.245	-70,06988593	-22,12232460
8	389.526	7.553.328	-70,07113731	-22,12157202
9	389.133	7.553.578	-70,07493433	-22,11928835
10	388.916	7.553.703	-70,07702395	-22,11814024
11	388.917	7.553.937	-70,07699920	-22,11602590
12	388.920	7.554.698	-70,07691876	-22,10915449
13	390.481	7.555.576	-70,06172742	-22,10132741
14	390.657	7.555.787	-70,06000710	-22,09943073
15	390.953	7.556.132	-70,05711516	-22,09633033
16	391.438	7.557.091	-70,05234587	-22,08769555
17	391.533	7.557.408	-70,05140476	-22,08484371
18	392.111	7.556.939	-70,04584180	-22,08911695
19	391.857	7.555.587	-70,04838874	-22,10131236
20	392.157	7.554.687	-70,04554068	-22,10946064
21	392.457	7.553.887	-70,04268567	-22,11670558
22	395.557	7.552.387	-70,01272997	-22,13044421
23	395.436	7.551.416	-70,01396395	-22,13920990
24	396.351	7.549.271	-70,00522808	-22,15863311
25	394.258	7.549.342	-70,02552384	-22,15786735
26	393.553	7.549.774	-70,03233044	-22,15392379
27	393.263	7.548.976	-70,03520189	-22,16111451
28	393.226	7.548.876	-70,03556469	-22,16201247
29	392.735	7.547.648	-70,04040941	-22,17307639
30	390.415	7.548.610	-70,06284215	-22,16424442
31	390.184	7.548.707	-70,06507571	-22,16335108

[77] Coordinates referenced to Sirgas Chile Datum, UTM Projection - Huso 19S.

[78] Coordinates referenced to the Sirgas Chile Datum.

VERTEX	PROJECTED COORDINATES[77]		GEOGRAPHICAL COORDINATES[78]	
	EAST	NORTH	LONGITUDE	LATITUDE
32	390.140	7.548.724	-70,06550202	-22,16319989
33	390.123	7.548.671	-70,06566971	-22,16367336
34	390.094	7.548.625	-70,06595431	-22,16409045
35	390.031	7.548.502	-70,06657353	-22,16519232
36	389.982	7.548.437	-70,06705413	-22,16578080
37	389.951	7.548.388	-70,06735867	-22,16621497
38	389.845	7.548.157	-70,06839472	-22,16829526
39	389.817	7.548.091	-70,06867291	-22,16889641
40	389.790	7.548.011	-70,06894168	-22,16961214
41	389.751	7.547.945	-70,06932935	-22,17020655
42	389.736	7.547.915	-70,06947071	-22,17048102
43	389.696	7.547.810	-70,06986472	-22,17142028
44	389.676	7.547.730	-70,07006888	-22,17214491
45	389.632	7.547.639	-70,07049709	-22,17296017
46	389.594	7.547.548	-70,07087744	-22,17378085
47	389.546	7.547.411	-70,07134665	-22,17501353
48	389.477	7.547.248	-70,07202784	-22,17648247
49	389.421	7.547.049	-70,07258437	-22,17828252
50	389.410	7.547.018	-70,07269632	-22,17856357
51	389.302	7.546.837	-70,07375039	-22,18019126
52	389.203	7.546.646	-70,07472801	-22,18190775
53	388.393	7.546.750	-70,08257292	-22,18091433
54	386.585	7.546.992	-70,10009059	-22,17861038
55	384.172	7.547.312	-70,12347509	-22,17555952
56	383.345	7.547.425	-70,13148292	-22,17448829
57	384.457	7.548.640	-70,12061393	-22,16358298
58	385.542	7.550.945	-70,10993309	-22,14283945
59	386.757	7.550.287	-70,09819469	-22,14886134
60	386.681	7.552.342	-70,09878959	-22,13029185
61	387.345	7.554.113	-70,09222706	-22,11433793
62	387.358	7.554.109	-70,09209964	-22,11437647
63	387.377	7.554.098	-70,09192086	-22,11447566
64	387.402	7.554.066	-70,09167689	-22,11477127
65	387.545	7.553.797	-70,09031053	-22,11720869
66	387.573	7.553.756	-70,09004144	-22,11757377
67	387.589	7.553.738	-70,08988881	-22,11773971
68	387.608	7.553.723	-70,08970775	-22,11787715
69	387.630	7.553.710	-70,08949319	-22,11799569
70	387.673	7.553.692	-70,08907892	-22,11816098

VERTEX	PROJECTED COORDINATES[77]		GEOGRAPHICAL COORDINATES[78]	
	EAST	NORTH	LONGITUDE	LATITUDE
71	387.769	7.553.657	-70,08814770	-22,11848268
72	388.086	7.553.552	-70,08508726	-22,11944950
73	388.121	7.553.535	-70,08474480	-22,11961430
74	388.142	7.553.518	-70,08454586	-22,11976381
75	388.174	7.553.482	-70,08423544	-22,12009331
76	388.310	7.553.245	-70,08293082	-22,12224107
77	388.388	7.553.119	-70,08218793	-22,12338127
78	388.731	7.552.683	-70,07889107	-22,12734430
79	388.830	7.552.565	-70,07793984	-22,12841894
80	388.884	7.552.515	-70,07742253	-22,12887168
81	388.963	7.552.455	-70,07665968	-22,12941926
82	389.201	7.552.310	-70,07435743	-22,13074380
83	389.202	7.552.280	-70,07435521	-22,13101297
84	389.219	7.552.205	-70,07419361	-22,13169221
85	389.224	7.552.146	-70,07414316	-22,13222732
86	389.219	7.552.008	-70,07420713	-22,13347571
87	389.228	7.551.969	-70,07411677	-22,13382286
88	389.364	7.551.589	-70,07283247	-22,13726972
89	389.510	7.551.192	-70,07144231	-22,14086287
90	389.634	7.550.921	-70,07025185	-22,14331452
91	389.699	7.550.791	-70,06963535	-22,14449359
92	390.751	7.550.335	-70,05946963	-22,14867988
93	391.298	7.550.098	-70,05417821	-22,15085891
94	391.451	7.550.221	-70,05268709	-22,14975867
95	392.000	7.550.690	-70,04733381	-22,14555696
96	392.737	7.551.290	-70,04014205	-22,14017541
97	392.710	7.551.367	-70,04040023	-22,13947878
98	392.583	7.551.566	-70,04161839	-22,13767367
99	392.483	7.551.663	-70,04258678	-22,13679272
100	392.379	7.551.751	-70,04358144	-22,13599764
101	392.266	7.551.801	-70,04468117	-22,13553649
102	391.938	7.551.917	-70,04785436	-22,13446451
103	391.684	7.552.042	-70,05030869	-22,13332540
104	391.030	7.552.389	-70,05662173	-22,13015011
105	390.934	7.552.440	-70,05755269	-22,12968183
106	390.912	7.552.451	-70,05776266	-22,12957621
107	390.884	7.552.466	-70,05803074	-22,12944136

PDGE Tocopilla Province (Polygon 2)

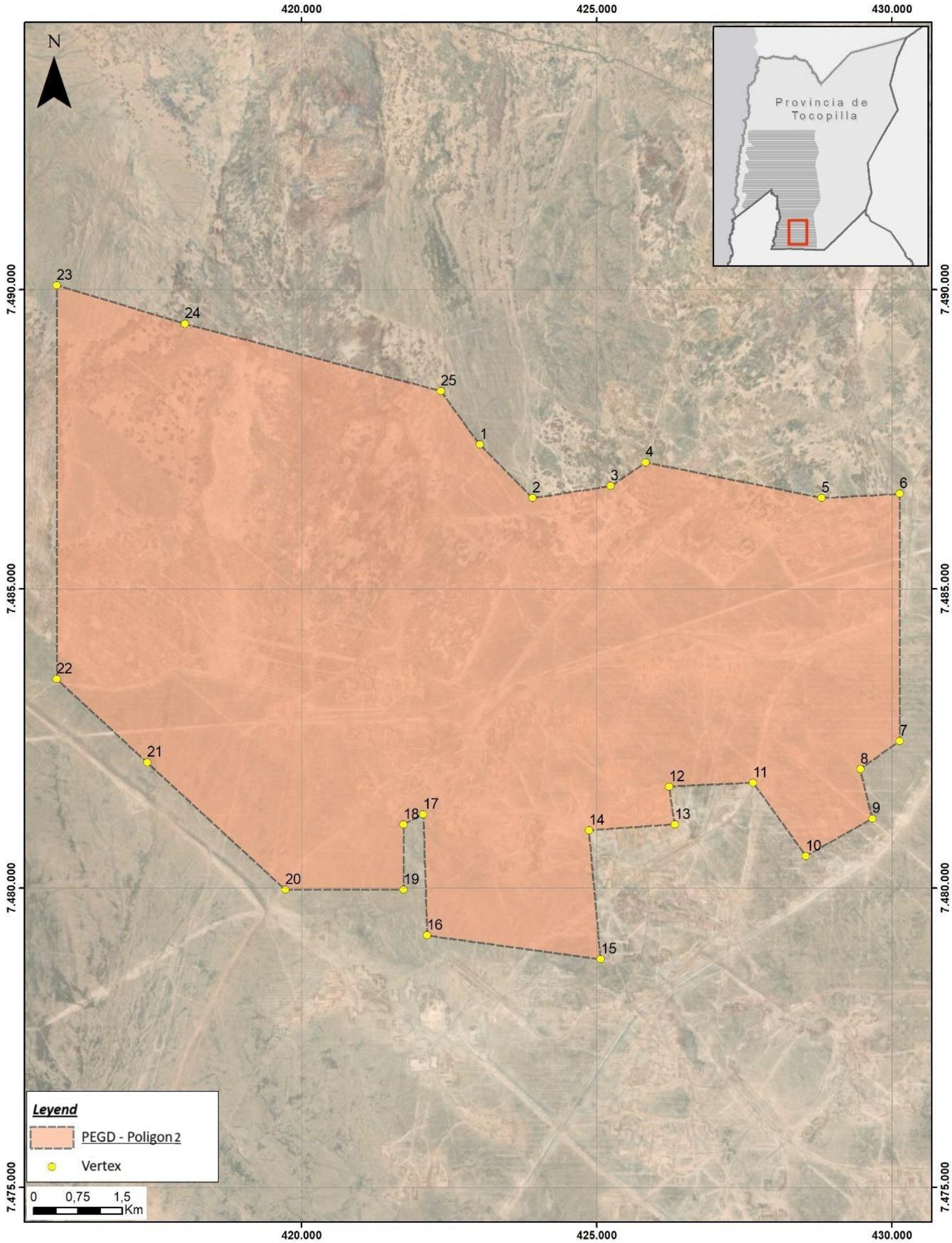


Figure 62: PDGE Tocopilla - Polygon 2.

Table 15: Polygon 1 vertex coordinates - Province of Tocopilla.

VERTEX	PROJECTED COORDINATES[79]		GEOGRAPHICAL COORDINATES[80]	
	EAST	NORTH	LONGITUDE	LATITUDE
1	423.016	7.487.414	-69,74963757	-22,71880040
2	423.909	7.486.521	-69,74098618	-22,72690713
3	425.232	7.486.719	-69,72809466	-22,72517383
4	425.827	7.487.116	-69,72227900	-22,72161513
5	428.804	7.486.521	-69,69332248	-22,72712095
6	430.133	7.486.593	-69,68038186	-22,72652192
7	430.133	7.482.459	-69,68056674	-22,76386480
8	429.465	7.481.990	-69,68708599	-22,76807764
9	429.664	7.481.163	-69,68519037	-22,77555470
10	428.539	7.480.535	-69,69617286	-22,78118353
11	427.646	7.481.758	-69,70481496	-22,77009164
12	426.224	7.481.692	-69,71867068	-22,77062737
13	426.324	7.481.064	-69,71773390	-22,77630793
14	424.868	7.480.965	-69,73191402	-22,77713979
15	425.067	7.478.815	-69,73008437	-22,79656718
16	422.123	7.479.212	-69,75874149	-22,79284839
17	422.057	7.481.229	-69,75928503	-22,77462189
18	421.726	7.481.064	-69,76251493	-22,77610025
19	421.726	7.479.972	-69,76256972	-22,78595883
20	419.724	7.479.972	-69,78207622	-22,78586440
21	417.382	7.482.102	-69,80478300	-22,76651649
22	415.847	7.483.496	-69,81965028	-22,75384380
23	415.847	7.490.072	-69,81929650	-22,69444673
24	418.022	7.489.431	-69,79815820	-22,70034162
25	422.355	7.488.307	-69,75603387	-22,71070389

79 Coordinates referenced to Sirgas Chile Datum, UTM Projection - Huso 19S.

80 Coordinates referenced to Sirgas Chile Datum.

PDGE Antofagasta Province (Polygon 1)

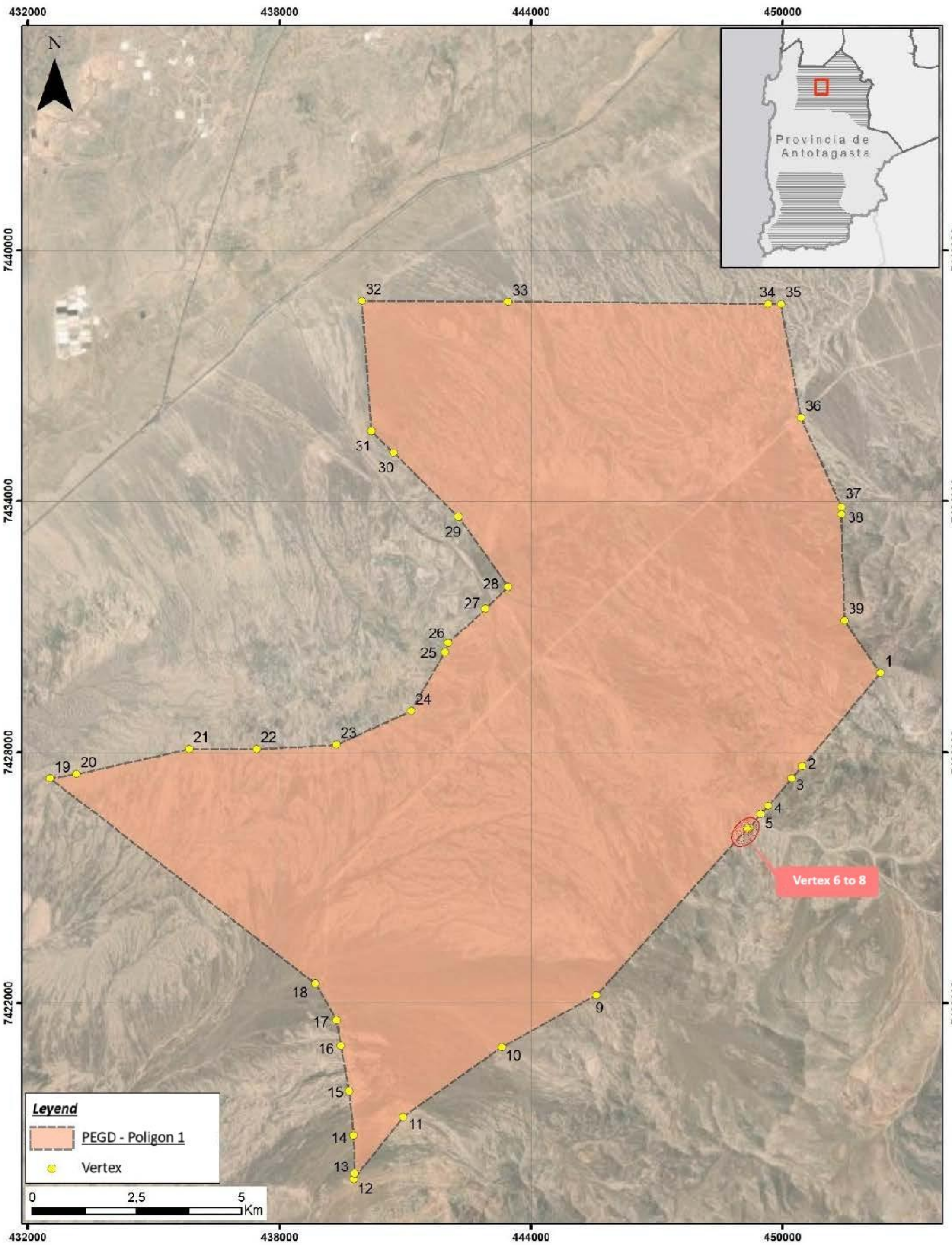


Figure 63: PDGE Antofagasta - Polygon 1.

Table 16: Polygon 1 vertex coordinates - Province of Antofagasta.

VERTEX	PROJECTED COORDINATES[81]		GEOGRAPHICAL COORDINATES[82]	
	EAST	NORTH	LONGITUDE	LATITUDE
1	452.346	7.429.892	-69,46582684	-23,23948807
2	450.465	7.427.677	-69,48427708	-23,25944092
3	450.215	7.427.382	-69,48673321	-23,26209646
4	449.655	7.426.722	-69,49223285	-23,26804208
5	449.482	7.426.518	-69,49393424	-23,26988128
6	449.208	7.426.195	-69,49662246	-23,27278712
7	449.175	7.426.157	-69,49694260	-23,27313317
8	449.152	7.426.177	-69,49717022	-23,27294666
9	445.552	7.422.187	-69,53251161	-23,30887718
10	443.302	7.420.952	-69,55456208	-23,31995804
11	440.952	7.419.287	-69,57761181	-23,33491251
12	439.765	7.417.787	-69,58928037	-23,34841813
13	439.785	7.417.926	-69,58907502	-23,34716115
14	439.752	7.418.850	-69,58936721	-23,33881659
15	439.652	7.419.908	-69,59030315	-23,32925340
16	439.452	7.420.987	-69,59221622	-23,31950231
17	439.352	7.421.587	-69,59317022	-23,31407906
18	438.852	7.422.487	-69,59802391	-23,30593114
19	432.523	7.427.382	-69,65969826	-23,26146688
20	433.152	7.427.487	-69,65354625	-23,26054595
21	435.852	7.428.087	-69,62712540	-23,25523403
22	437.452	7.428.087	-69,61148418	-23,25529571
23	439.352	7.428.187	-69,59290617	-23,25446366
24	441.152	7.428.987	-69,57527878	-23,24730295
25	441.952	7.430.387	-69,56740509	-23,23468557
26	442.027	7.430.607	-69,56666325	-23,23270391
27	442.908	7.431.439	-69,55801489	-23,22521374
28	443.456	7.431.956	-69,55264813	-23,22056503
29	442.265	7.433.623	-69,56422130	-23,20546718
30	440.735	7.435.153	-69,57911114	-23,19159396
31	440.201	7.435.687	-69,58430774	-23,18675217

[81] Coordinates referenced to the Sirgas Chile Datum, UTM Projection - Huso 19S.

[82] Coordinates referenced to Sirgas Chile Datum.

VERTEX	PROJECTED COORDINATES[81]		GEOGRAPHICAL COORDINATES[82]	
	EAST	NORTH	LONGITUDE	LATITUDE
32	439.963	7.438.782	-69,58651258	-23,15878138
33	443.456	7.438.754	-69,55239587	-23,15915507
34	449.655	7.438.705	-69,49183643	-23,15980020
35	449.964	7.438.703	-69,48881378	-23,15983179
36	450.441	7.436.004	-69,48424895	-23,18422381
37	451.393	7.433.861	-69,47501059	-23,20361087
38	451.398	7.433.681	-69,47496468	-23,20523411
39	451.472	7.431.162	-69,47432099	-23,22799077

PDGE Antofagasta Province (Polygon 2)

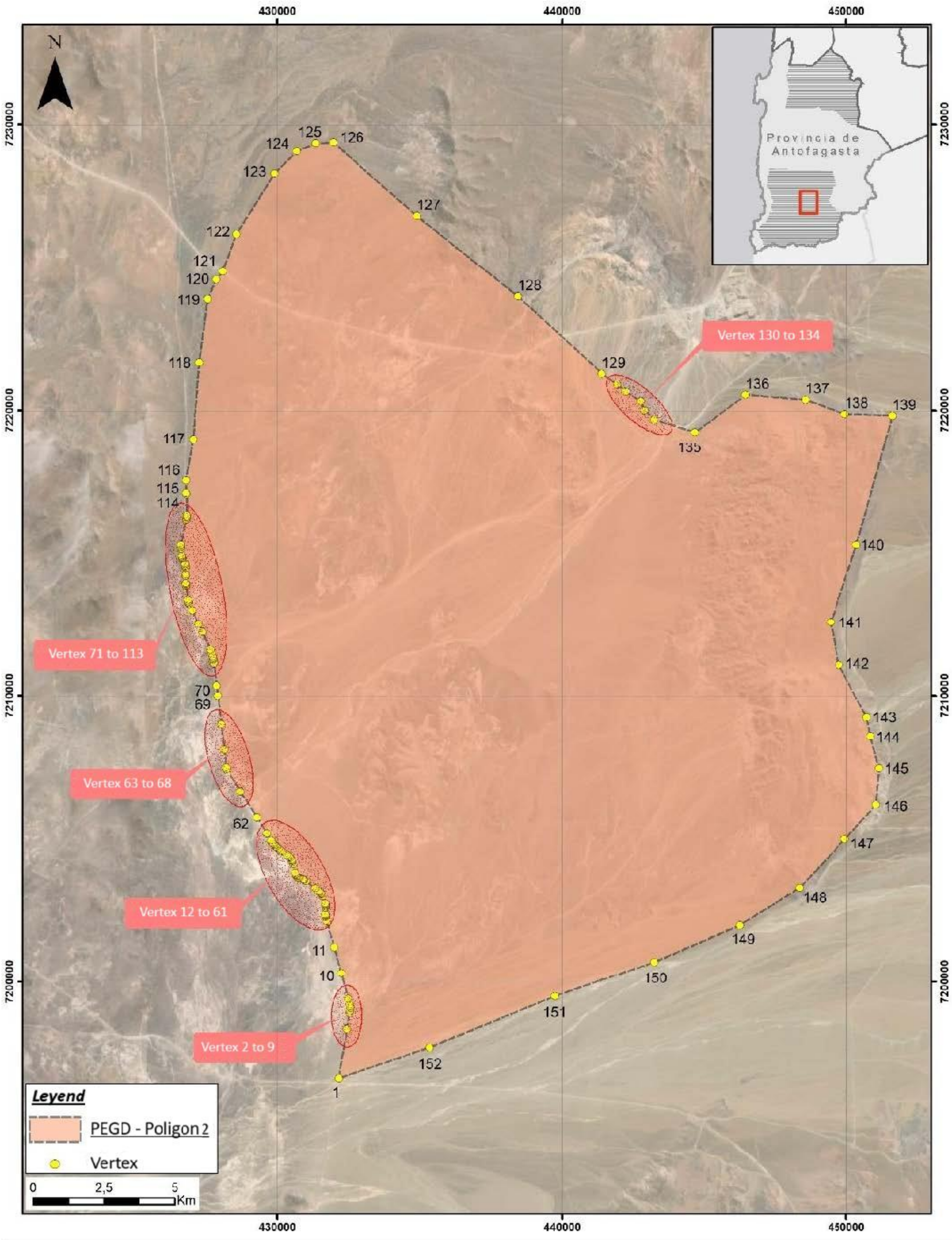


Figure 64: PDGE Antofagasta - Polygon 2.

Table 17: Polygon 2 vertex coordinates - Province of Antofagasta.

VERTEX	PROJECTED COORDINATES[83]		GEOGRAPHICAL COORDINATES[84]	
	EAST	NORTH	LONGITUDE	LATITUDE
1	432.146	7.196.617	-69,67431031	-25,34556440
2	432.431	7.198.336	-69,67139632	-25,33005334
3	432.524	7.198.903	-69,67043890	-25,32493165
4	432.535	7.198.966	-69,67033335	-25,32436706
5	432.542	7.199.011	-69,67025457	-25,32395991
6	432.549	7.199.087	-69,67018791	-25,32327205
7	432.546	7.199.120	-69,67021183	-25,32297869
8	432.531	7.199.186	-69,67036168	-25,32237876
9	432.478	7.199.389	-69,67087492	-25,32054366
10	432.227	7.200.307	-69,67332096	-25,31224413
11	431.981	7.201.204	-69,67571981	-25,30413586
12	431.728	7.202.120	-69,67818577	-25,29585199
13	431.685	7.202.289	-69,67860738	-25,29432500
14	431.680	7.202.315	-69,67865233	-25,29408184
15	431.677	7.202.336	-69,67868068	-25,29389662
16	431.677	7.202.365	-69,67868081	-25,29363855
17	431.692	7.202.593	-69,67852368	-25,29157546
18	431.692	7.202.627	-69,67851713	-25,29126878
19	431.690	7.202.654	-69,67854352	-25,29102189
20	431.685	7.202.681	-69,67858708	-25,29078223
21	431.677	7.202.714	-69,67866619	-25,29047836
22	431.667	7.202.744	-69,67876627	-25,29020833
23	431.568	7.202.994	-69,67973804	-25,28795069
24	431.543	7.203.048	-69,67997681	-25,28746474
25	431.525	7.203.081	-69,68016082	-25,28716371
26	431.506	7.203.109	-69,68034515	-25,28690477
27	431.485	7.203.135	-69,68055011	-25,28667418
28	431.459	7.203.160	-69,68080760	-25,28644313
29	431.434	7.203.180	-69,68105054	-25,28626035
30	431.324	7.203.266	-69,68213929	-25,28547915
31	430.989	7.203.528	-69,68545643	-25,28310028

[83] Coordinates referenced to the Sirgas Chile Datum, UTM Projection - Huso 19S.

[84] Coordinates referenced to Sirgas Chile Datum.

VERTEX	PROJECTED COORDINATES[83]		GEOGRAPHICAL COORDINATES[84]	
	EAST	NORTH	LONGITUDE	LATITUDE
32	430.931	7.203.564	-69,68602684	-25,28277332
33	430.915	7.203.573	-69,68619306	-25,28269467
34	430.884	7.203.582	-69,68650067	-25,28261053
35	430.758	7.203.619	-69,68775029	-25,28226711
36	430.723	7.203.635	-69,68809174	-25,28211932
37	430.696	7.203.653	-69,68835625	-25,28196210
38	430.674	7.203.673	-69,68857662	-25,28178109
39	430.653	7.203.702	-69,68878699	-25,28151499
40	430.637	7.203.730	-69,68894628	-25,28126473
41	430.624	7.203.766	-69,68906639	-25,28093294
42	430.615	7.203.809	-69,68915835	-25,28054563
43	430.548	7.204.107	-69,68981215	-25,27785228
44	430.526	7.204.180	-69,69002391	-25,27719446
45	430.512	7.204.212	-69,69016151	-25,27690199
46	430.494	7.204.245	-69,69033699	-25,27660111
47	430.473	7.204.278	-69,69053929	-25,27630866
48	430.426	7.204.344	-69,69100757	-25,27570389
49	430.401	7.204.371	-69,69125437	-25,27546009
50	430.364	7.204.404	-69,69161987	-25,27516293
51	430.322	7.204.434	-69,69203684	-25,27488457
52	430.153	7.204.545	-69,69371302	-25,27387970
53	430.097	7.204.585	-69,69425792	-25,27351576
54	430.039	7.204.633	-69,69483564	-25,27307951
55	429.983	7.204.684	-69,69539149	-25,27261308
56	429.943	7.204.723	-69,69578055	-25,27225746
57	429.908	7.204.761	-69,69612924	-25,27192087
58	429.870	7.204.804	-69,69650578	-25,27152388
59	429.831	7.204.857	-69,69689067	-25,27104828
60	429.781	7.204.932	-69,69738560	-25,27036299
61	429.628	7.205.177	-69,69888807	-25,26814798
62	429.281	7.205.729	-69,70230942	-25,26314821
63	428.690	7.206.675	-69,70812116	-25,25457606
64	428.248	7.207.394	-69,71247191	-25,24805714
65	428.222	7.207.452	-69,71273093	-25,24753621
66	428.207	7.207.514	-69,71287335	-25,24698023
67	428.132	7.208.134	-69,71358559	-25,24137442
68	428.025	7.209.019	-69,71460313	-25,23337504
69	427.905	7.210.004	-69,71574275	-25,22447333
70	427.863	7.210.349	-69,71614127	-25,22136044

VERTEX	PROJECTED COORDINATES[83]		GEOGRAPHICAL COORDINATES[84]	
	EAST	NORTH	LONGITUDE	LATITUDE
71	427.769	7.211.125	-69,71703405	-25,21435142
72	427.763	7.211.171	-69,71708763	-25,21393080
73	427.753	7.211.256	-69,71718549	-25,21316255
74	427.747	7.211.296	-69,71724548	-25,21279904
75	427.740	7.211.331	-69,71731270	-25,21248119
76	427.731	7.211.369	-69,71740027	-25,21214492
77	427.698	7.211.467	-69,71771758	-25,21125491
78	427.646	7.211.609	-69,71822873	-25,20996731
79	427.358	7.212.240	-69,72105190	-25,20426003
80	427.231	7.212.518	-69,72229834	-25,20174023
81	427.010	7.213.005	-69,72447042	-25,19732982
82	426.906	7.213.234	-69,72549068	-25,19525817
83	426.894	7.213.268	-69,72560862	-25,19495137
84	426.883	7.213.302	-69,72571373	-25,19464228
85	426.874	7.213.341	-69,72580429	-25,19429109
86	426.867	7.213.387	-69,72586815	-25,19387506
87	426.867	7.213.396	-69,72587131	-25,19379245
88	426.795	7.213.867	-69,72655830	-25,18953628
89	426.789	7.213.898	-69,72661004	-25,18925533
90	426.788	7.213.932	-69,72662312	-25,18894787
91	426.786	7.213.962	-69,72663654	-25,18868056
92	426.784	7.214.218	-69,72664317	-25,18637278
93	426.784	7.214.252	-69,72664406	-25,18606217
94	426.782	7.214.491	-69,72665047	-25,18390139
95	426.780	7.214.529	-69,72666745	-25,18356047
96	426.774	7.214.569	-69,72673122	-25,18320173
97	426.762	7.214.607	-69,72684528	-25,18285441
98	426.750	7.214.641	-69,72696574	-25,18254476
99	426.672	7.214.807	-69,72772808	-25,18104176
100	426.665	7.214.827	-69,72779646	-25,18086408
101	426.655	7.214.855	-69,72788871	-25,18061362
102	426.648	7.214.884	-69,72796552	-25,18034715
103	426.641	7.214.921	-69,72803049	-25,18001782
104	426.612	7.215.149	-69,72830233	-25,17795115
105	426.611	7.215.187	-69,72831523	-25,17761245
106	426.612	7.215.221	-69,72830206	-25,17730281
107	426.614	7.215.263	-69,72827571	-25,17692136
108	426.621	7.215.305	-69,72821051	-25,17654372
109	426.798	7.216.162	-69,72640094	-25,16881108

VERTEX	PROJECTED COORDINATES[83]		GEOGRAPHICAL COORDINATES[84]	
	EAST	NORTH	LONGITUDE	LATITUDE
110	426.806	7.216.198	-69,72632574	-25,16848976
111	426.816	7.216.248	-69,72622004	-25,16803627
112	426.820	7.216.278	-69,72617548	-25,16776973
113	426.822	7.216.311	-69,72616154	-25,16746680
114	426.802	7.217.059	-69,72631337	-25,16071270
115	426.801	7.217.104	-69,72632246	-25,16030849
116	426.790	7.217.549	-69,72641288	-25,15628605
117	427.052	7.219.000	-69,72373420	-25,14319656
118	427.252	7.221.687	-69,72160752	-25,11894707
119	427.552	7.223.887	-69,71851581	-25,09909498
120	427.852	7.224.587	-69,71550393	-25,09278817
121	428.084	7.224.865	-69,71318723	-25,09028361
122	428.552	7.226.187	-69,70847916	-25,07837302
123	429.902	7.228.296	-69,69498012	-25,05938858
124	430.664	7.229.079	-69,68738626	-25,05235145
125	431.338	7.229.347	-69,68069321	-25,04996106
126	431.956	7.229.375	-69,67456573	-25,04974363
127	434.910	7.226.824	-69,64540638	-25,07290791
128	438.452	7.223.987	-69,61041420	-25,09867618
129	441.420	7.221.286	-69,58109173	-25,12318538
130	441.957	7.220.917	-69,57578617	-25,12653667
131	442.258	7.220.666	-69,57280351	-25,12881908
132	442.778	7.220.330	-69,56766237	-25,13186666
133	442.912	7.220.012	-69,56634525	-25,13474811
134	443.252	7.219.687	-69,56298919	-25,13769563
135	444.675	7.219.242	-69,54888420	-25,14176611
136	446.454	7.220.555	-69,53118509	-25,12997623
137	448.552	7.220.387	-69,51038424	-25,13156468
138	449.952	7.219.887	-69,49651441	-25,13612716
139	451.627	7.219.822	-69,47990216	-25,13676360
140	450.352	7.215.296	-69,49271274	-25,17760098
141	449.452	7.212.587	-69,50174435	-25,20203339
142	449.752	7.211.087	-69,49882183	-25,21558920
143	450.718	7.209.253	-69,48929209	-25,23217717
144	450.852	7.208.587	-69,48799236	-25,23820186
145	451.152	7.207.487	-69,48505317	-25,24814519
146	451.052	7.206.187	-69,48609285	-25,25988152
147	449.952	7.204.987	-69,49706049	-25,27068166
148	448.352	7.203.287	-69,51301517	-25,28597896

VERTEX	PROJECTED COORDINATES[83]		GEOGRAPHICAL COORDINATES[84]	
	EAST	NORTH	LONGITUDE	LATITUDE
149	446.252	7.201.987	-69,53392492	-25,29764440
150	443.252	7.200.687	-69,56377959	-25,30927288

PDGE Antofagasta Province (Polygon 3)

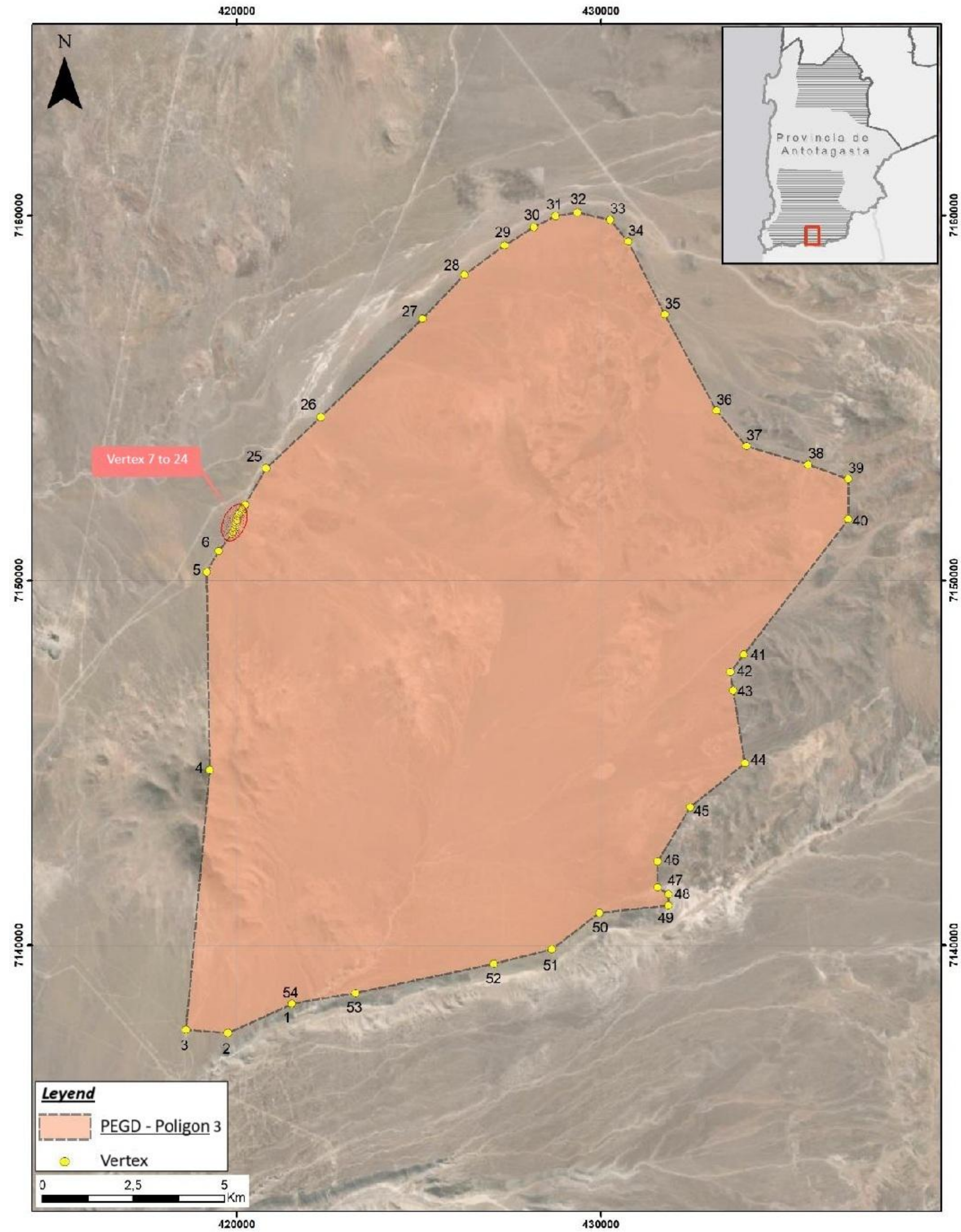


Figure 65: PDGE Antofagasta - Polygon 3.

Table 18: Polygon 3 vertex coordinates - Province of Antofagasta.

VERTEX	PROJECTED COORDINATES[85]		GEOGRAPHICAL COORDINATES[86]	
	EAST	NORTH	LONGITUDE	LATITUDE
1	421.497	7.138.377	-69,78355207	-25,87091245
2	419.752	7.137.587	-69,80101692	-25,87795577
3	418.597	7.137.677	-69,81253840	-25,87707368
4	419.249	7.144.801	-69,80559279	-25,81279347
5	419.167	7.150.234	-69,80607720	-25,76372988
6	419.493	7.150.802	-69,80279617	-25,75861816
7	419.862	7.151.273	-69,79908957	-25,75438362
8	419.894	7.151.317	-69,79876528	-25,75399290
9	419.918	7.151.358	-69,79852805	-25,75362448
10	419.945	7.151.412	-69,79825257	-25,75313489
11	419.963	7.151.463	-69,79806440	-25,75267674
12	419.977	7.151.517	-69,79792893	-25,75218856
13	419.983	7.151.570	-69,79786733	-25,75170997
14	419.990	7.151.648	-69,79778962	-25,75100656
15	419.998	7.151.703	-69,79770120	-25,75050979
16	420.015	7.151.754	-69,79753081	-25,75005357
17	420.037	7.151.795	-69,79731501	-25,74968205
18	420.063	7.151.832	-69,79704836	-25,74935213
19	420.098	7.151.872	-69,79669797	-25,74899292
20	420.138	7.151.915	-69,79629602	-25,74860561
21	420.170	7.151.956	-69,79597913	-25,74823762
22	420.193	7.151.995	-69,79574701	-25,74788658
23	420.211	7.152.038	-69,79555978	-25,74749387
24	420.223	7.152.076	-69,79543969	-25,74715502
25	420.797	7.153.077	-69,78965812	-25,73814471
26	422.297	7.154.477	-69,77462222	-25,72558389
27	425.094	7.157.174	-69,74658999	-25,70137704
28	426.252	7.158.387	-69,73498153	-25,69048827
29	427.352	7.159.187	-69,72397586	-25,68331947
30	428.152	7.159.687	-69,71597697	-25,67884404
31	428.752	7.159.987	-69,70998220	-25,67616439

[85] Coordinates referenced to the Sirgas Chile Datum, UTM Projection - Huso 19S.

[86] Coordinates referenced to Sirgas Chile Datum.

VERTEX	PROJECTED COORDINATES[85]		GEOGRAPHICAL COORDINATES[86]	
	EAST	NORTH	LONGITUDE	LATITUDE
32	429.352	7.160.087	-69,70399830	-25,67529040
33	430.252	7.159.887	-69,69504095	-25,67713931
34	430.752	7.159.287	-69,69008994	-25,68258071
35	431.752	7.157.287	-69,68022762	-25,70068672
36	433.171	7.154.654	-69,66621754	-25,72452663
37	433.997	7.153.677	-69,65803133	-25,73338090
38	435.697	7.153.177	-69,64110791	-25,73797127
39	436.797	7.152.777	-69,63016038	-25,74163098
40	436.797	7.151.677	-69,63021279	-25,75156357
41	433.926	7.147.970	-69,65902339	-25,78491377
42	433.552	7.147.487	-69,66277883	-25,78925910
43	433.633	7.146.980	-69,66199499	-25,79384178
44	433.952	7.144.987	-69,65891410	-25,81185100
45	432.452	7.143.787	-69,67393900	-25,82261776
46	431.552	7.142.287	-69,68299567	-25,83611999
47	431.552	7.141.587	-69,68303196	-25,84244058
48	431.852	7.141.387	-69,68004881	-25,84426051
49	431.852	7.141.087	-69,68006430	-25,84696933
50	429.952	7.140.887	-69,69903429	-25,84868519
51	428.652	7.139.887	-69,71206071	-25,85765151
52	427.052	7.139.487	-69,72804995	-25,86118405
53	423.252	7.138.687	-69,76601930	-25,86821228
54	421.511	7.138.397	-69,78340651	-25,87073865

Ministerio de Energía

Gobierno de Chile

PELP

PLANIFICACIÓN ENERGÉTICA DE LARGO PLAZO

Strategic Planning and Sustainable Development Division

Ministry of Energy

pelp@minenergia.cl

energía.gob.cl/pelp

April 22, 2025