Ministerio de Energía

Gobierno de Chile

PELP

PLANIFICACIÓN ENERGÉTICA DE LARGO PLAZO

Planning together the future of energy in Chile

PRELIMINARY REPORT

Version for public comments of the Citizen Consultation Registry

August 30th, 2021

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Long-Term Energy Planning (PELP)
Period from 2023 to 2027

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This document is the Preliminary Report of the PELP 2023-2027, defined in Article 84 of the General Law of Electric Services (GLES), in the version for public comments of the PELP Citizen Consultation Registry.

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Energy Transition in Chile

Chile and the whole world are going through an extraordinary energy transition that will allow laying the foundations for a sustainable future for society. These changes have begun to take shape with unprecedented force and speed, constantly challenging us to adjust regulations to create favorable conditions for the development of a key sector for the country.

Long-Term Energy Planning allows projecting the energy sector, visualizing the combined impact of different measures, goals, actions and public policies. Its primary purpose is to be the main input that guides the expansion of transmission carried out by the National Energy Commission, establishing the future of electricity generation and storage that must be considered for purposes of evaluating the expansion of transmission systems.

It is necessary to start with a thorough understanding of the energy sector as a whole to identify the transmission infrastructure required by the country. Hence, this planning was developed through a path that connects energy scenarios, energy requirements, energy supply, infrastructure needs and modernization of the sector.

Today, we have new energy scenarios established with a participatory imprint and we will begin the process of developing poles in the provinces of Antofagasta and Tocopilla for a more efficient connection of the renewable projects that will be promoted in that area.

There are many challenges on the road to sustainable energy development, identifying the following as priorities:

1. Move forward with conditions that allow consumption to be electrified efficiently, such as, for example, the housing thermal reconditioning use.
2. Establish energy efficiency as a fundamental axis of energy development, mainly in those energy uses that employ polluting sources.
3. Urgently promote efforts to optimize and strengthen the electrical grid through technologies such as short-lived batteries, flexible FACTS devices and the use of dynamic capacity of DLR lines.
4. Define a portfolio of national and regional transmission structural works together with the National Energy Commission to achieve the goal of carbon neutrality before the year 2050, consistent with the growth of electricity consumption connected to distribution systems.
5. Continue promoting the insertion of large-scale and distributed renewable energy.
6. Through regulatory actions, enable investment signals to integrate energy storage into the electricity sector, including the possibility of incorporating it into distribution systems.
7. Initiate, along with the Electricity Coordinator, a continuous process of cutting-edge technological implementation with a focus on the provision of safety by power electronic converters, through digitalization and automation of the operation of the electrical power system, and conversion of coal-fired power plants to synchronous condensers, Carnot batteries and less polluting fuels, including pilot projects to enable technological adaptation pathways.
8. Promote the use of electric air conditioners and electromobility to reduce global and local emissions, along with effective demand management.
9. Consider an extremely dry hydrological condition due to the effect of climate change, relieving the role of natural gas as a transition fuel, for purposes of planning the future of the electricity sector.
10. A robust energy transition must have a reliable and resilient electric power system, which includes an emphasis on high-impact and low-probability events, to identify investment and operation solutions that improve performance and response capacity, managing to strengthen the quality of supply energy of the country.

1. Energy planning

Strong institutional framework and State approach

1.1. Regulatory framework

Infographics
"What is PELP?"
PELP 2023-2027

General Law of
Electric Services
(GLES)

Long-Term Energy Planning (or also known as PELP, for its acronym), is a process established between Articles 83 to 86 of the General Law of Electric Services (GLES) and regulated in Decree No. 134 of October 2016, which endorses the Long-Term Energy Planning Regulations. Its purpose is to plan the energy demand and supply of the country for different future scenarios, in a horizon of at least 30 years, so that they are considered in the planning process of the electrical transmission systems carried out by the National Energy Commission. The process must be implemented considering broad and effective citizen participation.

This document corresponds to the Preliminary Report of the new PELP 2023-2027 process. In particular, Article 83 of the GLES states that:

"Every five years, the Ministry of Energy must develop a long-term energy planning process for at least thirty years for different energy scenarios of the generation and consumption expansion.

The energy planning process must include scenarios for the projection of energy supply and demand, and in particular electricity, considering the identification of generation development poles, distributed generation, international energy exchanges, environmental policies that have an impact and energy efficiency objectives among others, elaborating their possible development scenarios. Likewise, the planning must take into account the regions' strategic plans for energy in its analysis. On an annual basis, the Ministry may update the projection of the demand, macroeconomic scenarios and other information considered in the stages defined by the decree referred to in Article 86.

For well-founded reasons, the Ministry of Energy may establish the energy planning process prior to the expiration of the period specified in the first paragraph"

In turn, Article 84 of the GLES states that:

"The Ministry of Energy must initiate the process at least twenty-four months before the expiration of the period of the decree establishing a long-term energy planning. Within the eight months following the start of the aforementioned process, the Ministry must issue a preliminary energy planning report…"

Finally, during the development of the PELP, the Ministry of Energy must identify and define the country's provinces as electric power generation development poles, to which a Strategic Environmental Assessment (SEA) must be applied. In short, the development poles correspond to a segment of the electrical transmission defined in Article 85 of the Law in question such as:

"Development poles shall be understood as those territorially identifiable areas in the country, located in the regions in which the National Electric System is located, where there are resources for the production of electricity from renewable energies, whose exploitation, using a single transmission system, is of public interest because it is economically efficient for the electricity supply, and must comply with environmental and land use legislation."

Thus, on December 29, 2020, through Exempt Resolution No. 31/2020, the second long-term energy planning process began for the period from 2023 to 2027.

1.2. Vision, projection and infrastructure

The PELP have three major deliverables:

1. *Definition of new long-term energy scenarios.*
   On this occasion, three energy scenarios have been cooperatively defined.
2. *Projections of energy supply and demand.*
   Based on energy scenarios, the energy needs of the entire society are identified and projected, as well as the respective energy supplies.

3. *Electric power generation development poles.*
   They correspond to territorially suitable areas for the sustainable development of renewable energies, in which transmission solutions could be recommended.

Information, processes and annual updates
PELP

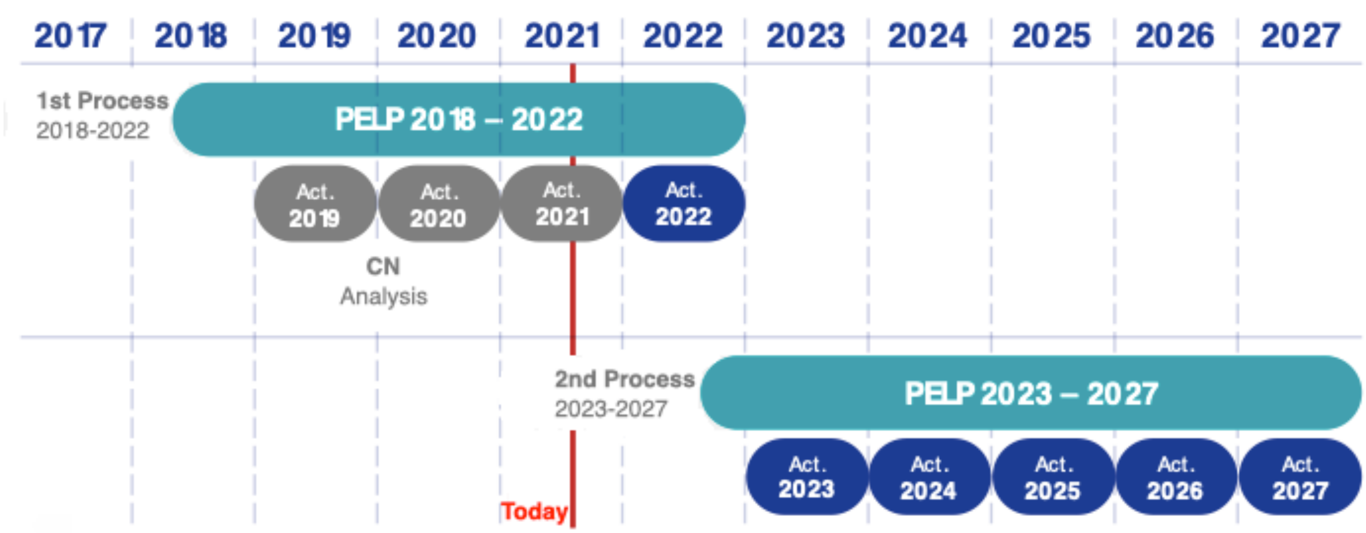
1.3. An ongoing process

Every five years, the PELP process that defines energy scenarios and development poles must be updated. In addition, energy demand and supply projections are updated annually, taking into account updates of demand projections and macroeconomic variables, the cost and development of new technologies, and other factors of varying nature.

The diagram presents the historical and projected evolution of the PELP process, from the first PELP 2018-2022 process, to the completion of the new PELP 2023-2027 process.

Carbon Neutrality in Energy Plan Report
PELP

The continuity of this process allows it to be endowed with substantial improvements over time. As indicated by the General Law of Electric Services (GLES), the next PELP 2028-2032 process should begin no later than the end of 2025.



1.4. Planning the energy transition

The energy planning process is of fundamental importance in the energy projection of the country. Thus:

a) it defines different possible paths for the development of the sector,

b) projects the future of energy consumption and supply required by society,

c) identifies the possible existence of favorable territories for the development of renewable energy projects that allow a sustainable energy future,

d) provides relevant information for decision-making on public policies and regulations,

e) guides, by legal mandate, the development of the electrical transmission of the country,

f) evaluates the opportunities for energy integration with other countries,

g) identifies the opportunities for innovation and technological implementation required for sustainable development,

h) considers broad and effective citizen participation, which allows cooperatively building the energy projection of the country and legitimizing the long-term view in energy matters,

i) provides a mapping of the necessary steps for the development of the energy sector in the medium and long term, allowing the establishment of priorities in public policy actions.

1.5. Incidence of the process

The projections of energy demand and supply for each of the long-term energy scenarios guide and directly affect the expansion of the country's transmission systems.

In order to comply with this legal mandate, the projection of electricity demand must be carried out with a full understanding of the total energy needs of the country. Hence, energy planning starts from a projection of the energy needs of society in the different sectors: residential, commercial, public, transport, industry, and mining. Once the current consumption is determined, based on the National Energy Balance carried out by the Ministry of Energy, these are projected in the long term, with which it is possible to identify the energy supply that allows supplying said needs in the different sectors: electricity, fuels, among others.

With the outbreak of new energy consumption that is and will be powered by electricity, such as electromobility, electric heating, green hydrogen production, among others, energy planning is now focused on all energy uses in the country. In this sense, important changes are projected in the type of energy that will supply the different uses with a strong predominance of clean energies in the energy supply, together with greater direct and indirect electrification, for example, green hydrogen.

In this way, the PELP process must ensure that all current and future energy needs of society are met in the best possible way. Thus, it can set up limits, conditions and recommendations, in such a way that the energy infrastructure, and in particular the electricity infrastructure, is developed in a sustainable manner with a focus on social, environmental, territorial, economic and technological aspects.

The PELP is a public policy instrument that guides society to promote a sustainable and efficient expansion of the sector, identifying those key investments and technologies for Chile's energy transition: *energy at the service of sustainable development for the country*.

1.6. Remembering the PELP journey

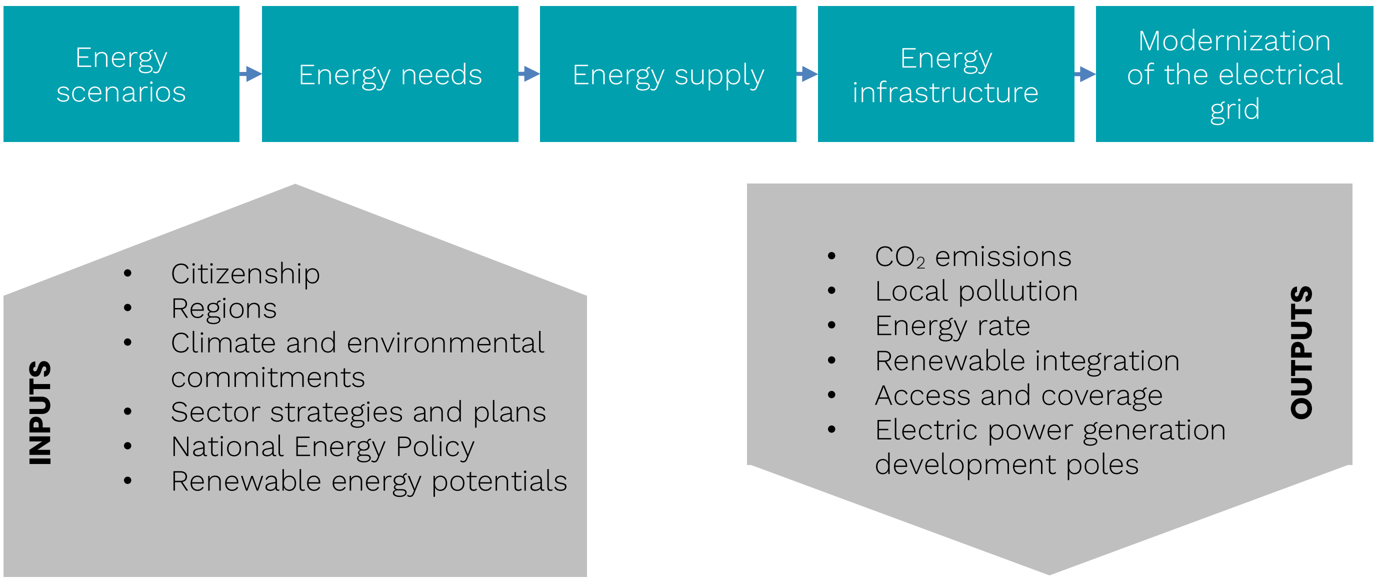
This section summarizes how the different steps of the PELP are interconnected, starting with long-term energy scenarios and ending with the identification of impacts and infrastructure requirements to achieve the energy vision.

Energy scenarios

All long-term planning begins with a vision, a possible route, the cooperative construction of a coherent story that outlines possible futures.

In this PELP 2023-2027 process, three new long-term energy scenarios have been defined and built in a cooperative and participatory manner. These scenarios will be the possible routes that will guide the energy projection in the short, medium and long term.

For this, different inputs were considered, coming from the citizens, regions, climatic and environmental commitments at the country level, different sectorial strategies and plans, and -of course- from the National Energy Policy.



In addition, an important input is to determine the renewable energy potentials within our country, understanding that renewable energy is key to the energy transition, and therefore in the energy planning process, and their respective projections of energy supply.

Energy needs

Once energy scenarios have been identified, energy planning will describe and project the short-, medium- and long-term energy needs of society as a whole.

In practical terms, the energy need is related to the uses of energy that will be required by the different sectors of society, for example, in home consumption such as heating, cooking and refrigeration, washing and drying clothes, electronic devices, etc.; transport; industry and mining; energy efficiency measures for the different sectors (including measures for the thermal improvement of homes); among many others.

Energy supply

Once the energy demand that will be required by society has been determined, energy planning identifies and projects the energy supply needed for said demand; that is, the energy supply required for it, identifying the most efficient options for supply, such as: electricity, fuel, firewood, pellets, etc.

In order to achieve the country's environmental and climate commitments, a robust and transforming energy transition must be guided and aimed at reducing pollution levels (global and local) and improving the quality of life of citizens. Energy planning strengthens renewable energies as the solution to this challenge, therefore, the level of electrification is expected to increase substantially, since renewable energies become increasingly cheaper, as well as the technologies that allow it to be used for different purposes: electromobility, electric heating, green hydrogen, etc.

In addition, green hydrogen -which has the potential to clean the energy matrix in those highly demanding energy uses- will be a clean fuel produced from electricity, and as such, is defined as an indirect electrification solution for certain energy uses. In its value chain, renewable energies and electrical power systems assume a fundamental role, as well as the technologies and processes that accompany the compression, storage, transport, and distribution of energy.

Currently, electricity contributes only a fraction of the energy supply, close to 25% of the total; however, projections show that electricity will exceed 50% in 2050, hand in hand with the growth in electricity demand, the new consumption that will be electrified, such as electric transport, heating, air conditioning, thermal processes, among others, and the production of green hydrogen, which will undoubtedly promote significant levels of use of renewable energies in the country.

Therefore, to determine the ideal energy supply to meet society's energy needs, energy planning considers all energy uses and all available energy supplies, and then determines how much of that will be covered by electricity. This allows the process to comply with one of its priority legal mandates, which is to guide the expansion of electricity transmission through the projection of the future power generating units, considering their territorial location, capacity and technology.

Energy infrastructure

Once society's energy needs and their supply are identified, energy infrastructure plays a fundamental role: energy transport systems, and in particular, electricity transmission. The planning identifies the infrastructure alternatives that allow the sustainable development of the country in the best possible way.

In this context, the PELP projects the favorable and indicative location for future power generation projects in the territory, which added to the projected demand requirements -including the proportion of green hydrogen connected to the grid- will ultimately define the electrical infrastructure required for each energy scenario.

Modernization of the electrical grid

Finally, in addition to the electrical infrastructure itself, the technological alternatives that allow reaching the projected energy future for each of the scenarios will be described. Technological options that allow making better use of the existing infrastructure, through optimization and reinforcement of facilities, as well as the expansion of required works.

They are also analyzed in technological alternatives that allow migrating the operation of the current electrical grid, towards the electrical grid that is glimpsed in the long term. Understanding that current decisions must enable the expected sustainable development and, of course, being consistent with energy projections. There is no doubt that this decade will be marked by the introduction of enabling technologies for a clean and highly renewable future.

1.7. A strong institutional framework

The new PELP 2023-2027 process has become a key element in expanding legitimacy and general participation. For this reason, an operational institutional framework has been put in place that allows for integration between the Citizen Consultation Registry, an Electrical Core Team, a Technical Support Group and Sectorial Organizations.

In this way, energy planning is built with the eyes and contributions of society (citizens and private organizations), key institutions in the operation of the energy sector, people who represent the scientific field that is so vital today for decision-making, and sectorial organizations that influence or are affected by energy development.

Long-Term Energy Planning
Ministry of Energy

Citizen Consultation Registry
- People
- Organizations

Voluntary open registration
Gender approach
Regional representation

Electrical Core Team
- National Energy Commission
- Superintendency of Electricity and Fuels
- National Electricity Coordinator

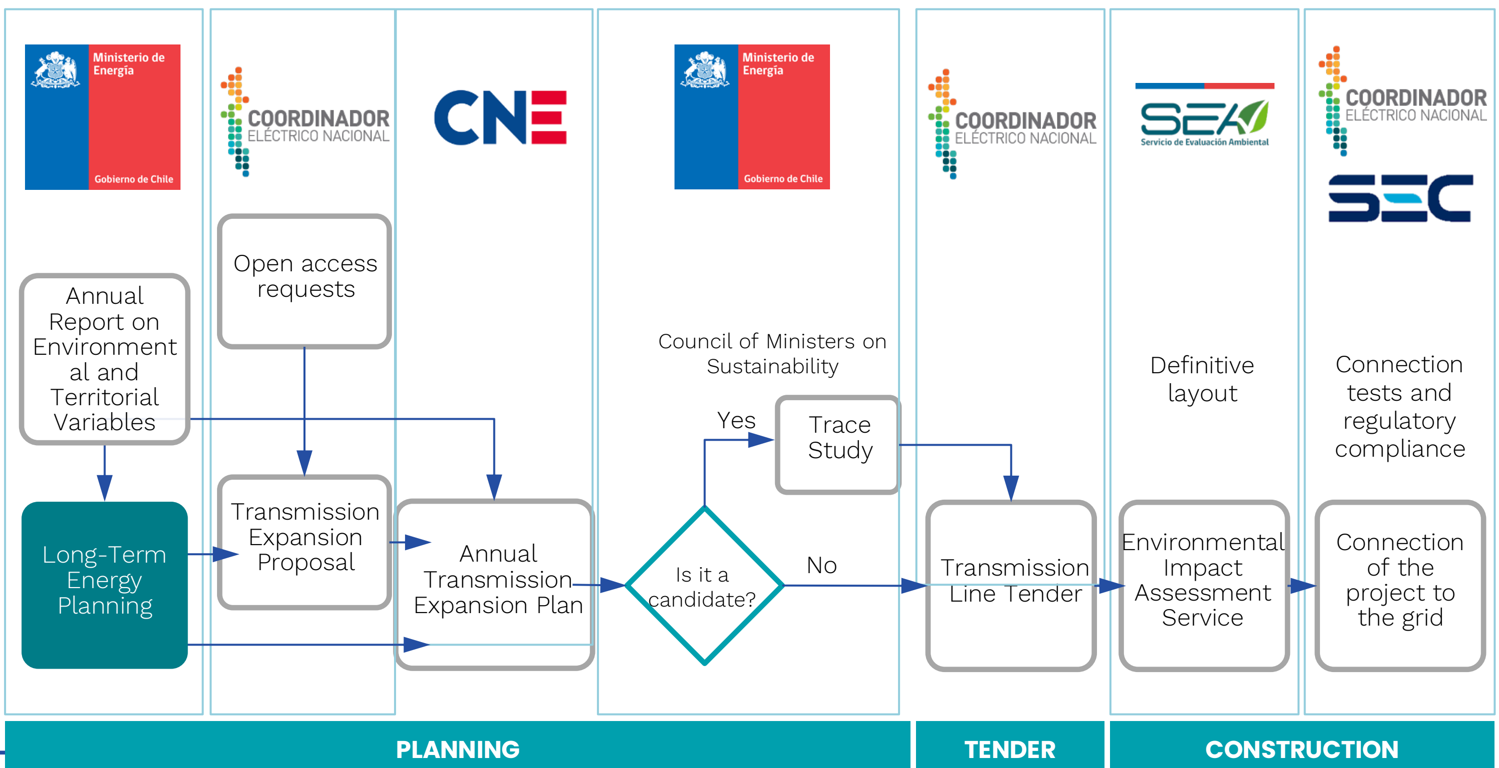
Technical Support Group
- Academia
- Research Centers
- Consultancy

Sectorial organizations
- Ministries
- Agencies
- Energy-related public service organizations

1.8. Transmission development

The PELP is the main input that guides the expansion and development of electricity transmission. The energy scenarios and the projection of the electricity supply outline the reinforcements, extensions and new infrastructure of the electricity network. The diagram shows the stages of the process involving various institutions, which motivates the permanent coordination that has been consolidated in the PELP 2023-2027 process.

Electrical transmission is essential to enable the environmental and climate goals that we have established as a country. For this reason, the participatory construction of the long-term perspective allows the transmission expansion process to be provided with a basic input that guides the works that must be carried out in the short term in such a way that they are consistent with the medium and long term.



2. Citizen consultation process

Democratizing energy planning

Infographics
"Consultation Process"
PELP 2023-2027

Energy planning with a long-term horizon is necessary because it is essential to expect, years in advance, the required infrastructure to cover the energy requirements that we will need in the future.

The final decision that emanates from the planning process corresponds to investment decisions at the national level in electricity transmission based on projections. These decisions affect us as a society in different areas and in different ways, so it is necessary to open a space to talk about the energy needs that we will have, and evaluate under what circumstances we would be willing to invest as a society in an expansion of the transmission that it will finally enable us to access the energy we will need.

In accordance with the provisions of Article 84 of the General Law of Electric Services (GLES), the long-term energy planning five-year process must be carried out through a broad participatory process. This participation is fundamental in the construction of this public policy, since it allows us to incorporate different perspectives in making investment decisions for electrical transmission at the national level, which has economic implications, local development, and direct impact on the territories and in those who inhabit them.

2.1. A collaborative energy planning

The participatory process is made up 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 contribution (open and voluntary registration), technical support group (academician-researcher and consultant) and a coordination group with public sector organizations. In this sense, the PELP process opens up a space for convergence of views between citizen participation, science and institutions, so that in a cooperative and consensual manner, the country's energy future routes are molded.

2.1.1. Citizen consultation process

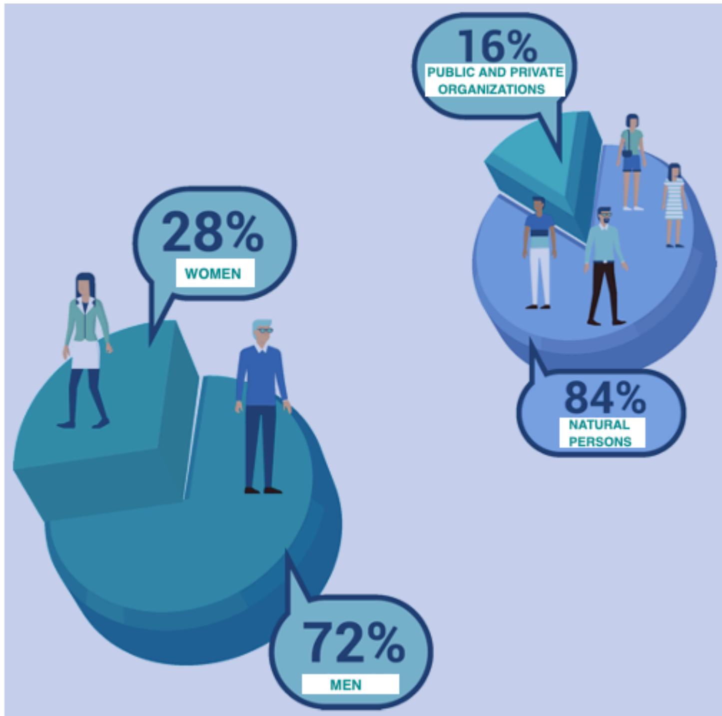
On December 29, 2019, the new PELP 2023-2027 process began, through the opening of registrations to participate in the workshops, the public hearings and the review of the different documents prepared, and that are shared to the people and organizations registered in the PELP 2023-2027 Citizen Consultation Registry. It was open for three months and ended on March 3 with a total of 706 registrations, between people and organizations of different natures; almost triple the number of participants in the previous PELP 2018-2022 process, which reached 262 registrations.

Citizen Consultation Registry
PELP 2023-2027

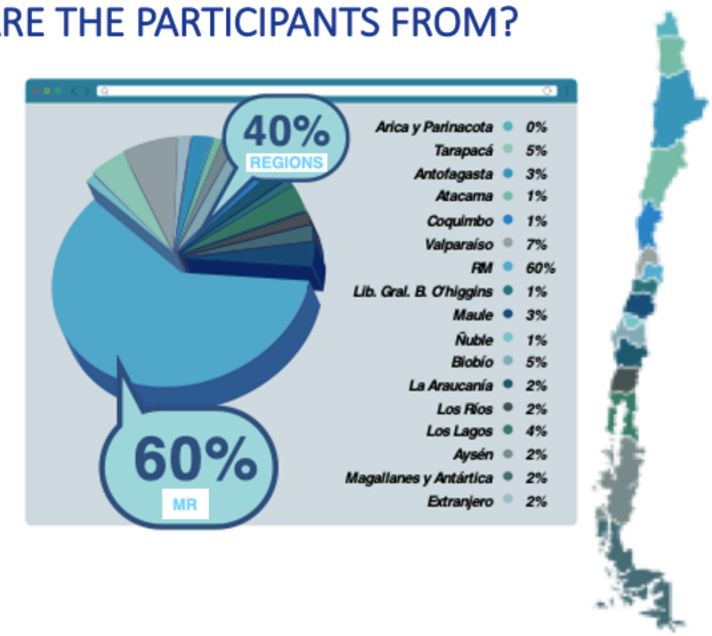
Aware of the importance of diversity in the composition of groups when discussing topics of general interest, especial attention is paid to adequate national representation. For this reason, a special and wide dissemination was carried out in order to incorporate elements related to gender approach and territorial decentralization in citizen consultation.

The final registry is made up of 28% women and the remaining 72% men. Of all registrations, 84% are registered as natural persons and the remaining 16% as organizations, whether companies, unions, NGOs, universities, or public entities such as ministries or municipalities. In terms of geographical distribution, there is a 60% share from the Metropolitan Region and 40% from the rest of the country's regions. Of these, the second region to participate is Valparaiso with 7%, and Biobío and Tarapacá with 5% each.

Infographics
“PELP Participants”
PELP 2023-2027



WHAT REGION
ARE THE PARTICIPANTS FROM?



2.1.2. Science and the contribution of the Academia

Considering both the technical challenges that are faced when making long-term energy projections, as well as the wide variety of sources of information and knowledge available, people from academia, research and consulting were invited to form a PELP 2023- 2027 Technical Support Group, whose main objective is to provide expert and diverse technical advice, provide scientific evidence and ensure the consistency of the PELP energy scenarios and projections.

The formation of the Technical Support Group was undertaken at the invitation of the Ministry of Energy, and with strict considerations of gender equality; in fact, 11 of the 21 participants are distinguished women academics. In addition to this, the group is composed of individuals with recognized competencies considered necessary to project the energy future, highlighting the transversal nature and breadth of the disciplines contributed, covering the following areas of knowledge: urban planning, mobility, sustainability, hydrogen, energy poverty, efficiency energy, bio-energy, renewable energy, energy storage, resilience and mathematical modeling, natural gas infrastructure, to name a few.

The Technical Support Group supporting the PELP process ad honorem is made up of the following people:

- Camila Álvarez, CR2.
- Ignacio Alarcón, Consultant.
- Paz Araya, Red de Pobreza Energética (Energy Poverty Network).
- Rodrigo Cienfuegos, CIGIDEN.
- Carolina Chávez, Universidad de Santiago, Chile.
- Marcelo Cortés, Universidad de Antofagasta.
- Patricia Galilea, Pontificia Universidad Católica.
- Alex Godoy, Universidad del Desarrollo.
- Rosa Herrera, Universidad de Concepción.
- Luis González, CLAPES UC.
- Francisca Jalil, Universidad Adolfo Ibáñez.
- Rodrigo Moreno, Universidad de Chile.
- Claudia Moraga, Universidad de Tarapacá.
- Alejandro Navarro, Universidad de Chile.
- María Luisa Ojeda, Universidad de Magallanes.
- Mauricio Osses, Universidad Federico Santa María.

- Claudia Rahman, Universidad de Chile.
- Fernando Peña, Universidad Católica de Temuco.
- Alejandra Schueftan, Instituto Forestal (Forest Institute).
- Enzo Sauma, Pontificia Universidad Católica.
- Rosa Serrano, PhD student at University of Manchester.

The contribution of the Technical Support Group is achieved by forming working subgroups around the following topics of interest:

- Mathematical modeling
- Energy scenarios
- Medium and isolated systems
- Resilience and adaptation
- Environment and territory
- Enabling technologies

Gender **parity**

Diversity of topics

Focus on **Sustainability**

Results orientation


Camila Álvarez
CR2


Ignacio Alarcón
Consultant - UAI


Paz Araya
UCH - RedPE


Rodrigo Cienfuegos
CIGIDEN


Carolina Chávez
USACH


Marcelo Cortés
U. Antofagasta


Patricia Galilea
PUC


Alex Godoy
UDD


Rosa Herrera
Consultant - UdeC


Luis Gonzáles
CLAPES UC


Francisca Jalil
UAI


Rodrigo Moreno
UCH - ISCI


Claudia Moraga
U. Tarapacá


Alejandro Navarro
UCH

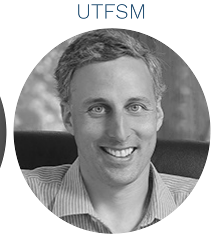

María Luisa Ojeda
U. Magallanes

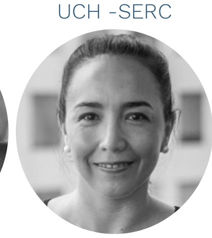

Mauricio Osses
UTFSM


Claudia Rahmann
UCH -SERC


Fernando Peña
UC Temuco


Alejandra Schueftan
INFOR-RedPE


Enzo Sauma
Centro Energía PUC


Rosa Serrano
U. of Manchester

Technical Support Group
PELP 2023-2027

2.1.3. Public coordination

To address one of the major gaps identified in the public sector, effective coordination among State institutions, a coordination group was established with sectorial organizations to bring together all services related to the energy planning process, such as:

- Ministry of Energy
- Ministry of Mining
- Ministry of the Environment
- Ministry of Housing and Urban Planning
- Ministry of National Assets
- Ministry of Transport and Communications
- Ministry of Agriculture
- Chilean Copper Commission
- Office of Agricultural Studies and Policies
- National Office for Emergency
- German Agency for International Cooperation GIZ
- National Energy Commission
- Superintendency of Electricity and Fuels
- National Electricity Coordinator
- Energy Efficiency Agency

This group's main objective is to ensure consistency with the plans, programs and policies related to long-term energy planning.

Along with them, a group called the Electrical Core Team was formed, with which sessions are held continuously to review, support and analyze improvements to the planning and operation processes of the national electrical power system. This group is made up of the following institutions:

- Ministry of Energy
- National Energy Commission
- Superintendency of Electricity and Fuels
- National Electricity Coordinator

Ministry of Energy	Ministry of Mining	Ministry of the Environment	Ministry of Housing and Urban Planning	Ministry of National Assets
Ministry of Transport and Communications	Ministry of Agriculture	Chilean Copper Commission	Office of Agricultural Studies and Policies	National Office for Emergency
German Agency for International Cooperation GIZ	National Energy Commission	Superintendency of Electricity and Fuels	National Electricity Coordinator	Energy Efficiency Agency

Sectorial bodies for public coordination
PELP 2023-2027

2.2. A process of collective construction

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

It is important to mention that this collective construction process will continue to be active for the entire five-year period corresponding to the PELP 2023-2027 process that motivates this report.

2.2.1. Citizen discussion process

The process begins with the opening of the registration records, which this time is made up of a group of 706 people and organizations with varied interests, experiences, and motivations to share.

Consultation process material
PELP 2023-2027

The work is structured around three stages with thematic workshops and three public hearings. The purpose of the workshop is to discuss and compare positions on issues relevant to the long-term energy planning process. For their part, public hearings, which are open to the public, serve to demonstrate the progress of the process.

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

- **Public Hearing 1:** It accounts for the general aspects of the energy planning process. More than 450 people connected simultaneously participate.

- **First stage of workshops:** It is composed of 4 consecutive workshops. Work is being carried out with the objective of building a proposal for energy scenarios, incorporating possible future situations that allow planning to adequately meet the needs of transmission and optimization of the country's energy development. There is a total attendance of 682 people.

- **Public Hearing 2:** The energy scenarios developed in the first round of workshops are presented. There are more than 200 people connected simultaneously.

- **Second stage of workshops:** It is made up of two workshops. Ongoing work aims to deepen the understanding of the concept of development poles and propose criteria for identifying territories and provinces as potential candidates. There is a total attendance of 138 people.

- **Third stage of workshops:** It is made up of a workshop, where work is carried out with the aim of evaluating the coherence of energy scenarios with the respective energy and electricity projections. There is a total attendance of 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.

In order to facilitate participation in the workshops, each workshop is held over two days, one in the morning (09:00 to 11:00 in Continental Chile) and another in the afternoon (17 :30 a.m. to 7:30 p.m. in Continental Chile) to ensure cross-sectional, diverse representation and according to the likelihood of participation of everyone registered in the Citizen Consultation Registry.

The virtual work methodology is specifically designed for each of the workshops and audiences. Mainly, it deals with a first descriptive part in a general way, which discloses the main antecedents to be considered in the discussion. A second part, which is made up of 15 people grouped in subgroups each, is developed using virtual tools such as online surveys, voting and discussion with the support of notes on a virtual wall, to which everyone has access. Finally, a third part is carried out, in which the main ideas of the discussion are shared in the plenary session, which conclude with an elaboration of the following steps.

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

Subsequently, with the information processed, 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.

2.2.2. Expert contribution

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

The sessions, which have an approximate periodicity of two weeks, were carried out virtually, and an expository and open discussion methodology is used.

2.2.3. 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 interference in the definition and subsequent implementation of measures related to long-term energy planning are identified and convened.

To this end, two groups are convened: one that is related to the energy field and all its derivatives in terms of scope and productive sectors, and another specific to the electrical field, where institutions with direct dependence on the Ministry of Energy and the National Electricity Coordinator prevail. Based on that, the groups called Sectorial Organizations and the Electrical Core Team are established, respectively.

Sessions are carried out virtually with an approximate periodicity of three weeks. The methodology is similar to that of the technical support group, i.e., through presentations of the key antecedents to be discussed to continue with an open discussion that allows identifying areas of coordination and collaboration.

2.3. General PELP co-construction architecture

The current five-year process for long-term energy planning focuses its working methods on participatory processes. At this time, a broad and diverse team is formed which, under the general coordination of the Energy Planning and New Technologies Team of the Ministry of Energy, integrates the citizen consultation process, energy policy and various technical teams that contribute to collaborative work.

As a general working methodology, an iterative and multi-stakeholder process is devised, allowing for expert participation and sectorial public coordination, always with citizen participation as the main axis.

The co-construction process begins with group sessions made up of 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 that focuses on transmitting basic elements to work on in subsequent workshop sessions. Once the workshops have started, the flow of information is reversed, so that the ideas and proposals raised by the citizens are taken and presented to the technical groups to challenge them to co-design the way in which they are incorporated into the energy models and scenarios. To this end, assumptions, simplifications, and state-of-the-art in relevant publications are discussed, which allow for proven work based on scientific evidence: models and techniques at the service of society.

YouTube Channel
Ministry of Energy

2.4. Open and transparent communication

Continuous and fluid communication, as well as transparency and availability of the generated material, are an essential part of the process, which is why different communication channels are available: PELP web platform, YouTube channel, satisfaction and identification surveys of new challenges and e-mail for the process: pelp@minenergia.cl, which is open at all times to receive and respond to all queries and suggestions regarding the energy planning process on a permanent basis.

The PELP website is the primary channel for communicating and providing process-related information. This website is constantly updated and designed based on the following information axes:

- **General information:** It consists of general information about 2023-2027 energy planning.

- **Citizenship education:** Space for common questions and answers about the PELP and a glossary of related terms.

- **Consultation process:** Publication of minutes, notes and videos of workshops and hearings of the 2021 participatory process.

- **Energy future:** Publication of energy and electricity scenarios and projections resulting from the process.

- **Climate change and air quality:** Publication of relevant reports related to emissions and international commitments for climate change, as well as a publication of the result of the calculations of emissions from 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 concepts of territorial development.

- **Repository:** Publication of the current PELP 2018-2022 process and annual background update reports.

Designed for easy navigation and easy access and download of information, the platform stands out for its gender-sensitive language and access to people with limited visual abilities.

As a complement to the topics and ideas shared in the citizen workshops, a massive survey plan is carried out on the entire registry of participants, allowing feedback about the user experience in each of the work sessions and validating and identifying socio-cultural and technological challenges to incorporate into the work agenda for the continuity of the process after the publication of the PELP 2023-2027 final report.

2.5. Citizenship: the key piece in PELP results

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

2.5.1. Priorities and interests for the energy future

During the participatory process, priorities and interests of different areas were addressed, and based on this information, it was proposed how we as a society should respond in certain situations. Different possible futures were studied, taking into account different economic well-being or different external circumstances, among others. 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 of the use of firewood, based on the pollution that affects our cities and that causes many harmful effects on human health.

2.5.2. Projection of energy requirements

Then, for each of these circumstances (scenarios) and based on the information collected and the preferences expressed in the workshops, projections of energy demand were built, which estimate the energy needs that we will have in each of these different circumstances. These projections were made after considering a series of assumptions based on the preferences worked on in the workshops. For example, if we are going to embark on a transition to gradually abandon firewood and consider the use of more sustainable energy sources, it implies that we will have to project the needs that we will have for the new energy sources and the new infrastructure, so it will have to be assumed that each year a large number of homes will be converted and, along with that, many will be refurbished homes to make them more efficient. Finally, this will translate into a growth in electricity requirements for heating in the different scenarios.

2.5.3. Projection of the electrical power system requirements

Based on the projections of energy requirements, the electrical requirements that will be needed to meet those needs are estimated, as well as how power generation units will have to be in order to meet them. This information is then submitted to the National Energy Commission (CNE, Chile) along with proposals for transmission expansion and recommendations from provinces in regions that should be designated as development poles. Finally, the CNE is the body in charge of determining transmission expansions in annual processes.

2.5.4. From a future vision to the clear sign of investment and expansion of the electrical power system

The information gathered during the participatory process is a fundamental piece in the construction of the new PELP, combined with a range of other inputs to build the electricity demand projection model.

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

3. Agreed vision of the energy future

New energy scenarios

3.1. What is an energy scenario?

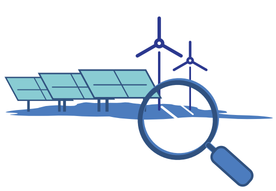
An energy scenario is a theoretical construction of how the energy sector will evolve[1] in the short, medium and long term. With them, it is possible to establish a variety of future development lines, determined by the vision that society builds in a participatory way.

Through the construction of energy scenarios, the purpose is to limit the range of future possibilities, understanding the uncertainty that the coming decades represent, and taking into account the commitments and goals, mainly in the energy and climate fields (both widely linked) that Chile has acquired in the last time.

Within the framework of the Long-Term Energy Planning Process, energy scenarios have the specific objective of guiding the expansion of electricity transmission, but they also allow to:

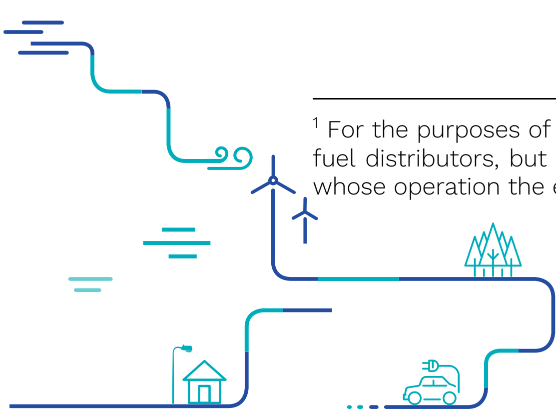
- Design and evaluate new or developing public policies, both in the energy sector and in other related sectors.

- Identify opportunities for the development of innovative technological solutions in order to take the actions required for their adoption and implementation.



- Survey specific needs of communities and territories throughout Chile in terms of the quality of energy services and the development of infrastructure projects.

- Develop additional analyzes and studies by the Ministry of Energy and other institutions, both public and private.



[1] For the purposes of this work, the energy sector will not only correspond to electricity companies or fuel distributors, but rather the energy sector will be understood mainly as any economic activity in whose operation the energy field is relevant, whether in production, transport or consumption.

The scenario concept is widely used by various institutions and agencies related to government or international energy issues, to name a few: the International Energy Agency (IEA), the World Energy Council (WEC), National Grid Electricity System Operator (ESO) (which corresponds to the electricity operator of the United Kingdom), ENTSO (which corresponds to the group of electricity and gas operators in Europe), International Renewable Energy Agency (IRENA), among others.

From these, it can be seen that the energy scenario allows to provide a conceptual framework for the energy reality being studied. In the case of the ESO – National Grid of the United Kingdom, the scenarios point to decarbonization, and the social change it implies. For the European electricity and gas operators ENTSO, energy scenarios are a tool to define climate and energy goals based on technological preferences, and national and local social and economic aspects.

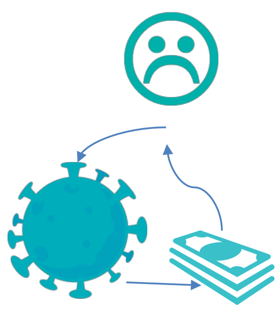
3.2. General description of the new energy scenarios

The energy scenarios were built cooperatively with the Citizen Consultation Registry, in the next round of workshops:

WORKSHOP 1 **EXTERNAL**	WORKSHOP 2A **TENSIONS**	WORKSHOP 2B **TENSIONS**	WORKSHOP 3 **TECHNICAL**	PUBLIC HEARING 2 **SCENARIOS**
• Introduction and leveling • Illustrative example • Presentation of external factors and their combinations	• Systematization workshop 1 • Presentation modifiable factors • Practical work around the tensions involved in the scenarios		• Presentation of the preliminary scenarios • Practical work around the inputs that emerged from the consultation process	• Presentation of the new long-term energy scenarios
May 4	May 11	May 18	June 8	June 25

At this time, the following three (3) long-term energy scenarios were defined:

1. Post Covid Slow Recovery **(RECOVERY)**
2. Course to Carbon Neutrality by 2050 **(CARBON NEUTRALITY)**
3. Accelerating the Energy Transition **(ACCELERATED TRANSITION)**



Post Covid Slow Recovery

The economic and social impact due to the COVID-19 pandemic, both globally and locally, translates into a slowdown in the energy transition. In Chile, where resource availability is low and the focus is on reactivating the economy, when it comes to energy, actions aimed at improving the quality of services and having a direct impact on people are prioritized.

In particular, efforts aim to improve air quality in cities through the regulation of the use of firewood, as well as the implementation of energy efficiency measures in homes.

In terms of international commitments, compliance with the provisions of the NDC to 2030 continues to be a priority and, therefore, all those measures that arise from the Electromobility Strategy and the Energy Efficiency Law are implemented, which constitutes a great effort considering the adverse conditions of the scenario.

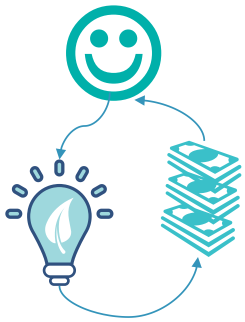
Road to Carbon Neutrality by 2050

Better economic conditions at the global and local levels, as well as the rapid drop in the costs of clean technology, have enabled the country to make progress in reducing local emissions and greenhouse gases.

This is how progress is made in the regulation of the use of firewood, and in the medium and long term its inefficient consumption is reduced due to the availability of alternatives such as the replacement of heaters and district heating, in addition to the implementation of measures of energy efficiency in homes that go beyond what is currently provided by the Law.

On the other hand, the adoption of new technologies allows reaching higher levels of electromobility penetration and efficiency measures in the productive sectors, which, hand in hand with the development of the green hydrogen industry, make it possible to achieve Carbon Neutrality in 2050.

Accelerating the Energy Transition



The rapid economic and social recovery following the COVID-19 pandemic, as well as the widespread development of cleantech alternatives, has accelerated the energy transition. In this sense, Chile is moving decisively toward the transformation of its energy system, deepening measures that reduce local and global emissions.

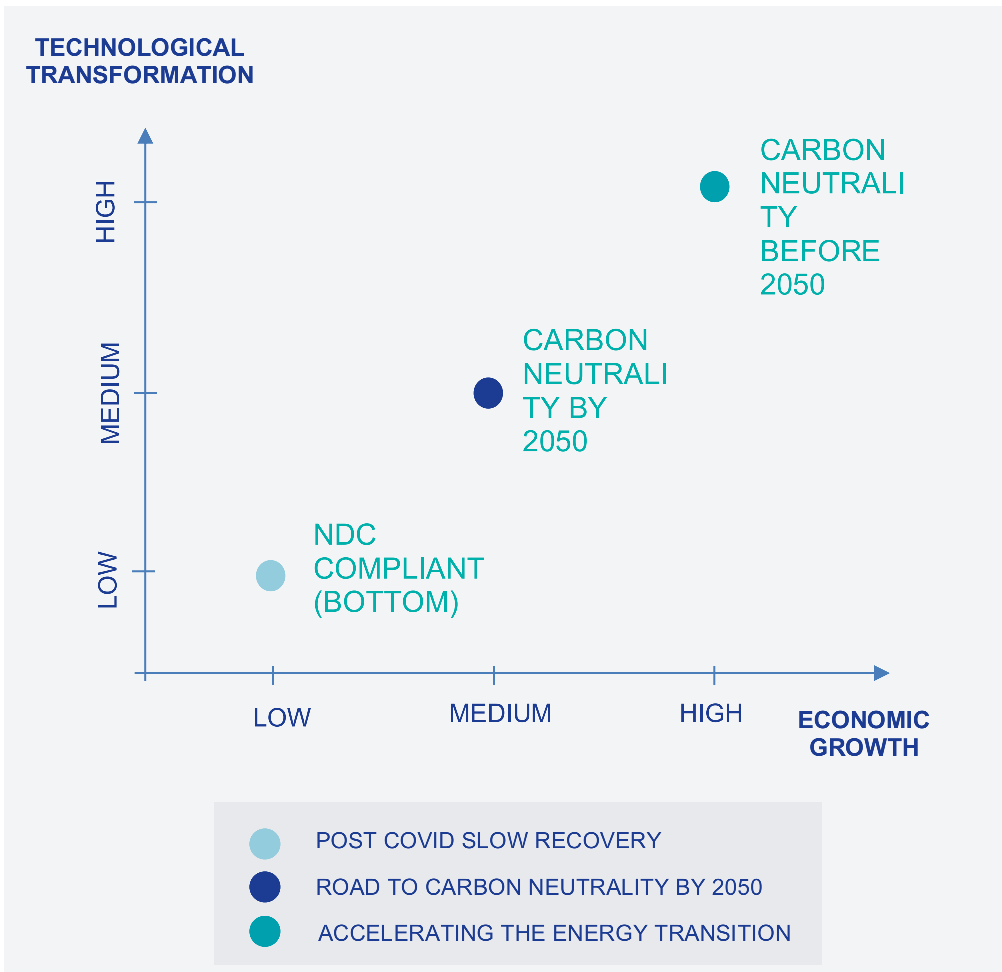
In particular, there is a progressive transition towards heating alternatives such as the replacement of heaters, district energy and the thermal insulation of homes, to the detriment of the use of firewood, which is restricted to specific areas and in a regulated manner.

On the other hand, the large-scale deployment of renewable energies in the electrical power system, combined with storage solutions, has enabled the consumption to be electrified in all economic sectors. This is how the integration of electromobility deepens and the green hydrogen and synthetic fuel production industry is widely developed, both for local use and for export.

All of this enables the electrical power system to operate 100% emission-free by 2050 and achieve Carbon Neutrality commitments before that year.

The energy scenarios differ in a large number of factors; therefore, it is possible to set up different graphs that show these trends. At this occasion, a graph is presented that shows the location of each scenario regarding the country's technological transformation and economic growth: greater economic growth fosters a strong technological transformation in the country, and vice versa.

It is important to mention that the objective of the scenarios is to search for a range of future situations that are likely to occur, as well as any other situation that is contained within them.



3.3. Factors considered

Factors are those elements that represent an important characteristic in shaping a future energy scenario. They can be divided into two broad categories based on the incidence or capacity of influence that society will have on them:

1. External Factors
2. Modifiable Factors

3.3.1. External factors

The external factors correspond to relevant aspects in the configuration of an energy future, for which their evolution determines in an important way the energy development in each scenario. They are called external factors because society as a whole has little ability to make decisions that strongly influence this factor in the short term, whereas it can be achieved in the medium or long term. This is the case of economic growth at the national level, expressed through the evolution of GDP, fossil fuel price trends and the costs of renewable electricity generation technologies.

EXTERNAL FACTORS	RECOVERY SCENARIO	CARBON NEUTRALITY SCENARIO	ACCELERATED TRANSITION SCENARIO
Economic growth	Low	Average	High
Fossil fuel prices	Low	Average	High
Cost reduction of generation technologies (NCRE)	Slow reduction	Average reduction	Fast reduction

CROSS-CUTTING FACTOR

• Resilience • Adaptation to climate change •

3.3.2. Modifiable factors

In essence, they correspond to the decisions that we want to make as a country. Society as a whole can influence them, and they represent how you want to respond to scenarios given by external variables and limited national resources.

LOCAL AND GLOBAL EMISSIONS

- Reduction of greenhouse gases (GEI)
- Reduction of local pollution in the residential sector
- Carbon pricing

It is related to the decarbonization of the energy matrix, and improvements to air quality in the cities of our country.

The fight against climate change, represented as the commitments that the country has acquired in terms of reducing GHG emissions, emerge as relevant and transversal aspects in the energy scenarios. This is where the mid-term (NDC 2030) commitment to reducing greenhouse gas emissions from the energy sector is believed to be achievable under all scenarios. Meanwhile, the great long-term commitment (Carbon Neutrality) is carried out to the extent that the economic and technological context allows it, considering that even in the most optimistic scenario, a greater ambition is achieved and thus reach said objective before 2050.

Local pollution in central and southern Chilean cities, mainly due to inefficient consumption of firewood, is a priority problem considered in all cases. This is how it is established that, as a basis, the regulation of the use and commercialization of firewood in the urban areas of the center-south of the country will be included. To the extent that economic and technological conditions allow it, hand in hand with a greater push by 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 restructuring of existing homes, to achieve "Net Zero Buildings" (in new homes) by 2050 for the most ambitious scenario.

		RECOVERY SCENARIO	CARBON NEUTRALITY SCENARIO	ACCELERATED TRANSITION SCENARIO
Carbon neutrality by 2050		Uncertain Complies with NDC (2030)	Complies	Accelerates Before 2050
Carbon pricing		Low	Average	High
Reduction of local pollution in the residential sector	Dry firewood	High in urban areas Firewood is still essential	High in urban areas Reduces long-term use	Substantially reduces the use of firewood in the long term What remains is dry
	District heating	Base	Average	High
	Replacement of heaters	Base	Average	High
	Thermal insulation	Base	Average	High +Net Zero Buildings (new)

NEW TECHNOLOGIES

- More decentralized energy system and a more active user role
- Incorporation and adoption of new technologies

Prospects for the development of new technologies in the national energy system and how this development unfolds in terms of decentralization.

The incorporation and adoption of new technologies is a key aspect that facilitates and allows the materialization of emissions reduction commitments and, in general, the energy transition of our matrix to clean energy. In particular, the development of electromobility, the deployment of green hydrogen industry, the development of carbon capture, use and storage (CCUS) applications, and the incorporation of large-scale energy storage in the 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 the international development of these technologies, as well as the promotion of the State as an enabling factor for them.

The alternative of having a more decentralized energy system, hand in hand with a more proactive user role, translates into greater or lesser development of distributed generation, as well as community solutions, both from the point of view of demand such as energy production. In particular, the challenge of green hydrogen production in Chile is addressed, for which the opportunity is raised for this industry to develop centrally (1 or 2 production poles), depending on the economies of scale that it entails, and/or in a more decentralized way, according to the territorial distribution of demand. This depends both on the temporality in the deployment of this industry and the level of export that each scenario considers.

		RECOVERY SCENARIO	CARBON NEUTRALITY SCENARIO	ACCELERATED TRANSITION SCENARIO
Electromobility		Current electromobility strategy	Electromobility + (carbon neutrality levels)	Electromobility ++
Green Hydrogen Production (H2V)		Low export / Low on-grid level	Average export / Average on-grid level	High export / High on-grid level
Storage in the National Electric System (SEN)		Low	High	High + (onsiders savings from hybrid projects)
Decentralization and user role	Distributed Generation	Base	High	High +
	Smart demand management	Heating management	Time, electromobility and heating management	Smart, electromobility and heating management
	H2V production	Centralized (Antofagasta and Magallanes)	Centralized (Antofagasta and Magallanes)	Decentralized (Antofagasta, Valparaíso, Biobío and Magallanes)
Carbon Capture, Use and Storage Technologies (CCUS)		No	Yes	Yes

OPERATION OF THE ELECTRICAL GRID

- Closure of coal-fired power plants
- Gas and diesel substitution

It refers to the operating conditions of the electrical power system due to the challenges faced by electricity generation based on fossil fuels.

The closure of coal-fired power plants is assumed as 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 electrical power system.

The use of natural gas in the power generation sector is considered to be the basis for the transition to a cleaner solution, allowing for the substitution of coal, to the extent that this type of power plant is withdrawn from the electrical power system. To the extent that economic and technological conditions allow it, their share in the matrix is declining and even, in an optimistic scenario, only the operation of this type of power plants with clean fuels and/or with the implementation of capture emission solutions is considered.

	RECOVERY SCENARIO	**CARBON NEUTRALITY** SCENARIO	**ACCELERATED TRANSITION** SCENARIO
Operation of gas and diesel power plants	Without restrictions	Only existing power plants	Only without CO2 emissions
Closure of coal-fired plants	Current (2040)	Accelerated (2035)	+ Accelerated (2030)

INTERNATIONAL INTEGRATION

- Energy import / export

It is related to the establishment of both physical and commercial networks of energy infrastructure with international markets.

Chile's anticipated opportunities for mass production of clean energy as well as emission-free synthetic fuels such as derivatives of green hydrogen suggest that there are opportunities for energy exports. That is why, in line with the considerations as to the deployment of the green hydrogen industry, the export of this energy source and its derivatives is included in two scenarios.

The export, or in general, the exchanges of electricity between Chile and its neighbors are not a part of the definition of the energy scenarios, but they will be analyzed later in order to shed light on the opportunities and challenges that an integration of this type represents.

	RECOVERY SCENARIO	**CARBON NEUTRALITY** SCENARIO	**ACCELERATED TRANSITION** SCENARIO
Energy import / export	Current	H2V export	H2V and synthetic fuels export

In ex-post analysis of the scenarios, the opportunities and challenges associated with the electrical interconnection with neighboring countries will be evaluated.

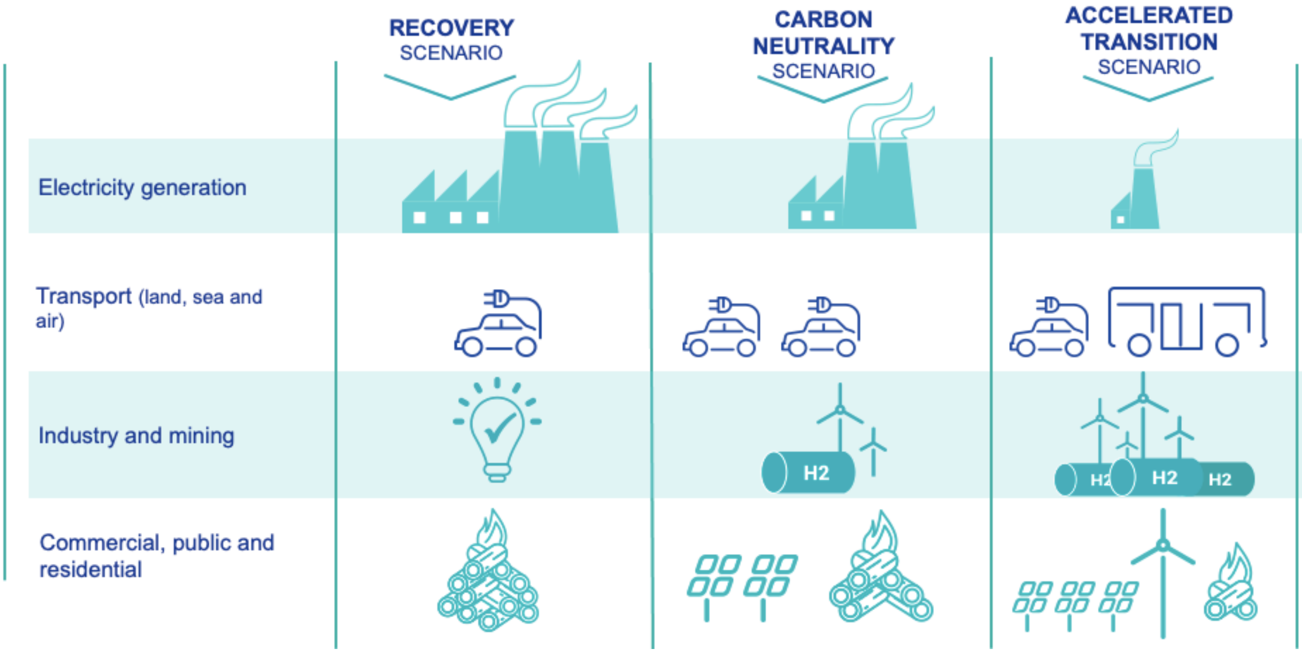
EFFICIENT USE OF ELECTRIC ENERGY

- Efficient use of energy in commercial, public and residential sectors.
- Efficient use of energy in transport, industry and mining sectors.

It refers to the establishment of the efficient use of energy, as a necessary condition towards the achievement of sustainable development.

Without a doubt, energy efficiency is a fundamental pillar of a clean and sustainable energy system of the future, and it plays an important role in all economic sectors, that is, commercial, public, residential, transport, industry and mining. In particular, a growing role of energy efficiency measures in households in line with better economic conditions is considered. This is how, in all scenarios, the measures deriving from the Energy Efficiency Law are included, as well as the relevance that attention to energy needs related to the thermal demand of homes has in the sector and how the different increasing applications of energy efficiency will be able to meet these challenges in each scenario.

In the productive sectors, the measures that emerge from the Energy Efficiency Law are also taken as a basis for all scenarios, and the better economic conditions, and the greater availability of new technologies allow progressively moving towards a replacement of thermal and motor uses to clean energies. At the same time, policies and actions that allow efficient use of energy minimizing energy demand through behavioral changes and smart demand management are promoted.



3.3.3. Characterization by sectors

The scenarios can also be defined according to the different sectors of the economy. For the construction of energy scenarios within the PELP framework, the following are considered: electricity generation, land, maritime and aviation transport, industry that includes, for example, cement, steel, paper mills, among others, and copper mining along with other minerals, and the commercial, public and residential sector.

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. In this way, for example, the transport sector will be clearly defined by the electromobility factor, but also the innovation and development of new technologies that could be expanded in the most optimistic scenarios, for example, with air transport using cleaner synthetic fuels, and the maritime sector using green hydrogen as fuel.

Below is the detail of the reductions by economic sector:

ELECTRICITY GENERATION

Post Covid Slow Recovery

Natural gas power plants play a key role in replacing electricity generation from coal-fired power plants that are being phased out of the system under the current schedule, and in the long term they greatly contribute to the flexibility required by the system to balance the massive entry of wind and solar generation.

Road to Carbon Neutrality by 2050

Existing natural gas power plants continue to operate to the extent that they incorporate technologies that significantly reduce their environmental externalities, while coal-fired generation speeds up their exit from operation. There is a growth in the penetration of storage technologies, mainly batteries, granting flexibility functions in the electrical power system insofar as these technologies become more competitive.

Accelerating the Energy Transition

Renewable energies, the development of zero-emission synthetic fuels, greater penetration of storage technologies, and the accelerated exit of coal from the electricity matrix led to a matrix of zero GHG emissions by 2040. Objective that is achieved not only at a centralized level, but also with a strong push for the development of small-scale distributed photovoltaic technology.

TRANSPORT (land, sea and air)

Post Covid Slow Recovery

Moderate growth of the fleet of electric and hybrid vehicles, leading to the goals established under the current Electromobility Strategy, influenced by the country's economic conditions and with consumers still aware of the cost of these technologies and in an environment in which the levels of demand for transport in all its modes also decrease due to the impacts of the COVID pandemic.

Road to Carbon Neutrality by 2050

The adoption of zero-emission light and medium vehicles, mainly electric vehicles, is a key component in achieving Carbon Neutrality. In the case of heavy transport, important levels of penetration of technologies related to the use of green hydrogen produced in Chile can also be seen.

Accelerating the Energy Transition

Mobility changes have been promoted in terms of greater use of non-motorized modes of transport and public transport, which coupled with flexible working conditions allowing fewer trips, allow reducing the need for private land transport. Furthermore, a high degree of electrification of private vehicles is observed, as well as the use of zero-emission green hydrogen and synthetic fuels in the case of heavy-duty transport. By 2035, internal combustion engine vehicles (gasoline and diesel) will no longer be sold. The national maritime and airfreight sub-sector has also significantly reduced emissions in the long run.

INDUSTRY AND MINING

Post Covid Slow Recovery

The industrial and mining sectors will maintain a trend of evolution, gradually integrating technical solutions and energy efficiency measures effectively promoted by the Energy Efficiency Law.

Road to Carbon Neutrality by 2050

It represents a greater integration of sustainable energies, substituting fossil fuels in thermal uses in industry and mining. CCS solutions are developed in those processes where alternative fuels are not possible. The desalination industry has grown substantially as a means of ensuring the normal operation of production activities under the protection of the growth of renewable energies.

Accelerating the Energy Transition

Industrial and mining demand makes a successful transition to a low-emission consumption matrix, in which electricity and hydrogen predominate. At the same time, the general supply of sustainable energy also stands out in the use of thermal energy in these sectors. On the other hand, CCS solutions are implemented in industrial processes that are difficult to decarbonize. Significant growth in the desalination industry is evident in securing human consumption and supplies for production activities.

CONSTRUCTION (commercial, public and residential)

Post Covid Slow Recovery

The Energy Efficiency Law facilitates a growing incorporation of energy efficiency actions in these sectors, mainly developing efforts to achieve significant reductions in local polluting emissions, highlighting important actions around improving the thermal insulation conditions of homes, such as updating thermal regulations for new homes and local district energy initiatives that take advantage of municipal waste and forest surplus for thermal use in homes and public and commercial constructions.

Road to Carbon Neutrality by 2050

It represents a greater integration of energy efficiency actions, enabled by the Energy Efficiency Law, with measures that concern major efforts to reduce both emissions of local pollutants and greenhouse gases. Fossil fuels can be replaced by electricity and/or zero-emission technologies, mainly for energy-intensive thermal uses, as long as the actions promoted are economically profitable.

Accelerating the Energy Transition

Significant energy savings are observed due to the implementation of energy efficiency actions in parallel with the renovation and thermal insulation of residential, public and commercial constructions.

Fossil fuels and inefficiently consumed firewood have managed to be replaced by electricity, hydrogen and other fuels, and zero-emission technologies, almost all of which are the most energy-intensive uses in these sectors.

At the local level, district energy initiatives are developed that take advantage of municipal waste, geothermal resources and industrial surpluses for the thermal use of part of homes and public and commercial constructions.

The construction of Net Zero Energy housing is promoted early, a significant reduction in local pollutants is highlighted for the benefit of people's health, motivated mainly by a complete replacement in the residential heating matrix of the urban areas of the center and south of Chile.

3.3.4. Summary of factors by scenario

Group	Factor		Recovery	Carbon Neutrality	Accelerated Transition
External	Economic growth		Low	Average	High
	Fossil fuel price		Low	Average	High
	Cost reduction of NCRE technologies		Slow reduction	Average reduction	Fast reduction
Local and global emissions	GHG mitigation climate commitments		Uncertain NDC and CN 2050	NDC and CN 2050	NDC and accelerates CN
	Reduce local pollution in the residential sector	Dry firewood	High in urban area	High in urban area Reduces long-term use	Substantial decrease in the use of firewood, what remains is dry
		District heating	Base	Average	High
		Replacement of heaters	Base	Average	Average
		Thermal insulation	Base	Average	High + net zero buildings
	Carbon pricing		Low	Average	High
New technologies	Electromobility		Current strategy	Carbon neutrality levels	Greater than Carbon Neutrality
	Green hydrogen (H2V)		Natural tendency	Carbon neutrality levels	Green H2 strategy
	Storage in SEN		Average	High	High +
	Energy system + decentralized /user role	Distributed generation	Base	High	High +
		Smart demand management	Heating management	EM time management Heating management	EM smart management Heating management
		H2V production	Antofagasta and Magallanes Low on-grid production Low export	Antofagasta and Magallanes Average on-grid production Average export	Decentralization with more production points in the country (Antofagasta-Valparaiso-Magallanes) High on-grid production Optimistic export
	Carbon Capture, Use and Storage Technologies (CCUS)		No	Yes	Yes
Energy efficiency	Efficient use in CPR		EE Law	EE Law+	EE Law + and Net zero buildings
	Efficient use in Transport, Industry and Mining		EE Law	EE Law+	EE Law++ High integration of renewables in thermal/motor uses
Operation of SEN	Use of gas and diesel		Without restrictions	Only existing power plants	Operation without CO2 emissions
	Closure of coal-fired plants		Current (2040)	Accelerates (2035)	+Accelerates (2030)
International integration	Energy import/export		Current	H2 export	H2+ and synthetic fuels export

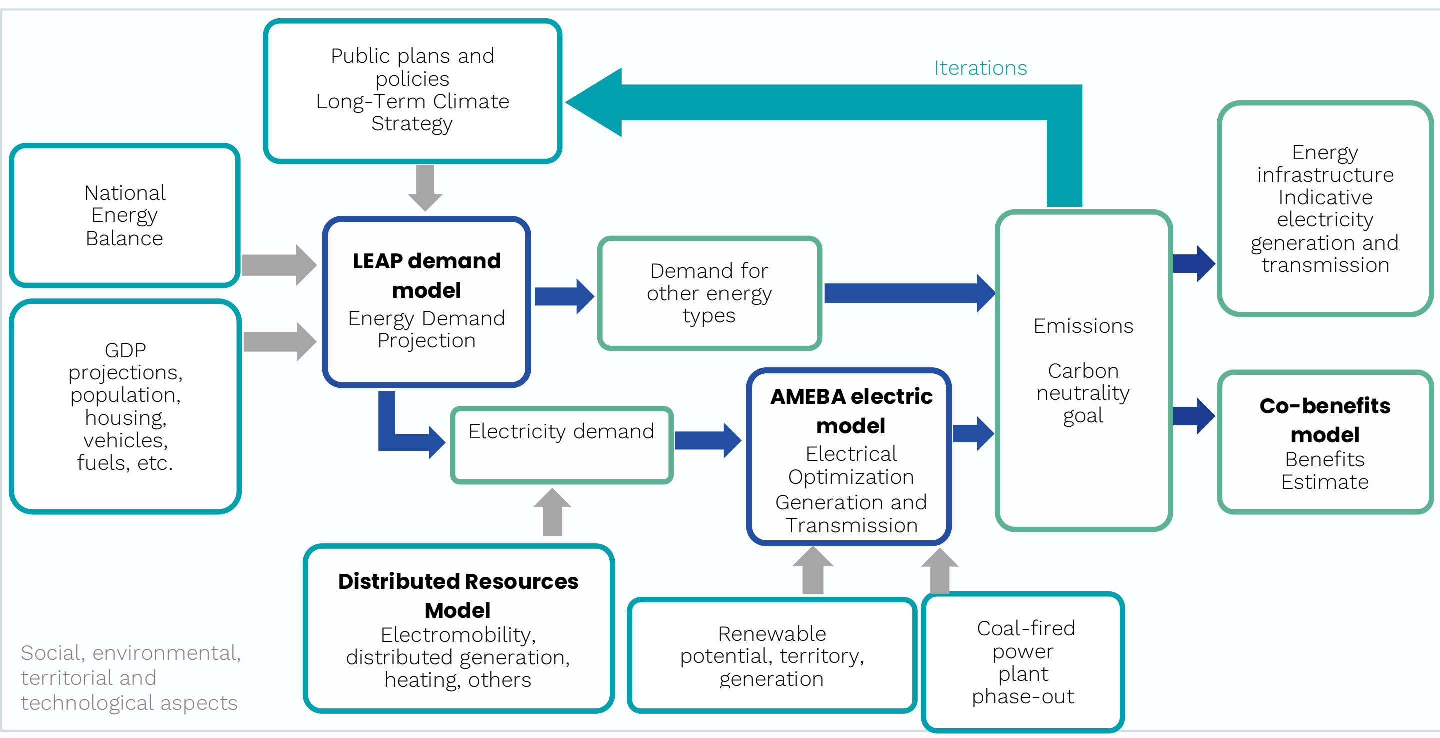
4. The energy sector

Projecting the energy requirements in the country

In order to comply with the provisions of the General Law of Electric Services (GLES), as to the Long-Term Energy Planning process and the permanent need to evaluate public policies in energy matters under different aspects of analysis, the Ministry of Energy has developed a series of tools and capacities that allow the construction of long-term energy scenarios.

4.1. Methodological relationship of the projection models

The construction of long-term energy scenarios mainly considers the operation of three simulation tools executed according to the following scheme:



4.1.1. Energy demand projection model

The tool used for the construction of long-term energy demand scenarios corresponds to the Long-Range Energy Alternatives Planning System (LEAP)[2], which consists of an energy system simulation software used for the analysis of energy policies in the medium and long term, through the integrated representation of energy demand by means of 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 disaggregation, considering for this the different final uses of energy in each sector.

The model allows the representation of all energy sources in the country, in accordance with the BNE. The modeling allows, through the projection of the main activity data and socioeconomic variables, to estimate future energy demand.

4.1.2. Power system optimization model

The computational simulations that determine the long-term balances that may occur in the National Electric System (SEN), are carried out on the AMEBA platform[3].

AMEBA is a web platform for energy system analysis, which has state-of-the-art technology in computational algorithms and mathematical models to comprehensively address decision-making in the electricity market[4]. It allows the study of short-term (economic dispatch and pre-dispatch), medium-long term (hydrothermal coordination) and long-term (planning of investment in generation and transmission) phenomena under the new operating paradigm of mass incorporation of renewable sources and storage. AMEBA has different tools that simplify modeling and analysis tasks, among which are its process gluer that allows the automatic launch of simulations in an orderly manner, and the data service in the cloud that allows the connection and use of infrastructure in the cloud for the use of Business Analytics tools to automate and speed up the data analysis process. AMEBA has an extensive server

[2] https://www.energycommunity.org/
[3] This software has been developed by SPEC (www.spec.cl).
[4] More information in www.ameba.cloud

platform in the cloud that enhances the simulation process by running multiple simulations in parallel, thus greatly reducing simulation time.

Generation plans and transmission reinforcements described in this report were determined through the INVX stochastic optimization model of the AMEBA platform. This model optimally solves a long-term centralized planning problem, which aims to determine future expansions of both the generation supply and the necessary transmission reinforcements, in order to cooperatively reduce the expected value of the operating costs (fuel and failure costs) and investment costs (capital and maintenance costs) of the electrical power system for a given time horizon and update rate. The model is capable of endogenously recognizing in its formulation, and at the same time, the technical restrictions of the operation of power plants (such as, for example, technical minimums, operating reserve requirements, among others), the flow of power in the transmission network considering AC and DC lines, water flows through hydrographic basins for several reservoirs, among others.

This can be summarized in the following optimization problem:

Minimum cost = Operating costs + Investment costs + Failure cost

Subject to

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

in which

- **Operating costs:** Expected annualized electricity generation costs and emissions taxes.
- **Investment costs:** Expected annualized investment costs and COMA (Operation, Maintenance and Administration Costs) for the expansion in generation, storage and transmission.
- **Failure cost:** Expected costs of unsupplied energy, system security flaws, and energy restrictions.

AMEBA makes it possible to obtain the optimal expansion plan in economic terms, compatible with the technical complexities of the system's operation, both of those technologies available to be incorporated into the electrical matrix and of the existing ones, recognizing their locations throughout the grid and the costs of transmission reinforcements necessary for its integration.

As far as the representation of the hydrographic basins is concerned, the reservoir model used includes overflows and seepage and allows the elimination of penalties for discharges and the use of fictitious tributaries. Likewise, it enables the modeling of multiple watercourses and turbines, and even the travel time of managed water across the basins. According to the considerations made within the framework of this process, decisions as to the state of water accumulation in the large power generation reservoirs are made on a monthly basis, with hydrological opening at the beginning of each hydrological year, considering the expected volume of each reservoir at the beginning of the hydrological year as the initial condition.

As a result of the computational simulation, AMEBA determines investment volumes by electricity generation technologies, development areas, location and year, deciding in turn on the optimal generation dispatch, and the management of water from the reservoirs to supply the electricity demand of the system. Likewise, AMEBA defines the transmission system reinforcements needed to accommodate next-generation infrastructure. This is done by calculating the total cost of the system (investment, operation and failure) and its subsequent minimization within the electrical restrictions included in the model.

4.1.3. Distributed resource model

An agent-based model is used to estimate the adoption of technologies linked to distributed generation in the residential, commercial and industrial sectors, respectively, using solar photovoltaic panels by the year 2050 in Chile. The modeling tool considers that the most relevant factors for individual adoption by an agent of a distributed generation system correspond to: investment payback period, economic income of the sector, communication leverage between agents and environmental benefits.

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, that is to say: in the first instance, the volumes of electrical energy needed are estimated for the satisfaction of the final energy uses of the national economic activity (including the residential sector), and once the final demand for electricity has been obtained for the entire period of analysis, it is this same vector that is incorporated into the model that optimizes planning as indicated in the corresponding figure through the connections to the different information modules.

4.2. External factors

4.2.1 Historical Energy Consumption

The National Energy Balance is used to establish the baseline in terms of energy consumption for each of the sectors of the economy: industry, mining, transport, commercial, public and residential, with regional disaggregation; and for each energy source: electricity, oil derivatives, natural gas, firewood, among others.

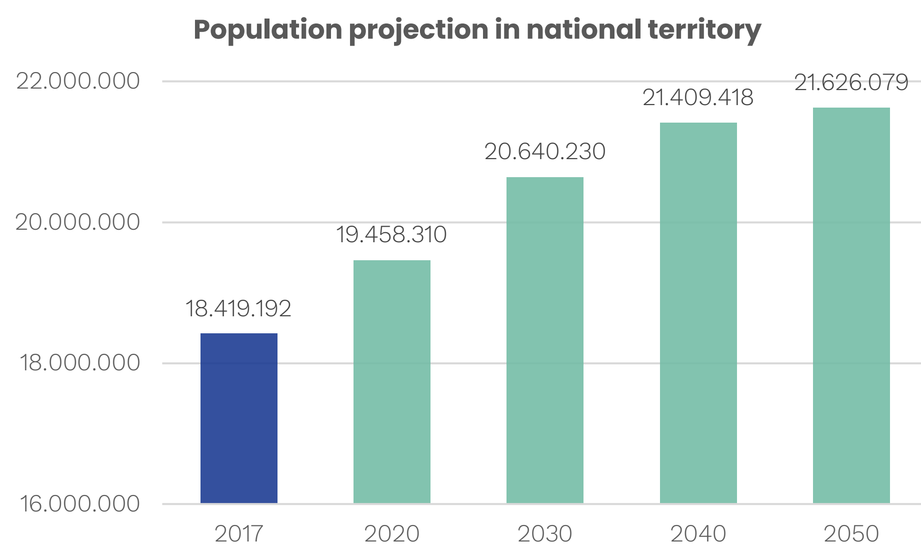
4.2.2 Growth projections of socioeconomic variables and productive activities of the country

For the projections of population, housing, public and private transport, mining-industrial production (cellulose, copper, iron), among others, various sources of information were used, such as the INE, CASEN, SEC, and data from other public utilities. In the case of activity levels (or "drivers"), these define directly, or indirectly, the energy requirement of the different sectors.

Economic Activity	Activity levels considered
Residential	Population
Copper	Production of copper concentrate [t]
Iron	Iron production [t]
Saltpeter	Nitrate production [t]
Various Mines	Total mineral production [t]

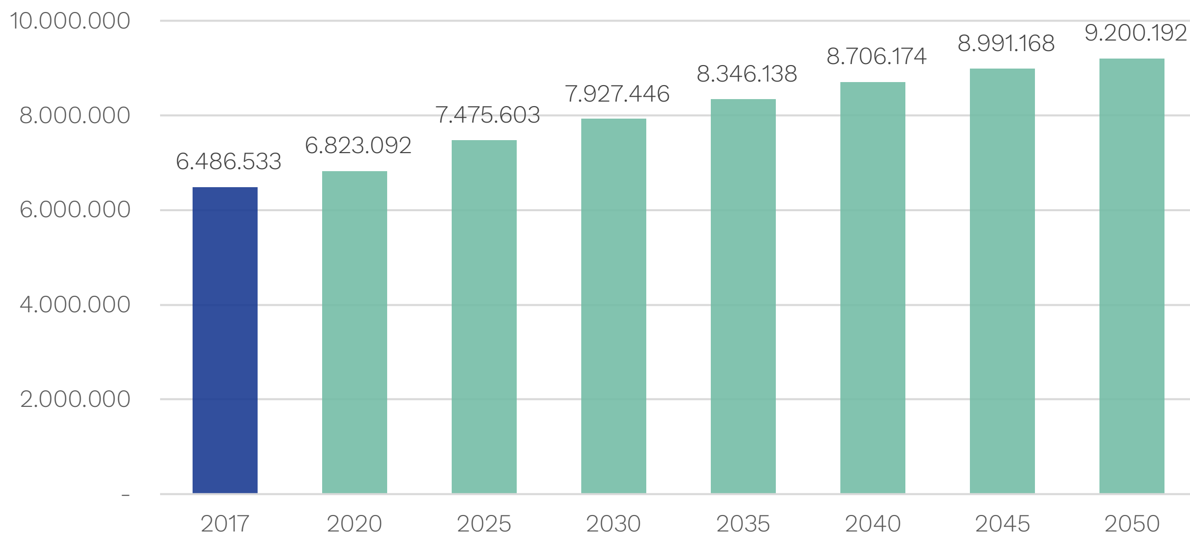
Economic Activity	Activity levels considered
Paper and cellulose	Cellulose production [t]. The projection considers surface restrictions due to new crops.
Iron and steel industry	Steel production [t]. BOF and EAF technologies are distinguished.
Cement	Cement and clinker production [t]
Sugar	Beet production [t]
Fishing	Extraction and cultivation [t]
Petrochemistry	Production of methanol and ethylene

Population growth is one of the main determinants of the evolution of energy projections. The statistics of the National Institute of Statistics, compiled from the last census carried out, are taken into account. Between 2017-2050, the average interannual population growth rate is 0.49%.



From the projection of inhabitants at the national level, distributed regionally, both the energy demand projection model is established, as well as a housing projection at the national level that considers the historical trend of the rate of inhabitants per home, and the economic growth curve considered in each energy scenario. For example, below is a housing projection for the Road to Carbon Neutrality scenario.

Housing projection 2017-2050



4.2.3 Economic Growth

The long-term energy scenario simulation work presents a projection of national economic growth for the period from 2018 to 2060 according to each energy scenario described in Section 3.2 of this report.

GDP Projection for PELP 2023-2027 Minute
Ministry of Finance

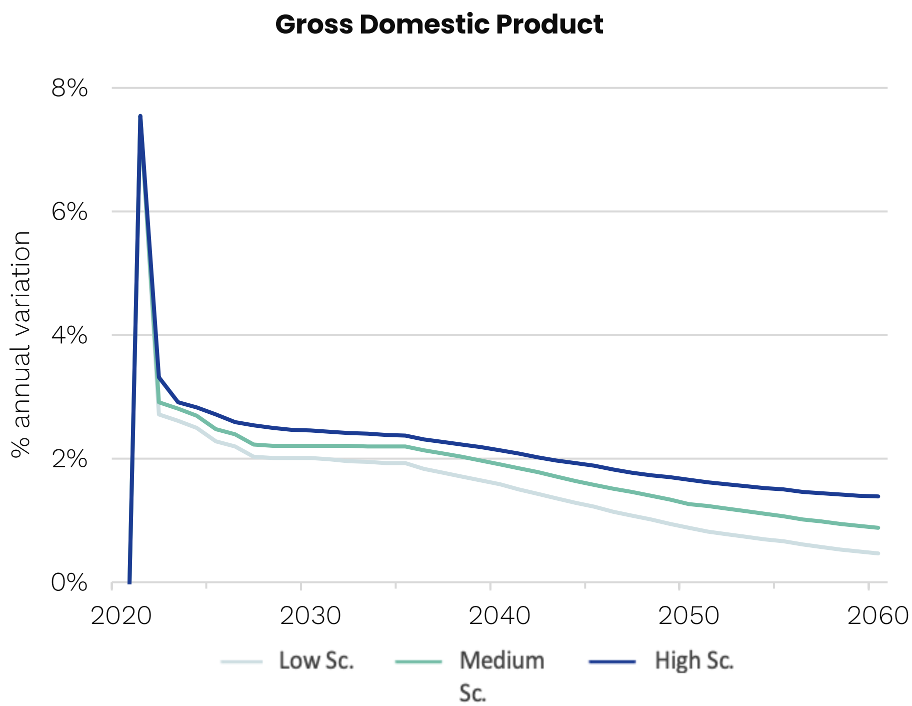
The GDP projection was carried out by the Budget Office (DIPRES), an agency dependent on the Ministry of Finance, based on a standard product growth model, which considers a Cobb-Douglas production function. In this, the GDP depends on the factors of production, capital, and work (which is made up, in turn, of employment and human capital), and 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 is GDP, K is capital, A is productivity, h is human capital, and

L is employment. The parameter α, meanwhile, represents the share capital in the level of production (GDP) and, consequently, $1-\alpha$ corresponds to labor share in production.

In this way, GDP growth will be determined by the growth of the four factors mentioned above.



The following table shows the average annual variation rates for each decade for the scenarios developed:

Period	Low Sc.	Medium Sc.	High Sc.
2021-30	2.8%	3.0%	3.2%
2031-40	1.8%	2.1%	2.3%
2041-50	1.2%	1.6%	1.9%
2051-60	0.6%	1.0%	1.5%

4.2.4 Fossil fuel price

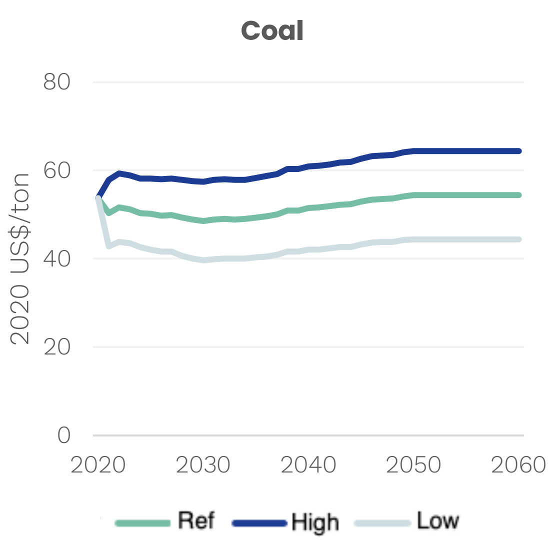
The fuel price projections were built based on national and international projections from various official sources, among which are:

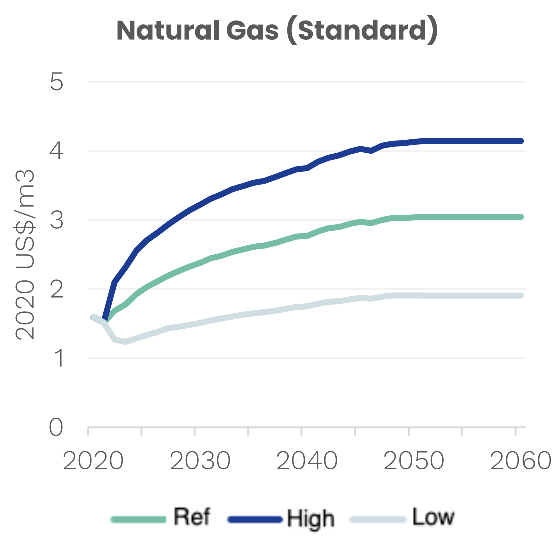
- Annual Energy Outlook 2021. Energy Information Agency (Department of Energy of USA).

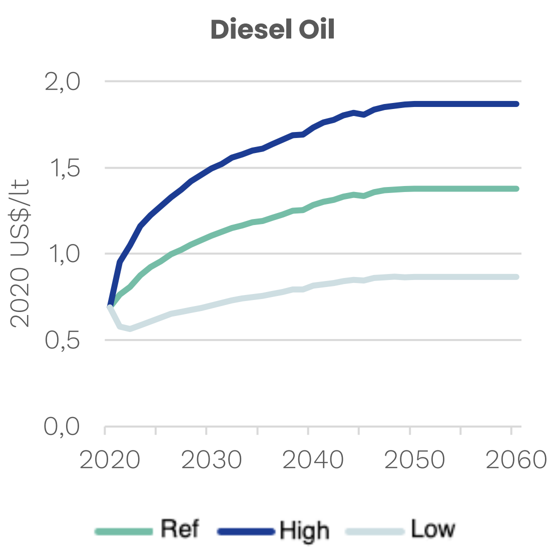
- Commodity Markets 2020. World Bank.

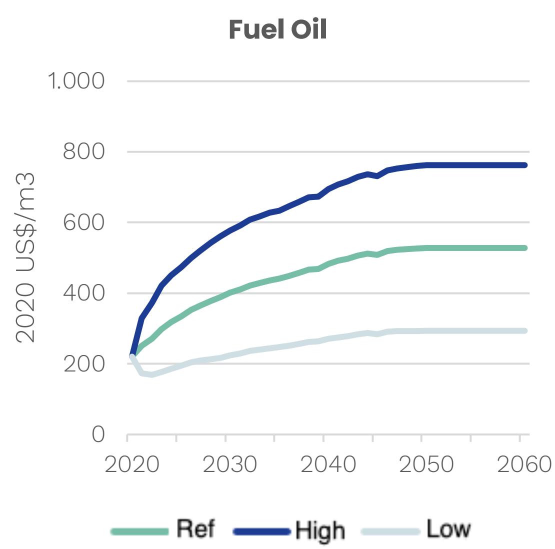
- New Energy Outlook 2020. Bloomberg New Energy Finance.
-
- Average Base Price, Fixing Report January 2021. National Energy Commission.

The projections were prepared through the parity price methodology, at the level of final consumption in Chile.









4.3. National Energy Balance

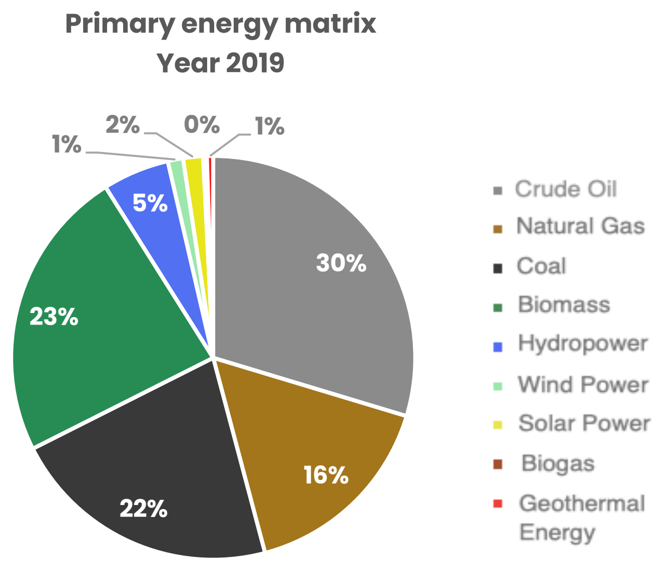
National Energy Balance
Ministry of Energy

The National Energy Balance is a fundamental annual process of the Ministry of Energy, which compiles energy flows with the aim of accounting for the total supply of energy available in the country in a calendar year, and quantifying how this supply was consumed by the main sectors of the national economy. The latest available edition of the National Energy Balance corresponds to the energy information consumed during the year 2019.

The National Energy Balance is divided into three large sections that represent the process from 1) obtaining the raw energy materials, 2) their transformation and finally 3) their use. These sections correspond to the primary matrix, electrical substations and final consumption, respectively.

4.3.1. Primary energy matrix

In 2019, Chile's primary energy matrix was 345,647 Tcal, of which fossil resources (crude oil, coal and natural gas) accounted for 68% of the total, also highlighting the 23% share of biomass. As a country, we have the great challenge of decarbonizing the entire economy, allowing renewable energies and energy efficiency to enter different sectors.

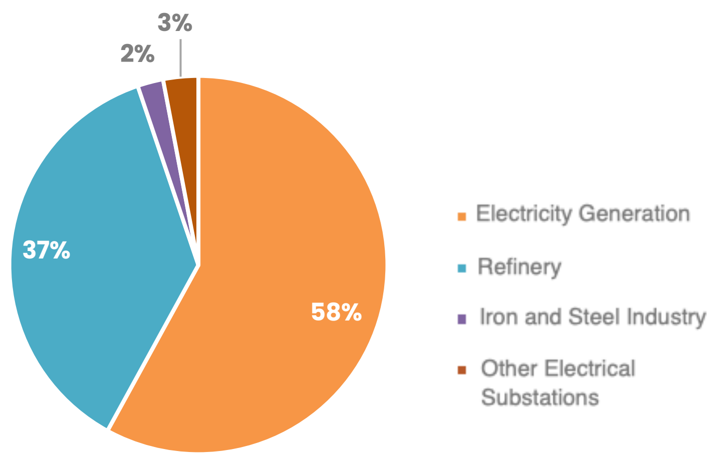


4.3.2. Consumption in electrical substations

The matrix of consumption in electrical substations represents all those energy consumptions, primary and secondary, used for the purpose of direct transformation to other energy sources for specific purposes. The main electrical substations in the country correspond to electricity generation, refinery, steel industry (composed in turn by coke ovens and blast furnace), and the activity of producing methanol from natural gas.

In 2019, the electrical substations processed 293,525 Tcal, which is 4% higher than the energy consumed for such purposes in 2018. Electricity generation constitutes the main electrical substation with a representation of 57%, followed by the oil refinery with 37%.

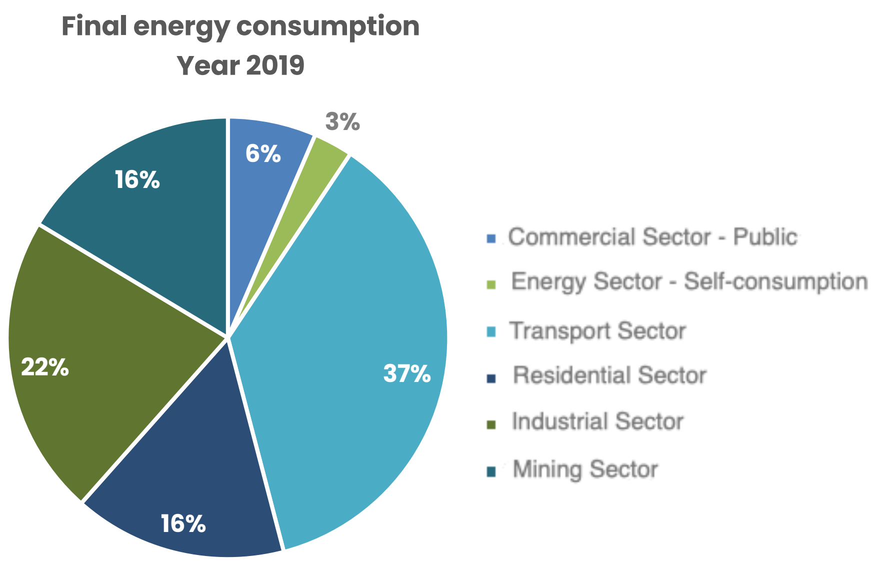
Consumption in electrical substations
Year 2019



4.3.3. Final energy consumption

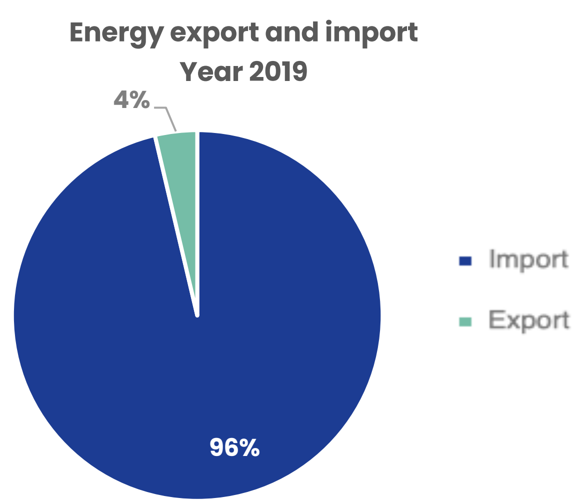
Final energy consumption is represented by a secondary energy matrix, corresponding to the energy assigned to the consumption sector of the national economy, including energy and non-energy use. Final energy consumption in 2019 was 301,629 Tcal, 0.2% more than in 2018, where 301,168 Tcal were reached.

Oil derivatives and electricity are the main components of the Chilean secondary matrix due to their transversal use in all economic sectors. In terms of sectorial consumption, the transport and industrial sectors consume most of Chile's energy, both accounting for 59% of the total.



4.3.4. Origin and destination of our energy sources

Finally, it should be noted that 91% of our primary energy supply is covered by exports. In turn, the level of energy exports and imports of our country has a proportion of 96% and 4%, respectively.



4.4. Measures by sectors of the economy

The construction of energy scenarios in a participatory manner was carried out by so-called modifiable factors, which were grouped according to their different areas or impacts, and, which follow different trends according to the scenario in which they are located. These 20 factors must be included in the LEAP model. This is done through the incorporation of more than 50 measures and actions, which have different impacts on energy demand, global emissions (greenhouse gases) and local emissions (particulate matter, among others). That is, the factor groupings are broken down into specific factors with different trends for each scenario, and then each of these factors is characterized in the LEAP model through various measures and actions. It is worth mentioning that their construction takes into account an extensive review of the coherence and consistency of measures in the modeling, i.e., in terms of the coexistence of actions and measures affecting the same needs. For example, this can lead to excessive energy efficiency results or with respect to GHG mitigation.

Each of the measures and actions simulated in the scenarios in the demand projection model (LEAP) are described below with the respective penetration levels. This section does not consider the measures of the electricity sector, which are simulated in the planning and operation model of the electrical power system (AMEBA).

4.4.1. Industry and mining

In the industry and mining sector, mitigation measures and actions are based on the recent energy efficiency law regarding energy management systems (SGE), and also considers other initiatives of the Ministry of Energy such as the National Hydrogen Strategy (2020)[5] and the National Heat and Cold Strategy (2021)[6].

There are major technological transformations in the Road to Carbon Neutrality and Accelerated Transition scenarios, specifically as to the use of green hydrogen in motor uses, reaching up to 97% share in copper mining and 92% in various industries by 2050. The sector is also highly electrified in all scenarios, reaching 53% electrification of motor uses in copper mining in the Post Covid

[5] Visit https://energia.gob.cl/sites/default/files/estrategia_nacional_de_hidrogeno_verde_-_chile.pdf

[6] Visit https://caloryfrio.minenergia.cl/

Recovery scenario.

<table>
<tr><th colspan="3">MEASURE</th><th>POST COVID RECOVERY</th><th>ROAD TO CARBON NEUTRALITY</th><th>ACCELERATING ENERGY TRANSITION</th></tr>
<tr><td colspan="3">Motor efficiency standards</td><td colspan="3">More demanding Minimum Energy Performance Standards (MEPS) in 2025 and 2035.</td></tr>
<tr><td colspan="3">Energy management systems (SGE) in large consumers</td><td colspan="2">Annual savings by SGE:
1.9% the first 6 years of implementation, 1% between years 7 and 20, 0.6% from year 21</td><td>Annual savings by SGE:
2.8% the first 6 years of implementation,
1% between years 7 and 20, 0.6% from year 21 onwards</td></tr>
<tr><td colspan="3">NCRE in thermal processes</td><td colspan="3">13% share of solar energy in thermal use of paper and cellulose, various industries, cement, sugar, steel, different mines by 2050</td></tr>
<tr><td rowspan="3">Green Hydrogen</td><td colspan="2">Thermal processes</td><td colspan="3">9% share in various industries by 2050</td></tr>
<tr><td rowspan="2">Motor Uses</td><td>Industry</td><td rowspan="2">n/a</td><td colspan="2">10% share by 2050</td></tr>
<tr><td>Mining</td><td colspan="2">97% copper mining and 65% various mines by 2050</td></tr>
<tr><td rowspan="4">Electrification</td><td rowspan="2">Motor Uses</td><td>Industry</td><td>n/a</td><td colspan="2">92% in various industries by 2050</td></tr>
<tr><td>Mining</td><td>21% share in various mines, 53% copper mining</td><td colspan="2">35% share in various mines, 3% copper mining</td></tr>
<tr><td rowspan="2">Thermal Uses</td><td>Industry</td><td colspan="2">7% in various industries
28% paper and cellulose (P&C)</td><td>28% thermal uses in various industries and P&C</td></tr>
<tr><td>Mining</td><td colspan="3">28% in various mines and ~72% in copper mining (smelting)</td></tr>
</table>

4.4.2. Commercial and public sectors

The commercial and public sectors have the least number of actions and mitigation measures. This is due in part to the difficulty of modeling measures in these sectors and, on the other hand, due to the lack of detailed information at the level of consumption in the sector. Some actions related to energy efficiency programs in the public sector are then simulated, where energy consumption has been identified. However, as will be seen later, these measures will not result in relevant changes in the energy demand of these subsectors.

MEASURE	POST COVID RECOVERY	ROAD TO CARBON NEUTRALITY	ACCELERATING ENERGY TRANSITION
Energy Efficiency in Streetlighting	8,000 units are replaced per year		18,000 units are replaced per year
Energy Efficiency Program for Public Buildings	5 public buildings are refurbished per year	15 public buildings are refurbished per year	
Energy Efficiency Program in Hospitals	5 hospitals are refurbished per year		5 hospitals are refurbished per year
Heating Electrification in Shopping Malls	n/a	100% use of electricity for heating by 2050	
Electrification of Motor Uses in Other Sectors	50% share in commercial motor uses	55% share in commercial motor uses	60% share in commercial motor uses

4.4.3. Residential sector

The residential sector has undertaken a range of measures, including the introduction of renewable energies in homes, reducing energy demand by improving appliance standards and thermal insulation, replacing heating methods with less polluting technologies, and electrifying consumption.

The penetration levels proposed for these measures represent an important energy transition for the sector. The efforts made in each scenario in terms of the thermal envelope of the houses stand out, even incorporating a large volume of construction of houses with the Net Zero[7] standard in the Road to Carbon Neutrality and Accelerating Energy Transition scenarios. The penetration levels of the proposed measures are mainly based on the goals established in the National Strategy for Sustainable Construction of the Ministry of Housing and Urban Development[8], the Long-Term Climate Strategy of the Ministry of the Environment[9], and the updating of the National Energy Policy of the Ministry of Energy[10].

Regarding the heating measures, the exclusive use of dry firewood is considered in all scenarios at the urban level in the medium term, and at the national level in the long term, which is in line with the solid biofuels bill led by the Ministry of Energy[11]. An important long-term electrification of heating consumption is also included in all scenarios, in line with the "*Recambia tu Calor*" Program[12] and leveraged by improvements in the thermal envelopes of the housing stock nationwide. A technological change in this area is the incorporation of geothermal energy for heating purposes, which in the Accelerating the Energy Transition scenario reaches a 6% share in houses by 2050 at the national level. It is worth mentioning that to date the incorporation

[7] Net Zero Building is understood as a building with net zero energy consumption, which during its life cycle (production, construction, operation, end of useful life), manages to minimize its embodied carbon emissions and offset any remaining carbon balance. However, for the purposes of the LEAP modeling carried out here, a Net Zero Building is considered to be a dwelling that reaches 75% savings of the total demand, discounting the savings of the construction standard.
[8] https://participacionciudadana.minvu.gob.cl/consultas-ciudadanas-virtuales/consulta-p%C3%BAblica-estrategia-nacional-de-huella-de-carbono-en-la
[9] https://cambioclimatico.mma.gob.cl/estrategia-climatica-de-largo-plazo-2050/descripcion-del-instrumento/
[10] https://energia.gob.cl/energia2050
[11] https://energia.gob.cl/noticias/nacional/ministerio-de-energia-celebra-aprobacion-de-nueva-regulacion-para-uso-de-la-lena-como-combustible-domiciliario-certificado
[12] https://www.recambiatucalor.cl/

of district heating in the different energy scenarios is pending.

<table>
<tr><th colspan="2">MEASURE</th><th>POST COVID RECOVERY</th><th>ROAD TO CARBON NEUTRALITY</th><th>ACCELERATING ENERGY TRANSITION</th></tr>
<tr><td colspan="2">Solar thermal systems (STS) for domestic hot water (DHW)</td><td>8,000 STSs per year from 2022 to 2050</td><td>12,000 STSs per year from 2022 to 2050</td><td>20.000 STSs per year from 2022 to 2050</td></tr>
<tr><td colspan="2">Minimum standards for refrigerators</td><td colspan="3">Minimum Energy Performance Standards (MEPS) are implemented</td></tr>
<tr><td colspan="2">Artifact labeling measures</td><td colspan="3">Average artifact consumption reduced to an additional 1%</td></tr>
<tr><td rowspan="3">Housing thermal envelope</td><td>Thermal Regulation (TR)</td><td>New TR in 2022</td><td>New TR in 2022.
It is updated and improved in 2031</td><td>New TR in 2022.
It is updated and improved in 2031 and 2041</td></tr>
<tr><td>Thermal reconditioning</td><td>Subsidies: 10,000 homes per year from 2022 to 2050</td><td>Subsidies: 20,000 homes per year from 2022 to 2050

Loans: 20,000 homes per year until 2050</td><td>Subsidies: 30,000 homes per year from 2022 to 2050

Loans: 30,000 homes per year until 2050</td></tr>
<tr><td>Energy rating of new homes</td><td>A+ 5%; A 15%; B 25%; C 30%;
D 20% & E 5%.</td><td>A+ 5%; A 10%; B 35%; C 40%;
D 10% & E 0%.</td><td>A+ 5%; A 35%; B 35%; C 20%;
D 5% & E 0%</td></tr>
<tr><td colspan="2">Net Zero Buildings</td><td>n/a</td><td>450,000 homes are built with the Net Zero standard between 2041-2050</td><td>900,000 homes are built with the Net Zero standard between 2041-2050</td></tr>
<tr><td colspan="2">Change to dry firewood</td><td colspan="3">100% at the urban level by 2030 and 100% at the national level by 2050</td></tr>
<tr><td rowspan="3">Consumption electrification</td><td>Heating</td><td>48% homes (houses and apartments) by 2050</td><td colspan="2">56% homes (houses and apartments) by 2050</td></tr>
<tr><td>Cooking</td><td colspan="2">10% share is reached by 2050</td><td>14% share by 2050</td></tr>
<tr><td>Domestic Hot Water</td><td colspan="2">17% share is reached by 2050</td><td>30% share by 2050</td></tr>
<tr><td colspan="2">Geothermal energy for heating</td><td>n/a</td><td>1% share in houses by 2050</td><td>6% share in houses by 2050</td></tr>
</table>

4.4.4. Transport sector

The measures in the transport sector focus on three main aspects: electromobility in private vehicles and public transport, implementation of energy performance standards in different vehicle segments, and the use of green hydrogen to replace diesel in day cabs and commercial flights nationwide.

Regarding the electromobility measures, it is based on meeting the goals of the Electromobility Strategy[13]. However, this strategy is currently being updated, and there are other instruments that have established milestones and more ambitious goals, such as the carbon neutrality work of the year 2019[14], the ECLP, and the update of the National Energy Policy. These have been taken as inputs to define the penetration levels in more ambitious scenarios.

The Law on Energy Efficiency (LEE) seeks to promote the renewal of the fleet with more efficient vehicles, with an emphasis on those with electric propulsion. For this, the LEE mandates the setting of energy efficiency standards for the fleet of new vehicles[15].

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. In addition, in the Accelerated Transition scenario, a measure is introduced in the air transport sector, where green hydrogen would supply almost 80% of the energy supply for domestic commercial flights by 2050.

[13] https://energia.gob.cl/electromovilidad/orientaciones-de-politicas-publicas
[14] https://energia.gob.cl/pelp/cambio-climatico-y-calidad-del-aire
[15] https://energia.gob.cl/ley-y-plan-de-eficiencia-energetica

MEASURE		POST COVID RECOVERY	ROAD TO CARBON NEUTRALITY	ACCELERATING ENERGY TRANSITION
Electromobility	Urban public transport	100% electric buses by 2045[16]		
	Taxis	100% electric vehicle fleet by 2046	100% electric vehicle fleet by 2038	
	Light vehicles	100% sale of zero-emission vehicles by 2050 40% share of electric vehicles by 2050	100% sale of zero-emission vehicles by 2040 60% share of electric vehicles by 2050	100% sale of zero-emission vehicles by 2035 60% share of electric vehicles by 2050
	Medium vehicles			100% sale of zero-emission vehicles by 2030 70% of medium electric vehicles by 2050
	Transformation from light vehicles to EVs	n/a	Replacement of 15% of the conventional vehicle stock to electric vehicles (EVs) by 2035	Replacement of 20% of the conventional vehicle stock to electric vehicles (EVs) by 2035
Energy performance standards	Light vehicles	2024 22,5 km/lge 2027 27,3 km/lge 2030 28,9 km/lge	2024 22,5 km/lge 2027 27,3 km/lge 2030 28,9 km/lge 2040 34,8 km/lge 2050 39,6 km/lge	2024 22,5 km/lge 2027 27,3 km/lge 2030 28,9 km/lge 2040 39,6 km/lge
	Medium vehicles	2025 15,2 km/lge 2028 18,5 km/lge 2031 20,0 km/lge	2025 15,2 km/lge 2028 18,5 km/lge 2031 20,0 km/lge 2040 25,0 km/lge 2050 30,0 km/lge	2025 15,2 km/lge 2028 18,5 km/lge 2031 20,0 km/lge 2040 30,0 km/lge
	Heavy vehicles (day cabs)	Improve performance by 40% (equivalent to reducing consumption by 27%) from 2030		
Green hydrogen	Heavy vehicles (day cabs)	50% of the fleet by 2050	84% of the fleet is promoted for 2050 100% zero sales and low emissions by 2045	
	Commercial air transport	n/a		78% share in energy supply on domestic flights
Bicycle Infrastructure		n/a	Linear increase in the share of bicycles to reach 6% of urban transport	Linear increase in the share of bicycles to reach 10% of urban transport

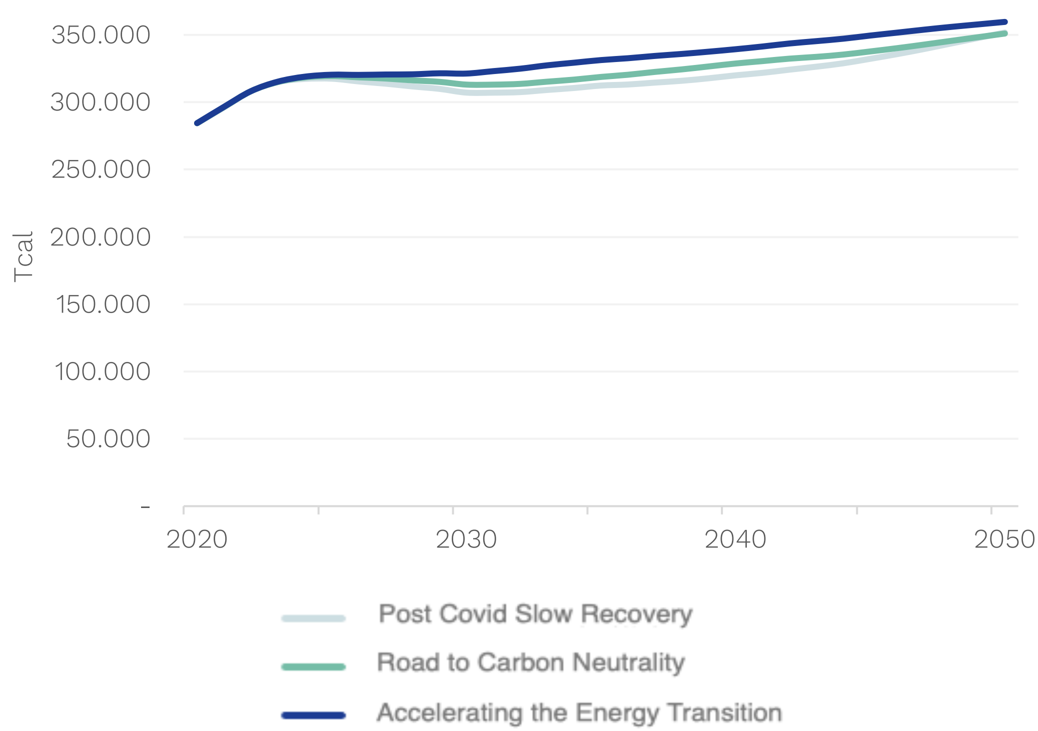
[16] Preliminary value. It will be adjusted in the next report until reaching 100% urban electric transport by 2040 as a basis for all scenarios.

4.5. Energy projections

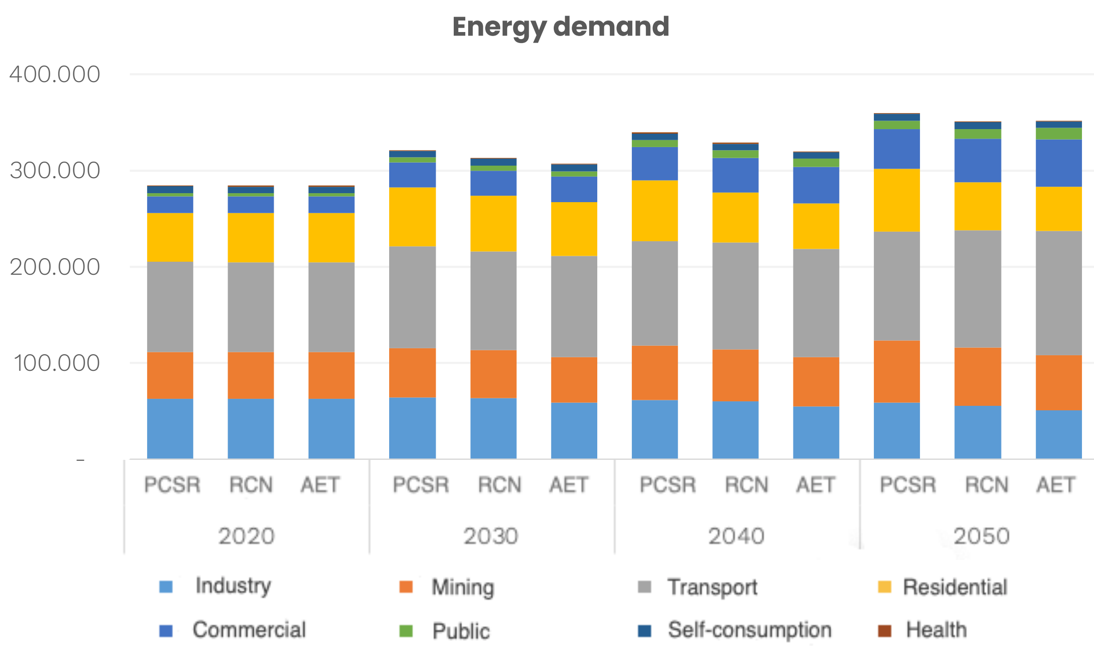
4.5.1. Energy demand

The national energy demand concentrates the energy demand from all the economic activities (industry, mining, transport, 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 the prospects for economic growth.

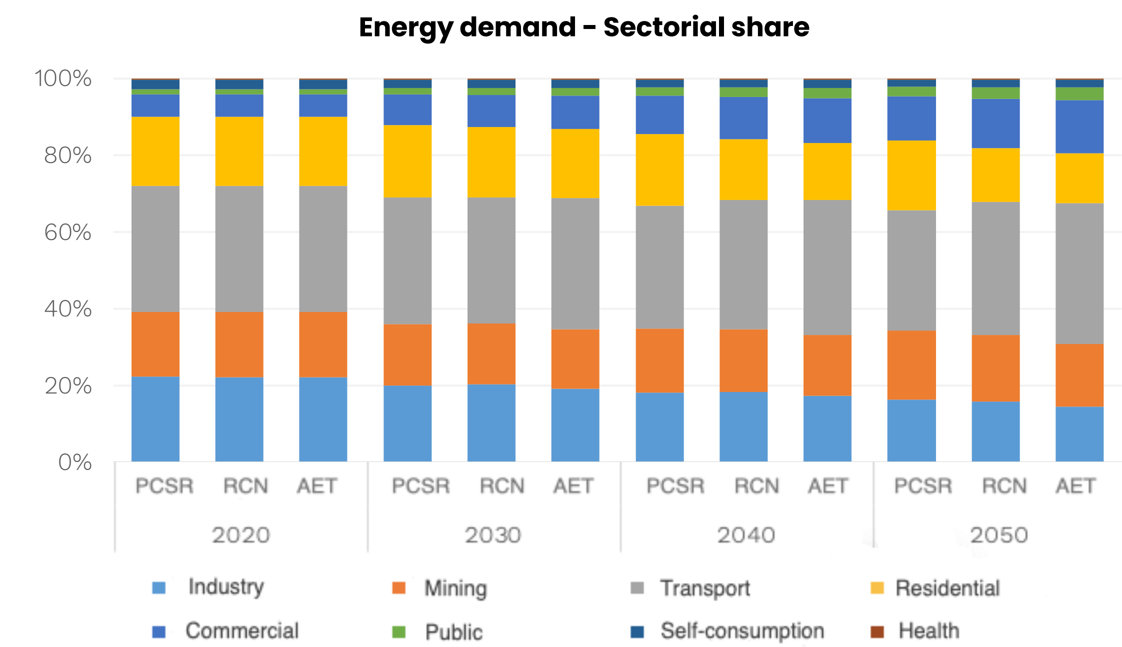
As mentioned in a previous section, both variables show continued growth between 2020 and 2050. This is why energy demand is expected to grow significantly across all long-term energy scenarios.

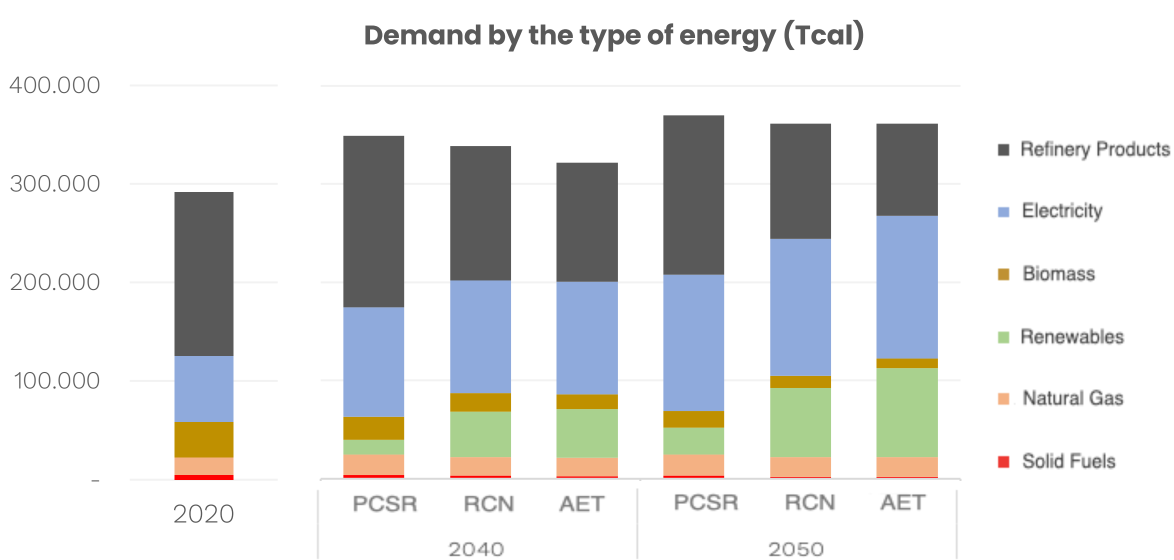


Compared to 2020, national energy demand is projected to grow by 23% to 26% by 2050, depending on the energy scenario. This growth is mainly explained by the evolution of the energy demand of the transport sector, which currently represents more than 33% of the national energy demand and presents growth rates by 2050 that vary between 21% and 38% depending on the energy scenario with respect to 2020.



The magnitude of the growth in energy demand at the national level hides the sectorial performance of each of the economic sectors, which do not always present a growth trend 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 energy efficiency and greenhouse gas mitigation efforts that are being considered in each of the economic sectors. For example, the industrial sector stands out, which shows a decrease in its energy demand by 2050 compared to 2020 in all scenarios. In the Slow Economic Recovery scenario, the industry reports a 7% decrease in demand compared to 2020, while in the Accelerating the Energy Transition scenario, a 20% decrease in industrial energy demand is observed.

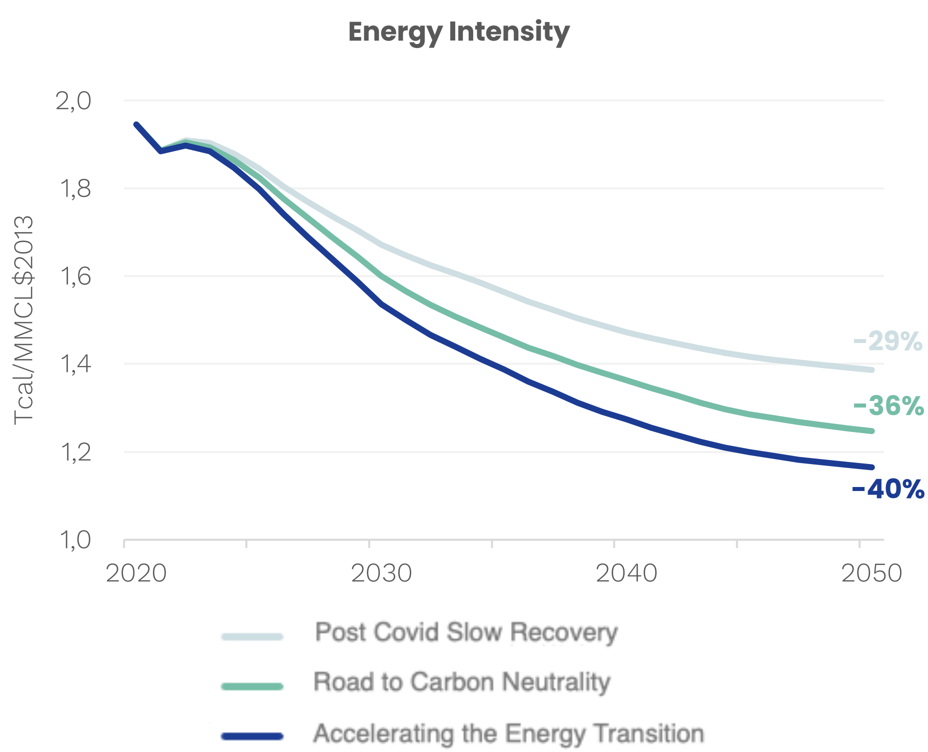

Energy demand - Sectorial share
100%
80%
60%
40%
20%
0%
PCSR RCN AET PCSR RCN AET PCSR RCN AET PCSR RCN AET
2020
2030
2040
2050
Industry
Mining
Transport
Residential
Commercial
Public
Self-consumption
Health


Demand by the type of energy (Tcal)
400.000
300.000
200.000
100.000
-
2020
PCSR RCN AET PCSR RCN AET
2040
2050
Refinery Products
Electricity
Biomass
Renewables
Natural Gas
Solid Fuels

As to the demand by the type of energy, it is important to highlight that the final demand for renewables in the energy sector (without considering renewable energies in the electricity sector) grows in absolute terms of demand 700 and up to 900 times a year by 2050 in the Road to Carbon Neutrality and Accelerated Transition scenarios, respectively.

4.5.2. Energy intensity

In the energy performance analysis of an economy, one of the main quantitative indicators corresponds to energy intensity. Energy intensity measures the relationship between energy use or demand and gross domestic product. This indicator has been constructed for each scenario, given that each energy scenario was designed considering a heterogeneous set of efforts related to energy efficiency, mitigation of greenhouse gas emissions, and reduction of local pollution.



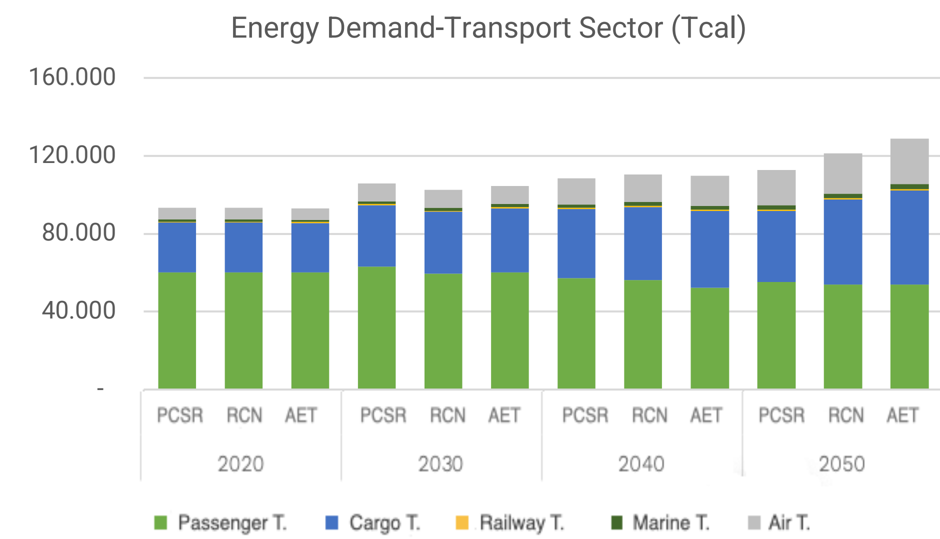
Looking at the long-term projections of the energy demand generated by each scenario, it is found that energy intensity decreases in all scenarios. By 2050, the energy intensity of the Slow Recovery scenario is reduced by 30%, and the energy intensity of the Accelerating the Energy Transition scenario is reduced by up to 40%.

Energy Intensity (Tcal/MMCL$2013)				
SCENARIO	2020	2030	2040	2050
Post Covid Slow Recovery	1.9	1.7	1.5	1.4
Road to Carbon Neutrality	1.9	1.6	1.4	1.2
Accelerating the Energy Transition	1.9	1.5	1.3	1.2

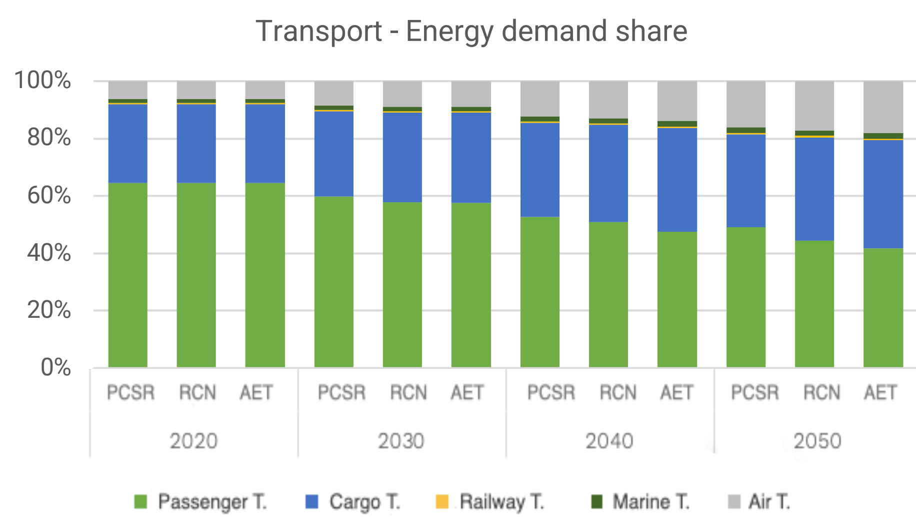
4.5.3. Transport sector

The energy demand of the transport sector, including land passenger transport, cargo transport, railway, maritime and air transport, grows in all scenarios by 2050. However, it is only in the last decade of 2040-2050 where the Road to Carbon Neutrality (RCN) and Accelerating the Energy Transition (AET) scenarios reach an increase that manages to differentiate the final demands of the scenarios to a greater extent. The demand for the year 2020 starts at around ~93,000Tcal total for the transport sector, and multiplies between 1.2 and 1.4 times for the year 2050.

The demand for passenger transport manages to reduce in all scenarios by the year 2050. However, the cargo and air transport sectors increase substantially, growing ~2 and ~4 times a year by 2050, respectively.

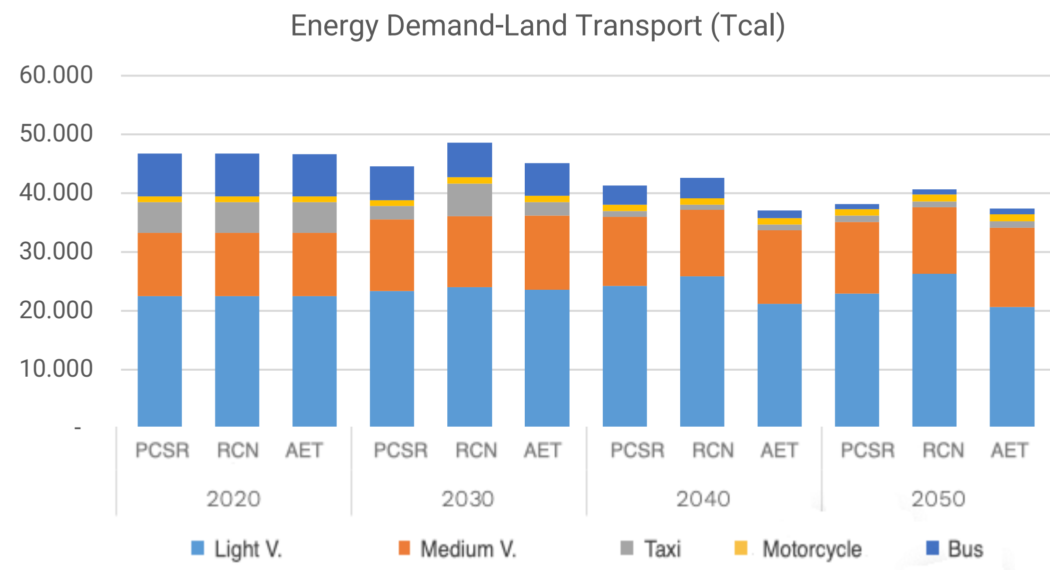


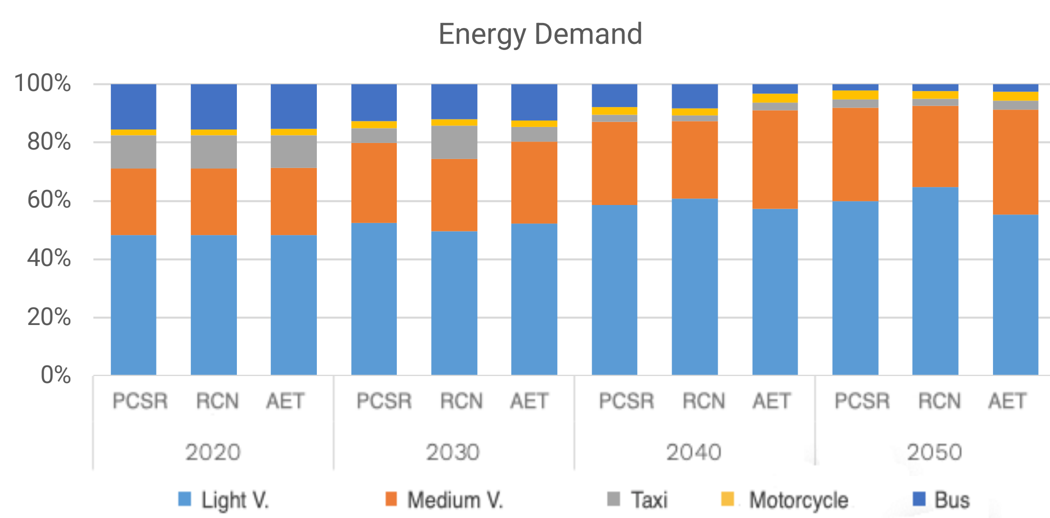
Relevant changes are observed in terms of the share of land transport, which goes from ~65% in 2020 to ~40% in 2050 in the Accelerating the Energy Transition (AET) scenario, and air transport, which goes from ~5% to ~ 20% from 2020 to 2050 in the same scenario mentioned.



Land and passenger transport

In all long-term scenarios, total energy demand for land and passenger transport is about 10-20% lower than at the beginning of the period. Demand for buses and taxis has fallen even more, and in some scenarios will be fully electrified by 2040.





Regional distribution of transport energy demand

It will also be decisive to analyze the regional distribution of future energy demand in relation to each energy scenario. The figures below show the distribution of transport energy demand (energy demand for land, rail, national maritime and national air transport concepts) at the regional level to 2050. The three regions with the highest demand in transport account for practically 50% of the total demanded. The Metropolitan Region alone represents 32% of transport energy uses in the Recovery scenario reaching up to 30% in the Accelerating Energy Transition scenario by 2050. This region is followed by the Antofagasta region, whose share is in the 9-10% range. In third place, the Biobío and Ñuble regions represent 8% of the transport demand.

Regional demand for the transport sector by 2050. Recovery Sc.

Regional demand for the transport sector by 2050. Road to Carbon Neutrality Sc.

Regional demand for the transport sector by 2050. Accelerated Transition Sc.

4.5.4. Residential sector and home heating

The construction of energy scenarios in the residential sector consists of great transformations in terms of the thermal quality of homes, both existing and new constructions, considering a significant number of buildings with a net zero standard by the year 2050. In turn, important changes are proposed regarding the use of heating technologies. These transformations are visible in the energy demand results of the three scenarios.

All the scenarios increase their energy demand for home heating until the year 2025. After that year, the demand continues to decline, producing the most pronounced drop in the Accelerating the Energy Transition (AET) scenario. By 2030, the three scenarios manage a very similar demand for heating, which ranges between 21,988 Tcal and 26,920 Tcal. The composition of the heating matrix is also very similar, with firewood and biomass still reaching a 60% share. However, all scenarios so far have significantly increased their heating electricity consumption to this date (over 1000% with respect to the demand for the year 2020).

By 2050, the Post Covid Recovery (PCSR) scenario has not been able to significantly reduce its demand for home heating, reaching an energy demand of 21,371 Tcal. In turn, in the same year, heating demand is reduced by a factor of 2.5 (8,522 Tcal) in the Road to Carbon Neutrality (RCN) scenario, while demand in the AET scenario is reduced by a factor of 3.7 (5,711 Tcal). This is due to the great transformation in the thermal insulation of existing homes and new constructions in the latter two scenarios, which greatly reduces the heating demand of homes.

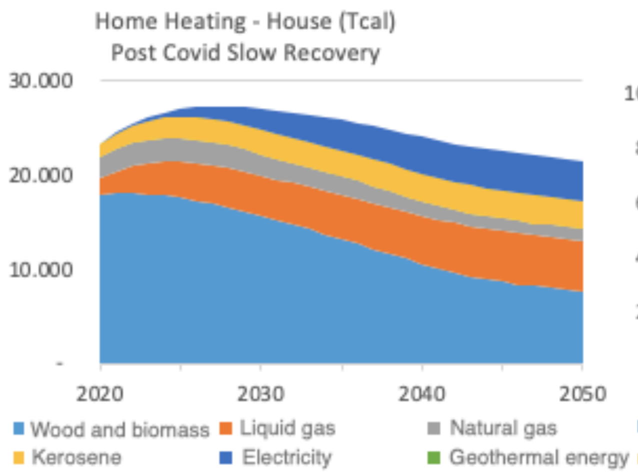
By 2050, as for energy sources, the scenario has reduced the demand for firewood and biomass by ~90% compared to 2020, but firewood continues to be an important part of the heating matrix with a 40% share. At the same time, the PCSR scenario to 2050 only reduces ~60% of firewood compared to 2020, and its heating demand increases by ~3000% compared to 2020.

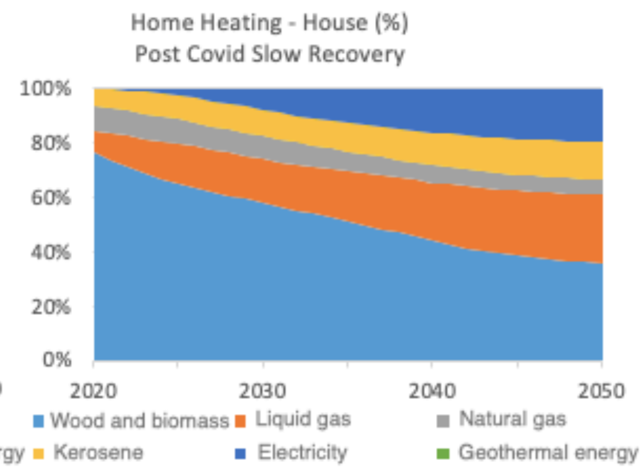
Heating Energy Demand to the year 2030 - Houses

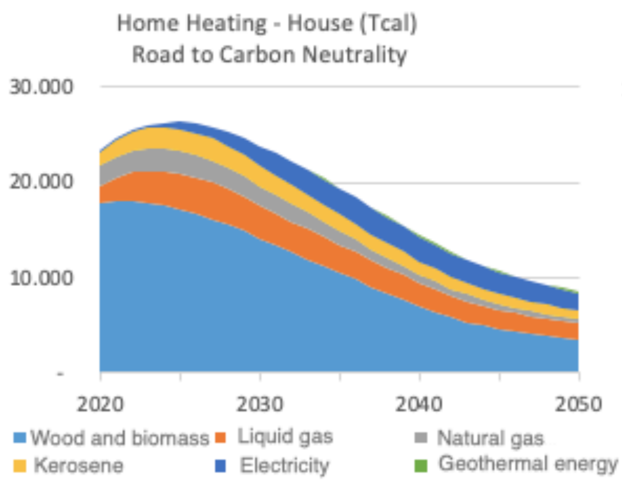
ENERGY TYPE	Energy demand (Tcal)			Share (%)			Variation (%) by 2030 w/r to 2020		
	PCSR	RCN	AET	PCSR	RCN	AET	PCSR	RCN	AET
Firewood and Biomass	15,534	14,064	13,001	58%	59%	59%	-13%	-21%	-27%
Liquid Gas	4,360	3,500	3,097	16%	15%	14%	141%	93%	71%
Natural Gas	2,282	2,033	1,888	8%	9%	9%	3%	-9%	-15%
Kerosene	2,583	2,092	1,854	10%	9%	8%	98%	61%	42%
Electricity	2,162	2,086	1,886	8%	9%	9%	1489%	1434%	1286%
Geothermal	0	57	264	0%	0%	1%	-	-	-
Total	26,920	23,833	21,988	**100%**	**100%**	**100%**			

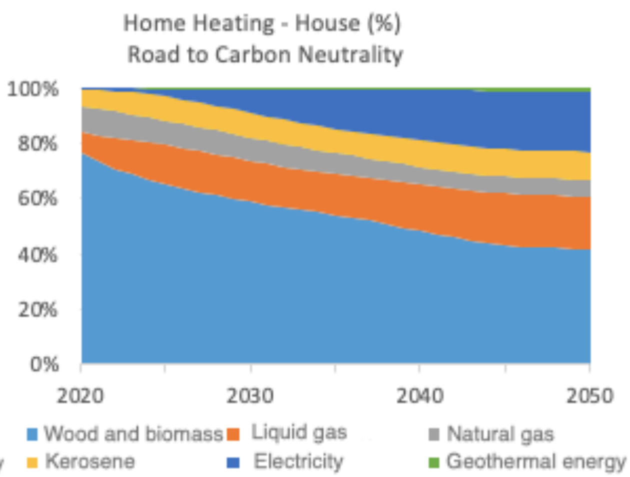
Heating Energy Demand to the year 2050 - Houses

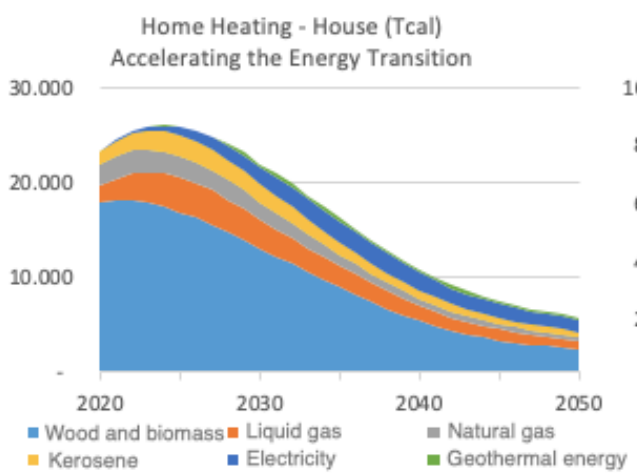
ENERGY TYPE	Energy demand (Tcal)			Share (%)			Variation (%) by 2050 w/r to 2020		
	PCSR	RCN	AET	PCSR	RCN	AET	PCSR	RCN	AET
Firewood and Biomass	7,628	3,528	2,295	36%	41%	40%	-57%	-80%	-87%
Liquid Gas	5,376	1,620	913	25%	19%	16%	197%	-11%	-50%
Natural Gas	1,221	531	432	6%	6%	8%	-45%	-76%	-81%
Kerosene	2,951	861	469	14%	10%	8%	127%	-34%	-64%
Electricity	4,195	1,873	1,262	20%	22%	22%	2983%	1276%	827%
Geothermal	0	109	341	0%	1%	6%	-	-	-
Total	**21,371**	**8,522**	**5,711**	**100%**	**100%**	**100%**			

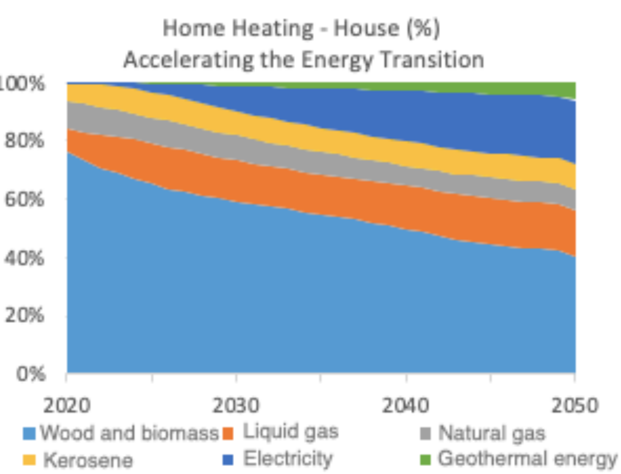

Home Heating - House (Tcal)
Post Covid Slow Recovery
30.000
20.000
10.000
-
2020
2030
2040
2050
Wood and biomass
Liquid gas
Natural gas
Kerosene
Electricity
Geothermal energy


Home Heating - House (%)
Post Covid Slow Recovery
100%
80%
60%
40%
20%
0%
2020
2030
2040
2050
Wood and biomass
Liquid gas
Natural gas
Kerosene
Electricity
Geothermal energy


Home Heating - House (Tcal)
Road to Carbon Neutrality
30.000
20.000
10.000
-
2020
2030
2040
2050
Wood and biomass
Liquid gas
Natural gas
Kerosene
Electricity
Geothermal energy


Home Heating - House (%)
Road to Carbon Neutrality
100%
80%
60%
40%
20%
0%
2020
2030
2040
2050
Wood and biomass
Liquid gas
Natural gas
Kerosene
Electricity
Geothermal energy

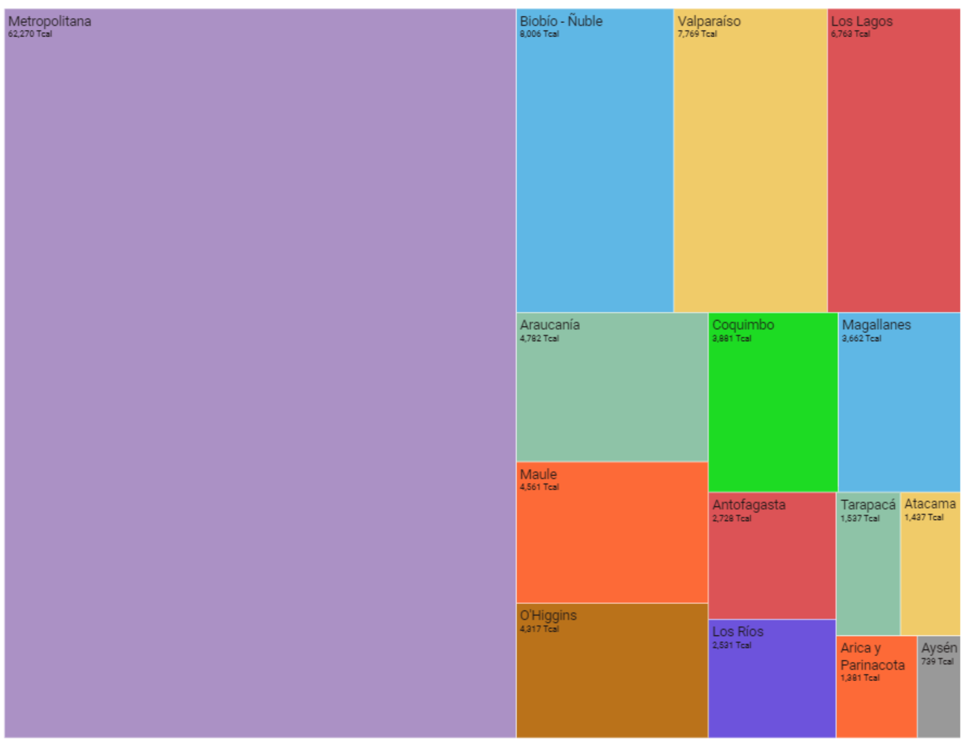

Home Heating - House (Tcal)
Accelerating the Energy Transition
30.000
20.000
10.000
-
2020
2030
2040
2050
Wood and biomass
Liquid gas
Natural gas
Kerosene
Electricity
Geothermal energy


Home Heating - House (%)
Accelerating the Energy Transition
100%
80%
60%
40%
20%
0%
2020
2030
2040
2050
Wood and biomass
Liquid gas
Natural gas
Kerosene
Electricity
Geothermal energy

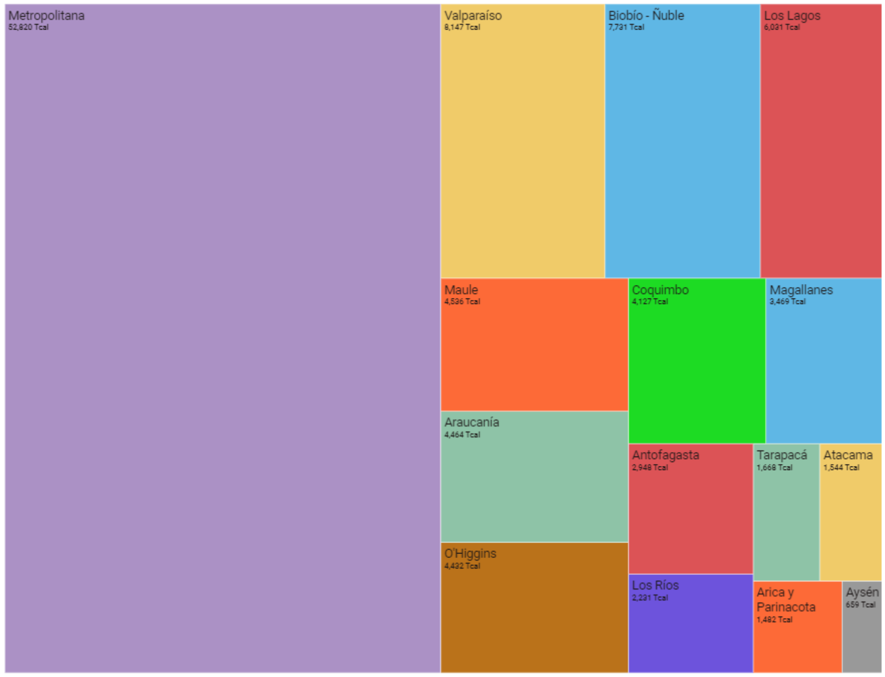
Regional distribution of the energy demand of the Commercial, Public and Residential sectors

The following figures show the final energy demands of the Commercial, Public and Residential sectors in 2050 for each energy scenario. Within this category, the share of the Metropolitan Region is largely dominant, explaining 54% of demand of these sectors in the Recovery scenario and up to 48% in the Accelerated Transition scenario. The shares of Valparaíso and Biobío-Ñuble regions are far behind, neither of which account for more than 8% of the energy needs at the sectorial level. Demand from the residential sector in particular explains about 44% of sectorial demand in each of the three regions.

Regional demand for the CPR sector by 2050. Recovery Sc.



Regional demand for the CPR sector by 2050. Road to Carbon Neutrality Sc.



Regional demand for the CPR sector by 2050. Accelerated Transition Sc.

4.5.5. Industrial – mining sector

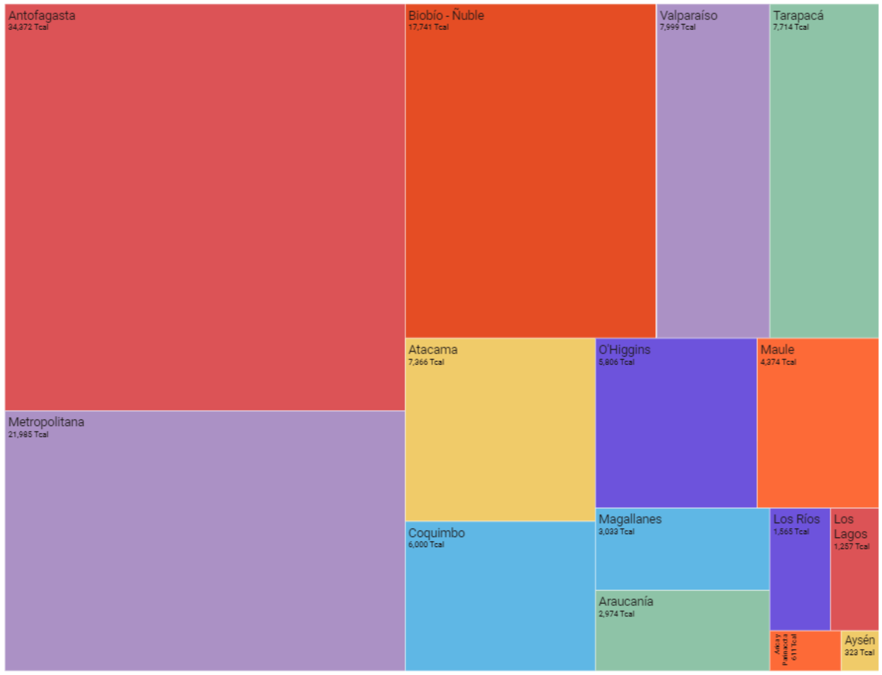
In the period from 2020 to 2050, industrial demand grows 17%, 11% and 10% in the Recovery, Carbon Neutrality and Accelerated Transition scenarios, respectively. Likewise, as the economic conditions between the scenarios increase, the direct and indirect consumption electrification increases.

Regional distribution of energy demand

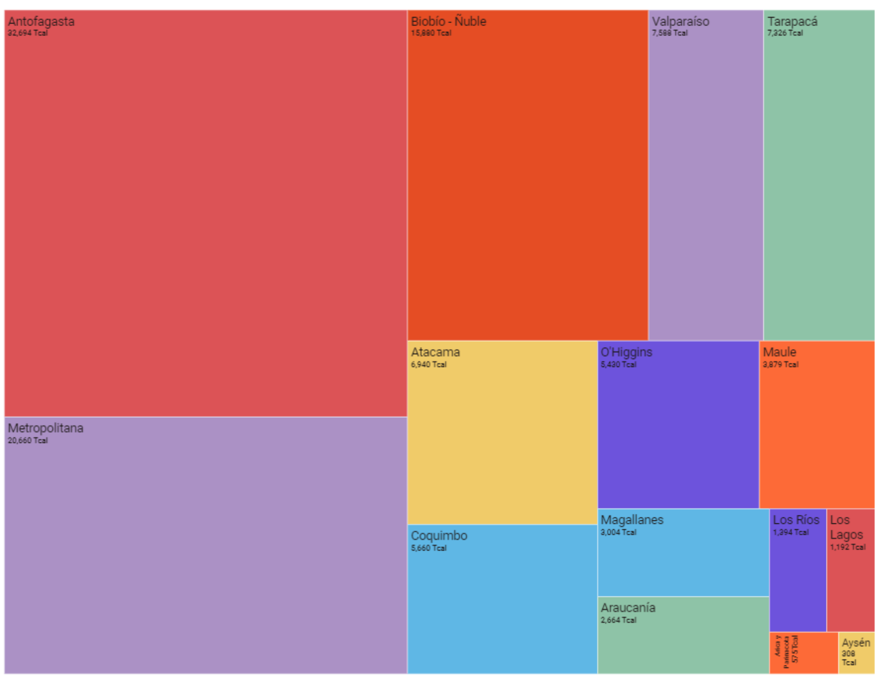
The following figures show the final energy demands in the year 2050 for each energy scenario. The Antofagasta, Metropolitan and Biobío-Ñuble regions concentrate practically 60% of the industrial and mining demand by the year 2050, without significant variations in their regional share between the three scenarios. Antofagasta's demand is mainly driven by mining, which accounts for 86% of said demand. While in the Metropolitan Region, 79% of demand comes from industry. Industrial energy demand in the combined Biobío-Ñuble regions is full and they do not have mining activity by 2050.

Regional demand of the Industrial and Mining sector by 2050. Recovery Sc.

Regional demand of the Industrial and Mining sector by 2050. Road to Carbon Neutrality Sc.



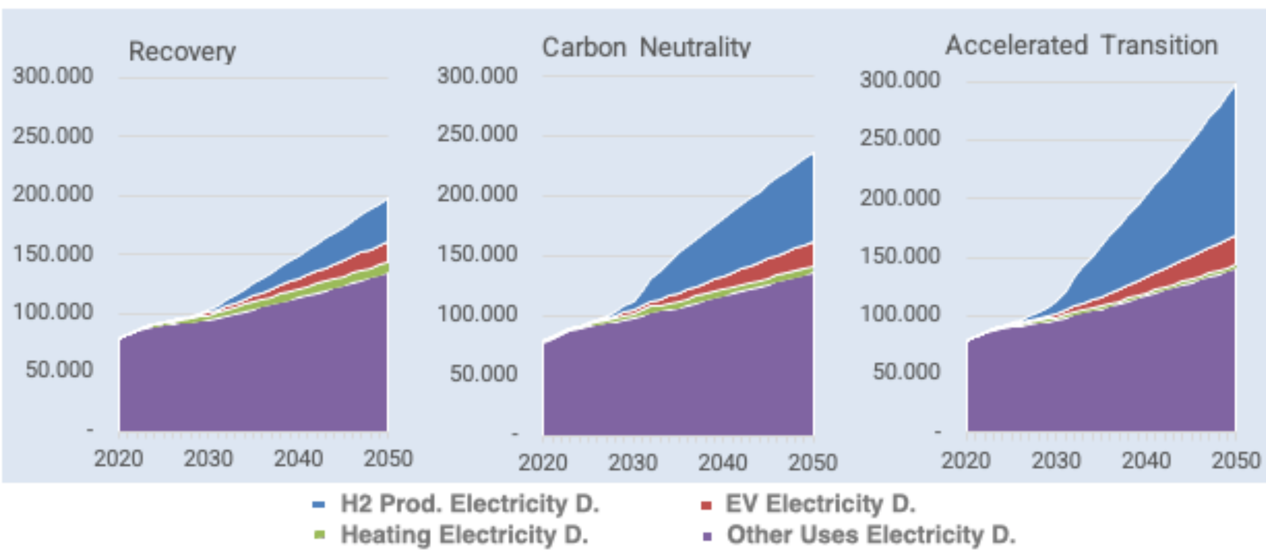
Regional demand of the Industrial and Mining sector by 2050. Accelerated Transition Sc.



4.5.6. Electricity demand for national uses

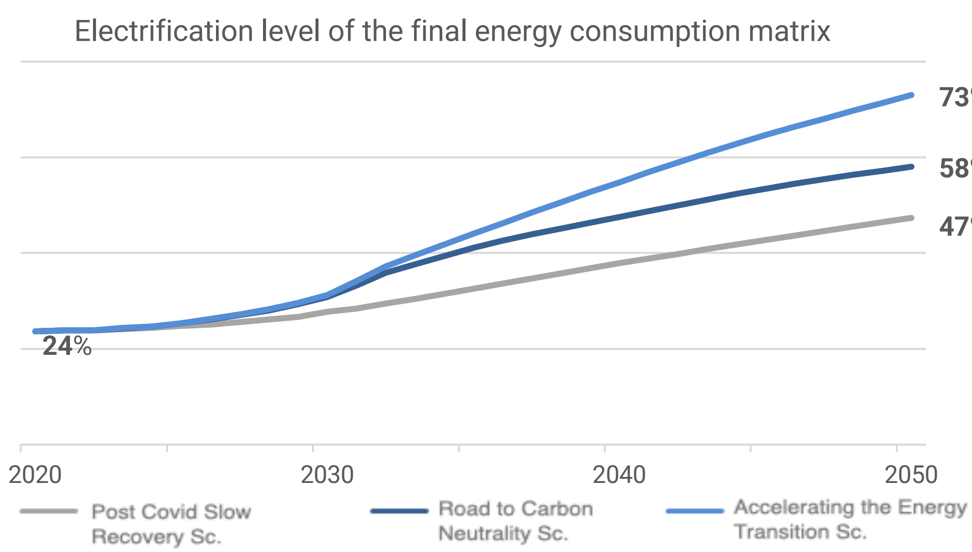
The demand for electricity becomes increasingly relevant throughout the period of time analyzed in each of the energy scenarios considered. The decarbonization of the electrical matrix, on the one hand, enables electricity as an important means of decarbonizing energy uses currently supplied through fossil fuels, while, on the other hand, the demand for electricity to produce green hydrogen for domestic consumption, both through fuel cell technology and through internal combustion engines, also has this important decarbonizing attribute.

The following table shows the magnitude of the final electricity demand according to the energy scenario, broken down into its electricity demand components for electromobility (electric land transport), electricity demand for residential heating uses, and electricity demand required for the production of green hydrogen destined to supply the national domestic consumption.



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

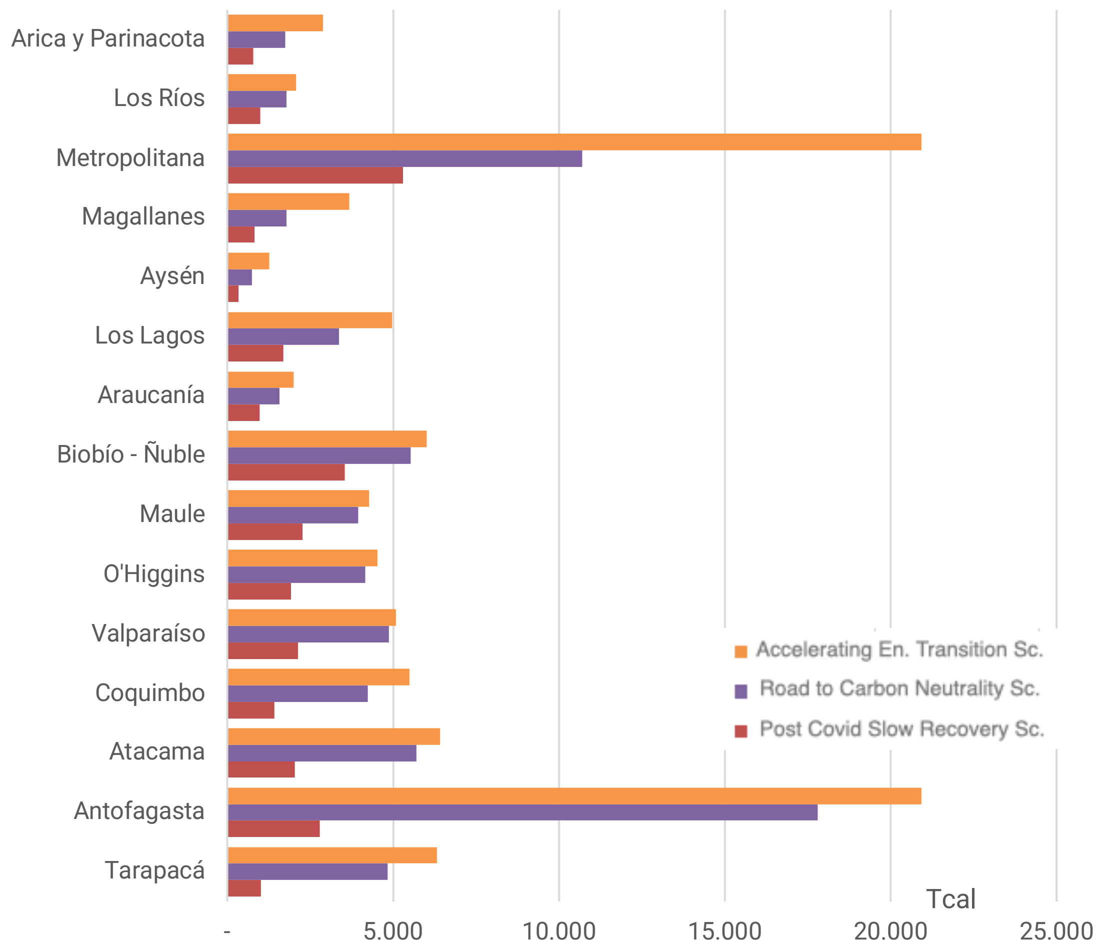
Electricity currently has a 24% share in the final energy matrix, which grows uninterruptedly throughout the analysis period, reaching between 47% and 73% of the matrix by 2050, depending on the energy scenario.



4.5.7. Hydrogen demand

As explained in the previous section, the national hydrogen demand has a significant impact on the growth of electricity demand throughout the period from 2020 to 2050 in each of the energy scenarios. The demand for electricity destined particularly for the production of green hydrogen, through electrolysis technology, for national consumption (but not for export) reaches between 19% and 43% of the total demand for electricity at the national level to the year 2050. Therefore, it is important to evaluate how the final hydrogen demand is distributed throughout the regions of the country, according to each energy scenario. For this, the representation of regional demand to the year 2050 has been determined in the following graph.

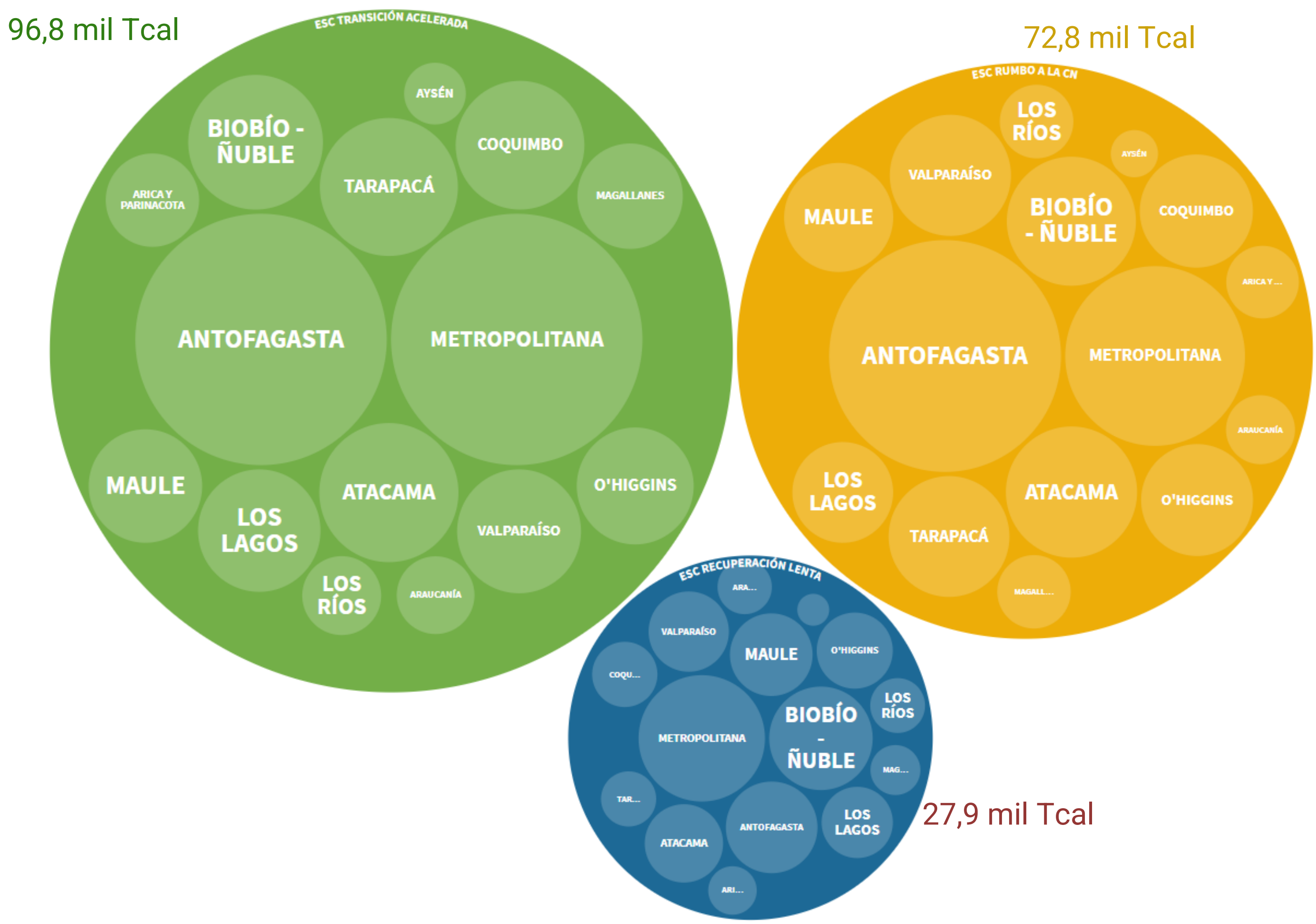
Final demand for green hydrogen by region and scenario to 2050



The Antofagasta and Metropolitan regions stand out with a greater share in the regional distribution of the final hydrogen demand, with Antofagasta representing between 10 and 24% of the national demand, depending on the energy scenario; while the Metropolitan region represents between 15% and 22% of the national demand for hydrogen depending on the energy scenario.

The final energy use of green hydrogen, depending on the scenario considered, has a share between 7 to 24% in the national energy matrix by 2050, where the land cargo transport (day cabs, and medium and light cargo transport) and mining motor uses two of the most important components of the final hydrogen demand, representing a 59% share for the first case, and between 24% and 33% for the second case, depending on the scenario.

Representation of the final demand for green hydrogen according to region and scenario to 2050



4.6. Greenhouse Gas Emission Projections

4.6.1. Global emissions

The technological transition to cleaner energies in all scenarios is reflected in a substantial drop in carbon dioxide equivalent (CO2eq) emissions. According to the construction of energy scenarios, this reduction is more pronounced in the Road to Carbon Neutrality scenario, which reduces its emissions by 56% by 2050 compared to 2018, and Accelerating the Energy Transition scenario, which reduces its emissions by 64% by 2050 compared to 2018[17].

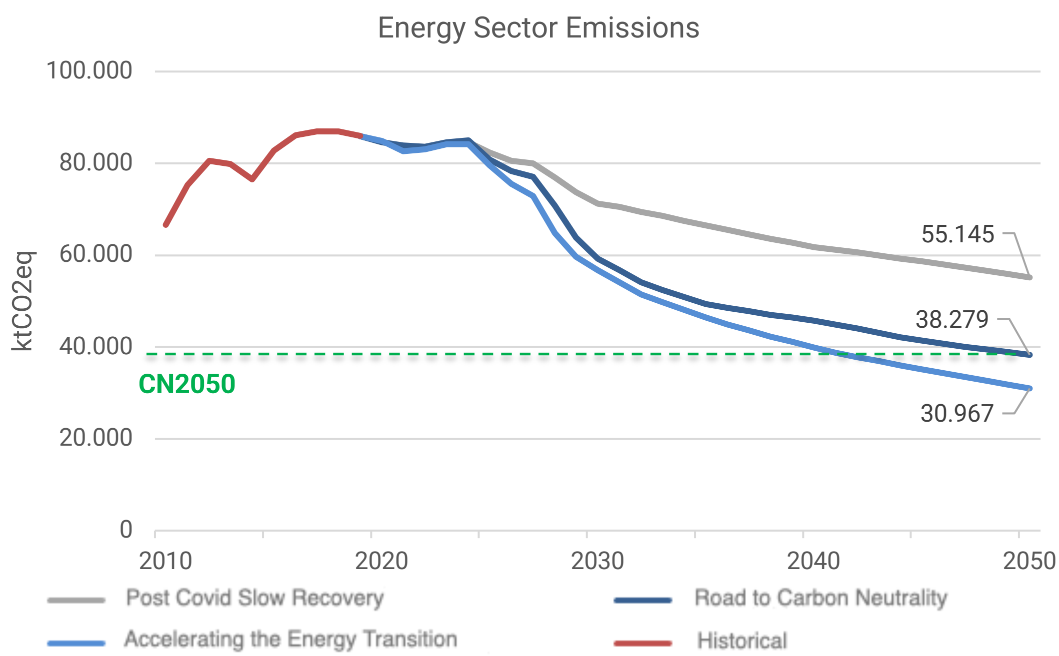
SCENARIO	Energy CO2eq Emissions			Reduction by 2030 w/r to 2018	Reduction by 2050 w/r to 2018
	2030	2040	2050		
Post Covid Slow Recovery	71,247	61,803	55,145	-18%	-37%
Road to Carbon Neutrality	59,275	45,751	38,279	-32%	-56%
Accelerating the Energy Transition	56,725	39,882	30,967	-35%	-64%

All scenarios reach a peak of emissions in the energy sector by 2024, which is in line with the goal of the updated Nationally Determined Contribution (NDC) of Chile (April 2021) of reaching a peak of national CO2eq emissions to the year 2025.

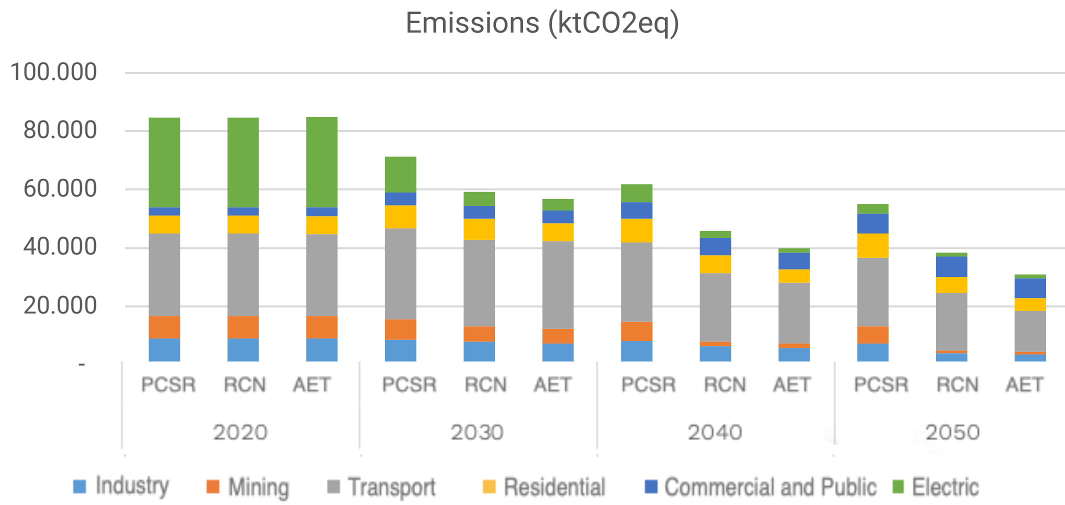
Regarding the goal of carbon neutrality by 2050[18], in the last inventory of greenhouse gases (INGEI) of the year 2018, absorptions or captures of the LULUCF[19] sector were reached for -63,992 ktCO2eq, while the emissions of the non-energy sectors[20] amounted to 25,358. That is, to achieve the goal of carbon neutrality by the year 2050 (CN2050), the energy sector should have a maximum emissions of 38,634 ktCO2eq in 2050, taking into account the values

[17] According to the latest inventory of greenhouse gases (INGEI), the energy sector reached 86,954 ktCO2eq in 2018. Ministry of the Environment, 2021.
[18] The Framework Law on Climate Change defines the neutrality of greenhouse gas (GHG) emissions as the state of balance between anthropogenic GHG emissions and absorptions in a specific period, considering that emissions are equal to or less than the absorptions.
[19] LULUCF: Land Use, Land-Use Change and Forestry.
[20] Non-energy sectors: industrial processes and product use (IPPU), agriculture and waste.

just mentioned. Hence, the Road to Carbon Neutrality scenario meets said goal in the year 2050, while the Accelerating the Energy Transition scenario would fulfill it by the year 2042.



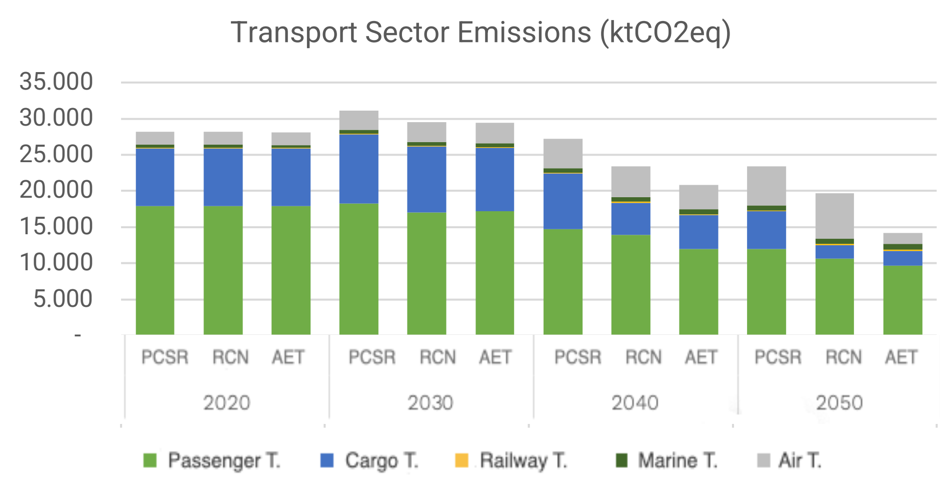
Large GHG reductions are seen in some economic sectors. In particular, the electricity sector almost manages to neutralize its emissions by 2050, reaching a reduction of 96% by 2050 with respect to the last national greenhouse gas inventory of 2018 (INGEI), which occurs largely due to the phase-out of coal-fired power plants by 2040. Due to the electrification of its consumption and the use of green hydrogen in most of its energy demand, the mining sector is able to reduce its emissions by as much as 90% by 2050 in some scenarios. The industry and transport sectors are close behind, both able to reduce emissions by ~50% by 2050 compared to 2018. In the residential sector, the only scenario that manages to reduce emissions by 2050 compared to 2018 is the Accelerating the Energy Transition (AET) with a modest 6% reduction. The commercial and public sectors increased their emissions by just over 100% in all scenarios, which was to be expected, since, as mentioned in previous chapters, they are the sectors with the least number and penetration of energy efficiency and GHG emission mitigation measures.



Percentage variation of GHG emissions with respect to INGEI 2018 by economic sector									
ECONOMIC SECTOR	2030			2040			2050		
	PCSR	RCN	AET	PCSR	RCN	AET	PCSR	RCN	AET
Industry	12%	1%	-6%	5%	-18%	-25%	-6%	-49%	-54%
Mining	-12%	-33%	-37%	-17%	-80%	-81%	-26%	-89%	-90%
Transport	9%	3%	5%	-5%	-18%	-27%	-18%	-31%	-50%
Residential	72%	58%	32%	75%	34%	-4%	82%	23%	-6%
Commercial and Public	32%	31%	32%	74%	75%	73%	103%	108%	104%
Electricity	-64%	-85%	-89%	-82%	-93%	-95%	-90%	-96%	-96%

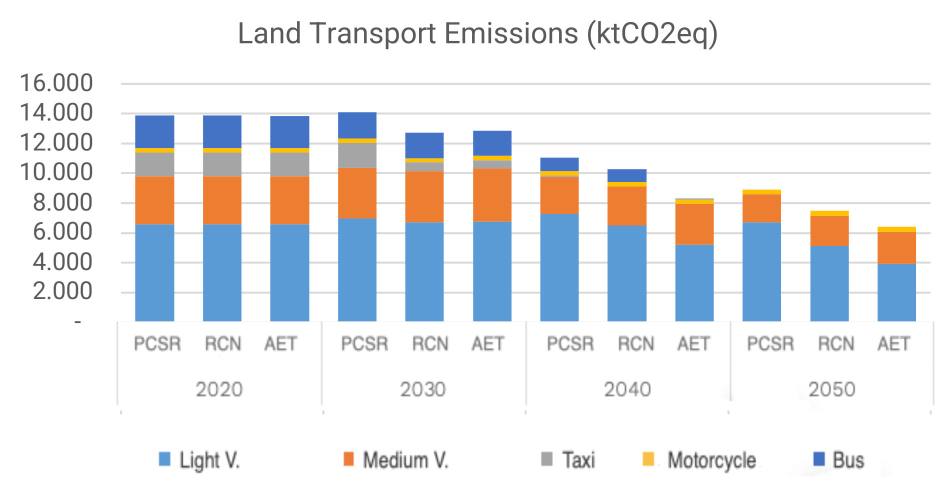
4.6.2. Sectorial emissions

The Accelerated Transition scenario achieves a halving of transport emissions by 2050. Only the Accelerated Transition scenario manages to decarbonize air transport.

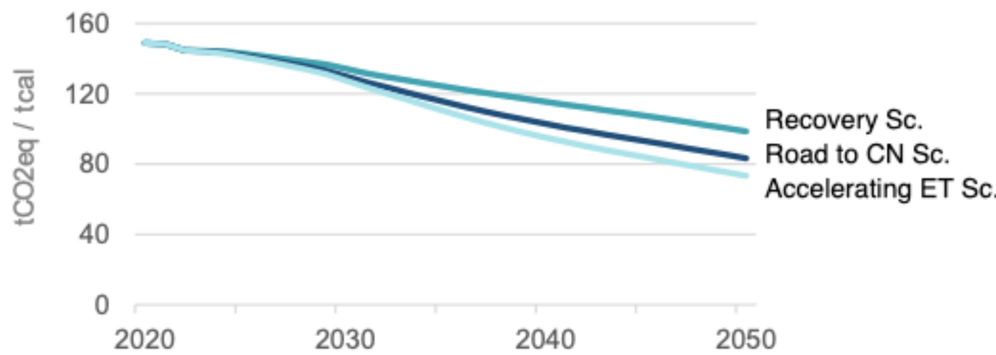


Land and passenger transport

From 2040, public transport and taxis seek to neutralize their CO2-equivalent emissions. The largest reduction in vehicle emissions occurs in the Accelerated Transition scenario. Compared to 2020, the PCSR scenario reduces emissions from land transport by ~35% by 2050, the RCN scenario by ~45% by 2050, and the AET scenario by ~55% by 2050.



Industrial and mining energy consumption manages to reduce its greenhouse gas emissions factor between 34% and 54%, depending on the scenario.



4.6.3. Carbon budgets

The Framework Law on Climate Change (PdLMCC) currently in Congress (Bulletin 13,919-2) establishes that the Long-Term Climate Strategy (LTCS) will contain both a national budget[21] for GHG emissions and sectorial[22] GHG budgets. The national GHG budget was determined and published in the update of the NDC in April 2020, establishing as a goal not to exceed 1,100 million tCO2eq at the national level for the period from 2020 to 2030. Meanwhile, the LTCS conducted a public consultation in July 2021 specifying the scope of sectorial GHG budgets that would be allocated to the different sectorial Ministries set up in the PdLMCC.

For the above reasons, the energy sector and other sectorial ministries (especially mining, transport and housing) are interested in evaluating emission projections for different economic sectors. Cumulative projected emissions for the period from 2020 to 2030, according to different economic sectors, are shown below.

[21] According to the PdLMCC, the national GHG emissions budget is understood as the maximum amount of GHG emissions accumulated at the national level in a given period and which it represents.
[22] According to the PdLMCC, the sectorial budget for GHG emissions is understood as the maximum amount of GHG emissions accumulated at the sector level in a given period and which represents the sum of the total emissions of said gases in each year included in the respective period, as determined by the ECLP.

Emissions of the Period 2020-2030 (ktCO2eq)			
Economic Sector	**Post Covid Recovery**	**Road to Carbon Neutrality**	**Accelerating the Energy Transition**
Industry	102,144	99,207	96,270
Mining	86,642	80,310	78,822
Transport	336,579	332,919	335,754
Residential	81,673	79,269	74,370
Commercial and Public	40,585	40,519	40,491
Electricity	237,703	219,747	202,436
Total	**885,327**	**851,971**	**828,143**

5. Electric Sector

The future of the electrical grid

5.1. Territorial considerations

The challenges facing energy development in the territories, hand in hand with the great potential for renewable energy that we have as a country, the phase-out of coal-fired power plants, the opportunities for new technological developments, the need for energy infrastructure, compatibility with other uses and local interests and environmental protection, among others, lead us to increasingly consider the sensitivities, potentialities, and opportunities of the territory on the path to sustainable development.

Since 2014, the Ministry of Energy has been incorporating territorial considerations in energy development, which was formalized –in the first place– through the National Energy Policy (2015) and later in Law 20,936 that establishes a New Electric Transmission System and creates an Independent System Operator of the National Electric System (2016), which led to several lines of work on the matter that are maintained and perfected to this day.

In the current PELP 2023-2027 process, the challenge of strengthening and deepening this line of work has been raised, in order to contribute to having more sustainable and balanced results in its territorial deployment, which has been reinforced by the results of the participatory spaces of the process that expressed the relevance of this matter.

Transversely to the planning process, work has been done to sensitize the PELP modeling territorially through the consideration of what we call *Environmental*[23] *and Territorial*[24] *Variables* within the framework of the identification of power generation potentials from renewable sources that serve as input for said modeling:

[23] An environmental variable should be understood as the element of the environment in its different dimensions, natural or artificial, which is subject to probable or frequent changes, derived from the activities and/or power generation projects likely to generate effects on the base condition.

[24] Territorial variables should be understood as variables that have been identified in territorial order, planning or management tools and that influence or regulate the location of power generation.

- On the one hand, those variables that affect the use of renewable resources, called **technical factors**, such as altitude, slope of the land, wind speed, radiation, etc. have been considered, applying the minimum continuous area standard and estimated plant factor for each technology, that set up the technical generation potential.

Source		**Wind**	**Solar photovoltaic**	**Solar CSP**	**Hydropower**	**Geothermal**
Technical Factors	DNI (Direct Normal Irradiation)	-	-	-	-	-
	Slope	> 15°	> 10° North orientation and > 4° for the rest of the orientations	> 7°	-	-
	Altitude	> 3,000 masl for the entire country	> 4,000 masl for the entire country	-	-	-
	Cloud cover percentage	-	-	< 20%	-	-
	Percentage of hours with wind speed greater than 15 m/s at 5.5 m height	-	-	< 0,5%	-	-
	OPC Project Areas	Presence exclusion zones	Presence exclusion zones	Presence exclusion zones	-	-
	Distributor Bidding Project Areas	-	-		-	-
	National Assets for Energy Purposes	-	-		-	-
	Taltal Reserve Area	-	-		-	-
	Wind Potential 2021	-	-		-	-
Standards	Plant factor	< 30%	< 21%	-	< 50%	-
	Continuous minimum area	112 ha between Arica and Coquimbo; 168 ha between Valparaíso and Magallanes (equivalent to 5.6 MW)	12 ha (equivalent to 3 MW)	700 ha (equivalent to 100 MW)	3MW minimum	Not applicable

- On the other hand, those variables that affect the development of energy generation have been identified, evaluating them according to a **legal-normative criterion** regarding their impact, and degree of conditioning established in the current legal system, and to a **development criterion** of the project regarding its impact on the processing and deadlines for execution of the projects. When the analyzed variables are valued according to the above criteria, they are called Territorial Valuation Objects (OdVT); where, for this process, those who have a *high* impact or conditioning for the development of such projects are selected.

In the consideration of the territorial valuation objects (OdVT) of *high* impact or conditioning to the development of energy generation projects based on renewable sources, in accordance with the planning decisions that have been made in the process, they have been exposed to different treatments:

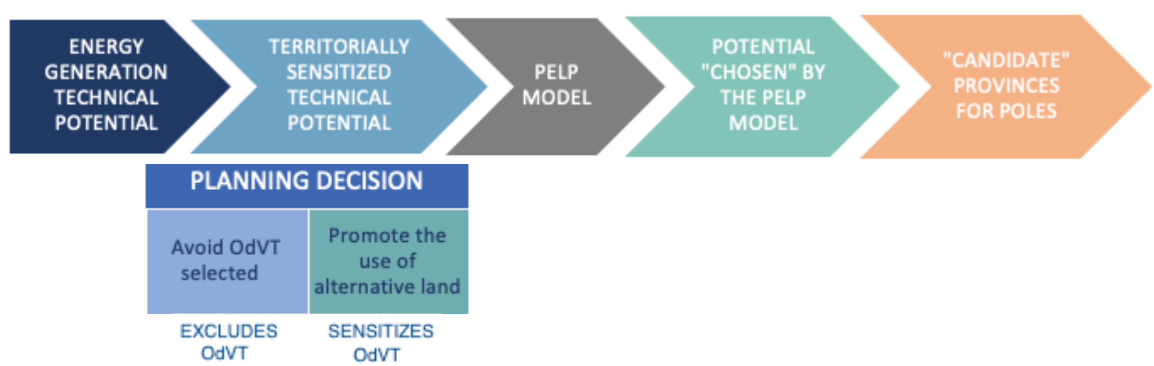
- **OdVT not considered:** Two valued variables were identified that could not be incorporated due to technical limitations, as is the case of the Virgin Region Reserve, for which there is currently none decreed, and Archaeological Sites, for which there is no official information available at the national level. In the last case, this variable will be reinstated in the planning of the Electric Power Generation Development Poles as long as official information is available.

- **OdVT excluded:** Set of 22 valued variables that, although they do not constitute a limitation, determine the convenience of avoiding them, so they are excluded from the power generation potential based on renewable sources entering the modeling process. Variables such as National Parks, Monuments and Sites of Cultural Significance, among others, are included in this framework.

- **Sensitized OdVT:** Set of 5 valued variables with respect to which it is determined to promote the use of alternative land through an additional cost of 10% and 20% -depending on the percentage of the land that is affected by these variables- to its development that is applied to the potential generation of energy from renewable sources within the framework of the modeling process, in order to make alternative soils more competitive. In this framework, variables such as Indigenous Lands with recognized rights (Law No. 19,253) and Zones of Touristic

Interest (ZTI) are counted only for wind potential to collect the landscape variable, among others.

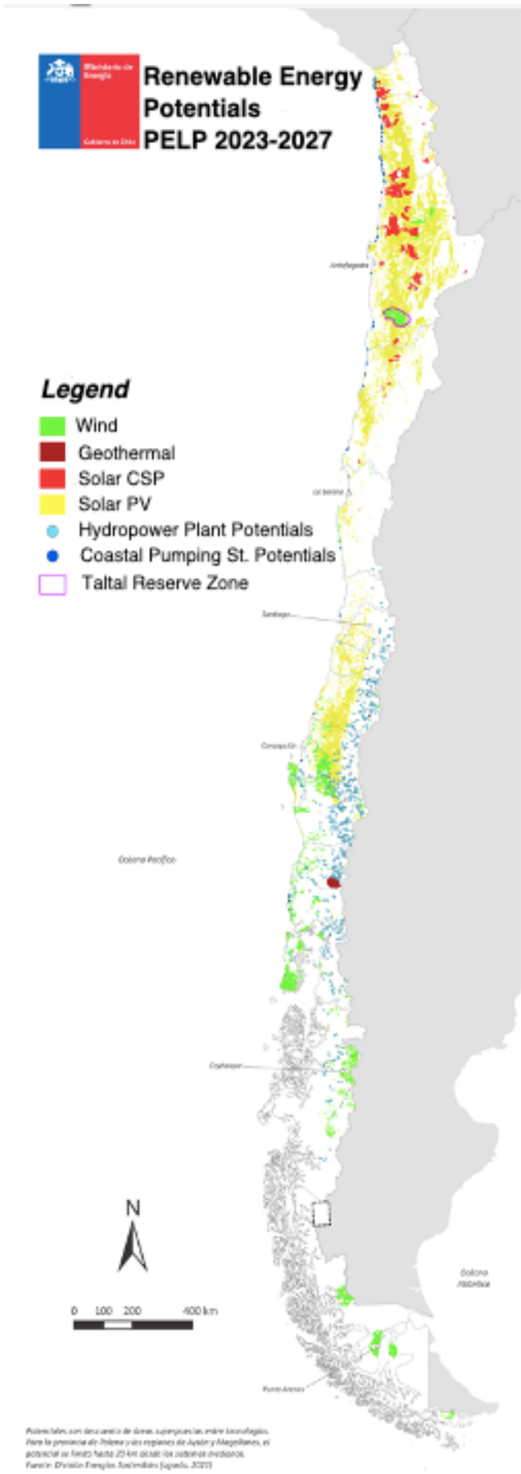
Valuation Criteria	Methodological treatment		
	Not considered	**Excluded**	**Sensitized**
Normative	1. Virgin Region Reserve 2. Archaeological Site	1. National Parks (except in Geothermal) 2. Natural Monuments (except in Hydro) 3. Ramsar Sites (except in Geothermal) 4. Historical Monument 5. World Heritage Site 6. Typical Zone 7. Marine Coastal Spaces for Indigenous Peoples (ECMPOs)	1. Indigenous lands with recognized rights: Law No. 19,253 2. Paleontological site (Paleontological Fossiliferous Potentiality)
Development		8. National Reserves (except in Hydro) 9. Forest Reserves (except in Hydro) 10. Native Forest (species with conservation problems)[25] 11. Sites of cultural significance 12. Soil classes I, II and III (CSP) *Only for Wind, PV and CSP potential* 13. Salt Flats (300m) 14. Inventory of Water Bodies (300m) 15. Glacier Inventory (300m) 16. Active Volcanoes 17. Urban Limits and Consolidated Urban Areas (1000m) 18. Inventory of Anthropized Water Bodies (300m) 19. Inventory of Rivers/Hydrographic System (300m) 20. Road System (60m) 21. Coastline (100m) 22. Mining Tailings	3. Indigenous Development Area 4. Zones of Touristic Interest (ZTI) (Wind) 5. Soil classes I, II and III (PV)



[25] Species with conservation problems identified in the official lists of the MoE: Endangered, Critically Endangered and Vulnerable.

Renewable Potential
Vertical Version
PELP 2023-2027

Renewable Potential
Horizontal Version
PELP 2023-2027



In this way, the PELP results for all defined scenarios will have this territorial awareness and, hence, candidates for Electric Power Generation Development Poles will also take these considerations into account.

5.2. Renewable potential

The map contains the renewable technical potential for all the regions of the country that have been considered on this occasion, which is reviewed from the environmental and territorial variables before entering the electrical optimization model as candidates.

In order not to consider more than one energy use per territory, the potential considers discounting the overlapping areas between technologies and considers the following priorities:

1. Wind.
2. Geothermal energy.
3. Solar CSP.
4. Solar PV.

For the province of Palena and the regions of Aysén del General Carlos Ibáñez del Campo and Magallanes, and the Chilean Antarctic Territory, the potential is limited to 20 km, measured from the transmission or distribution systems in the respective medium systems. In this way, this development of renewable potential at the national level will allow energy planning analyzes to be extended to regions in which the National Electric System is not located.

Solar CSP Analysis
PELP 2023-2027

Regarding the potential of Solar CSP potential, an analysis[26] was conducted this time to optimize the best territories to locate projects based on three configurations: CSP with 6 hours of storage, CSP with 9 hours of storage and CSP with 13 hours of storage.

Finally, the total potential for energy planning purposes is summarized in the following table:

Technology	Potential (GW)
Solar PV	2,086
Wind	81
Solar CSP	152
Geothermal Energy	4
Hydropower	10
Pumped Hydro Storage	42
Total	**2,375**

[26] The collaboration of the Fraunhofer Chile Research teams, and CORFO, represented at that time by the Solar and Energy Innovation Committee, is appreciated for the support in the potential definition analysis for Solar CSP technology in its different configurations.

Cost projections, LCOE and LCOS
PELP 2023-2027

5.3. Investment costs of generation technologies

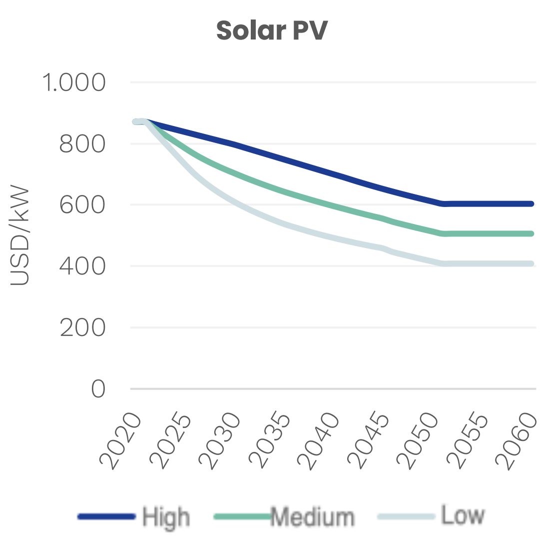
This section presents the investment cost projections for generation technologies. The main sources of information are:

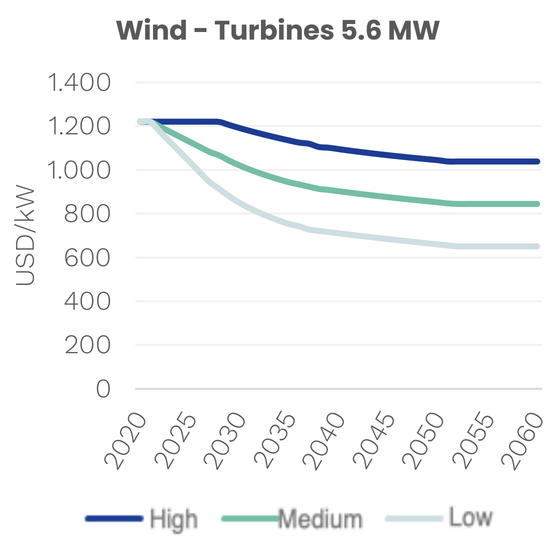
1. Generation Technologies Cost Report, National Energy Commission. To adjust the starting point of the costs.

2. For cost projections, sources such as BloombergNEF, NREL Annual Technology Baseline[27] and the Annual Energy Outlook of IEA[28] are used.

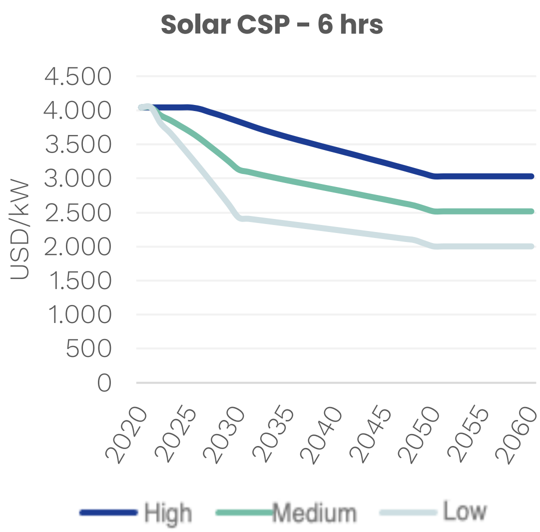
3. Geothermal technology costs come from the Geothermal Table held during the years 2017 and 2018.

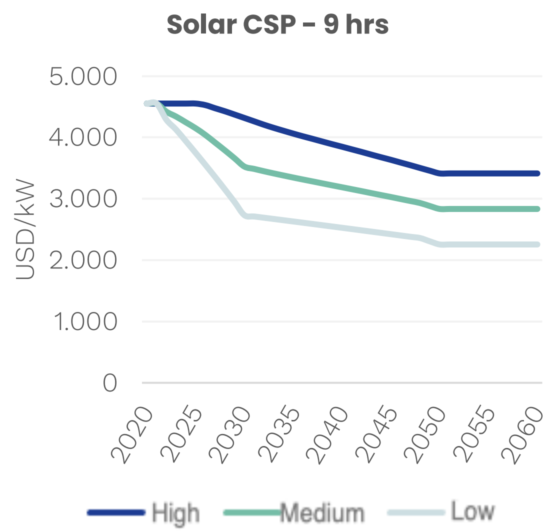
In addition, a cost breakdown analysis was carried out this time, identifying what is related to technological maturation itself, as well as components related to other items such as land, construction and start-up within the national territory.

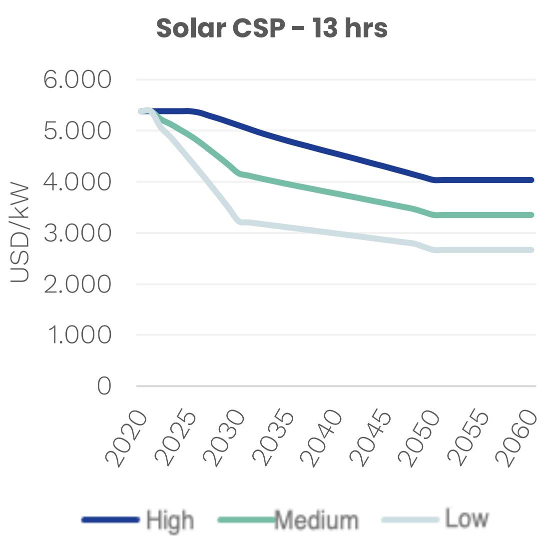


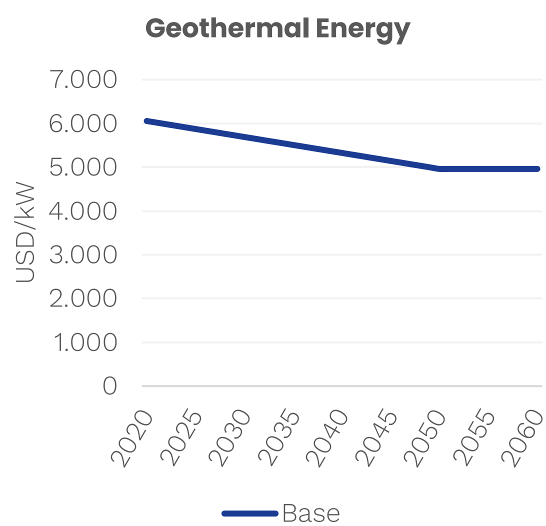


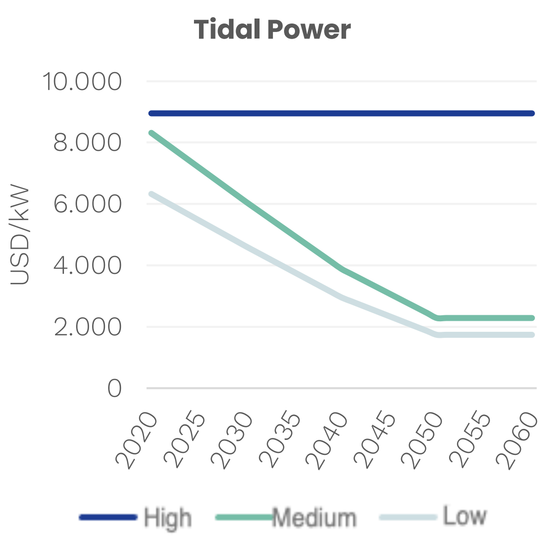
[27] NREL: National Renewable Energy Laboratory.
[28] IEA: International Energy Agency.

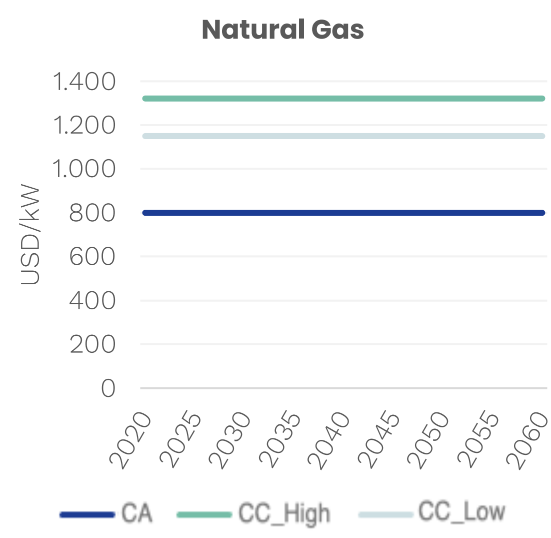

Solar CSP - 6 hrs
USD/kW
4.500
4.000
3.500
3.000
2.500
2.000
1.500
1.000
500
0
2020 2025 2030 2035 2040 2045 2050 2055 2060
High
Medium
Low


Solar CSP - 9 hrs
USD/kW
5.000
4.000
3.000
2.000
1.000
0
2020 2025 2030 2035 2040 2045 2050 2055 2060
High
Medium
Low


Solar CSP - 13 hrs
USD/kW
6.000
5.000
4.000
3.000
2.000
1.000
0
2020 2025 2030 2035 2040 2045 2050 2055 2060
High
Medium
Low


Geothermal Energy
USD/kW
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0
2020 2025 2030 2035 2040 2045 2050 2055 2060
Base

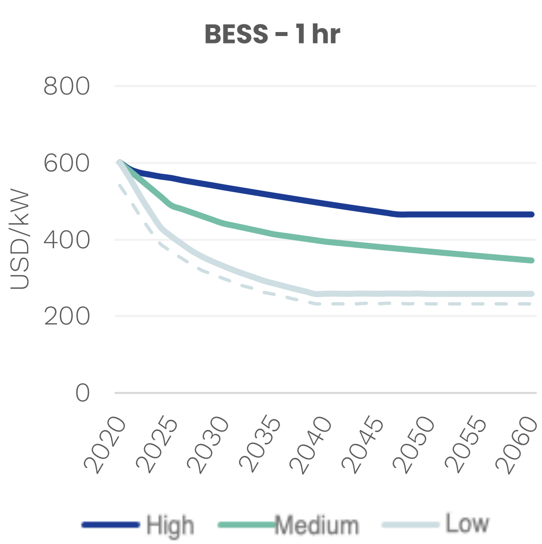


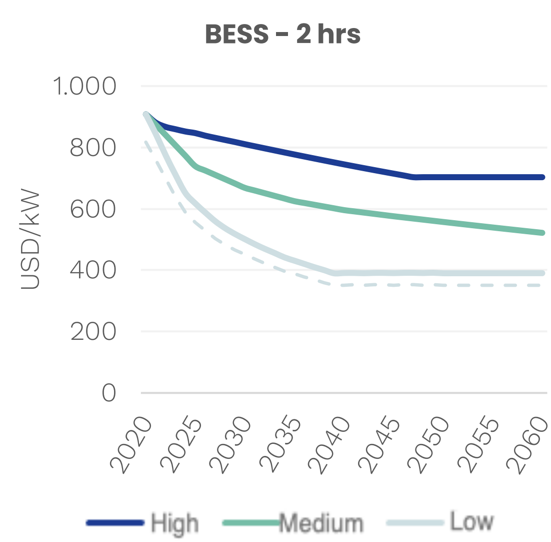


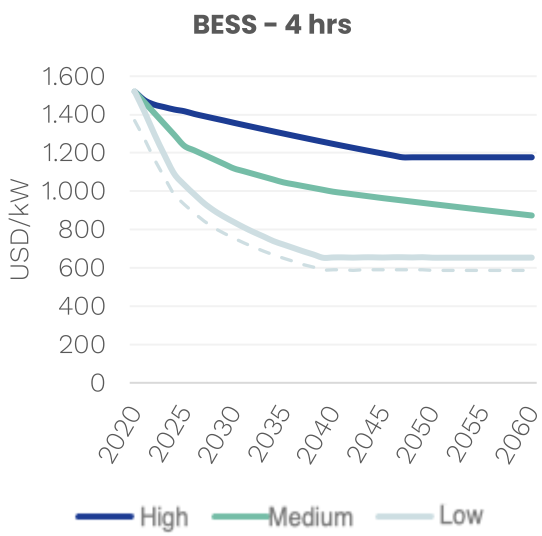
Cost projections, LCOE and LCOS
PELP 2023-2027

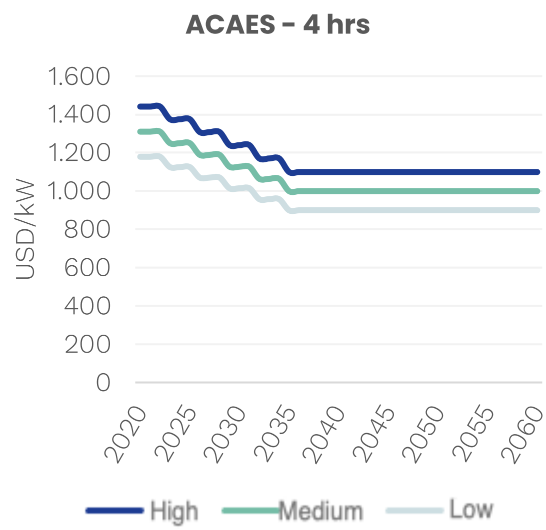
5.4. Investment costs of storage technologies

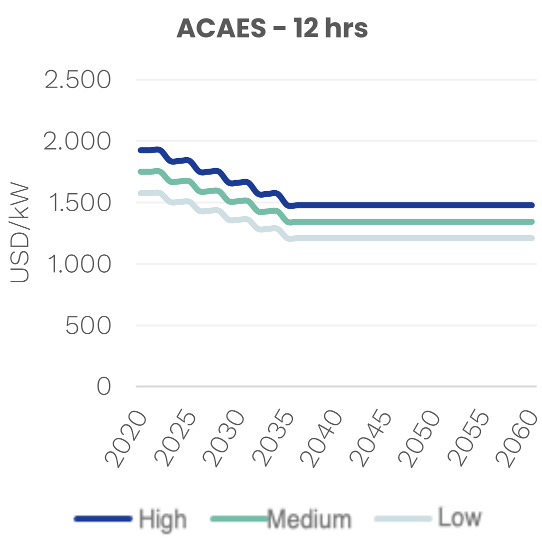
This section presents cost projections for storage technologies. The main source is BloombergNEF.

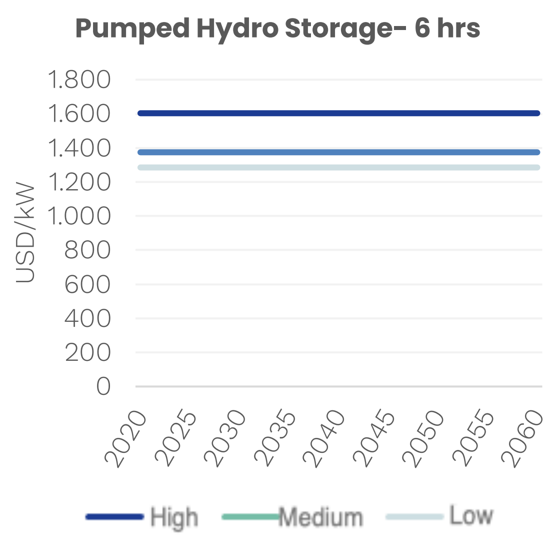




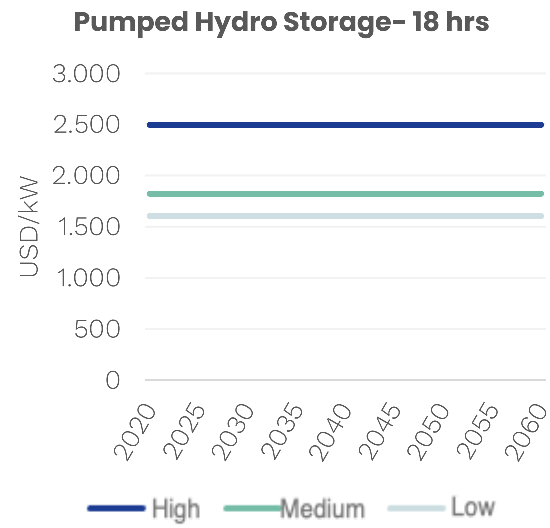






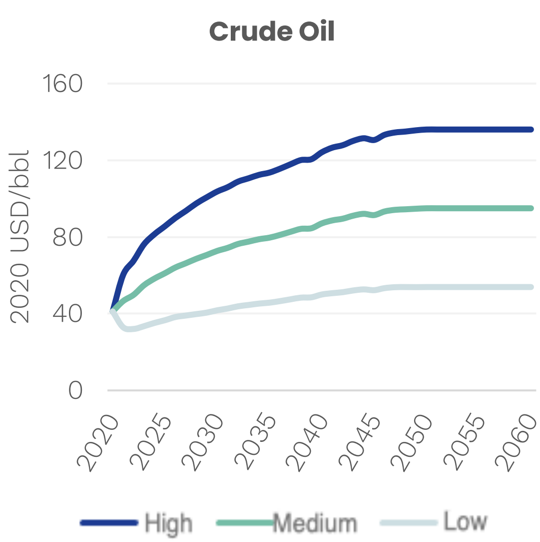


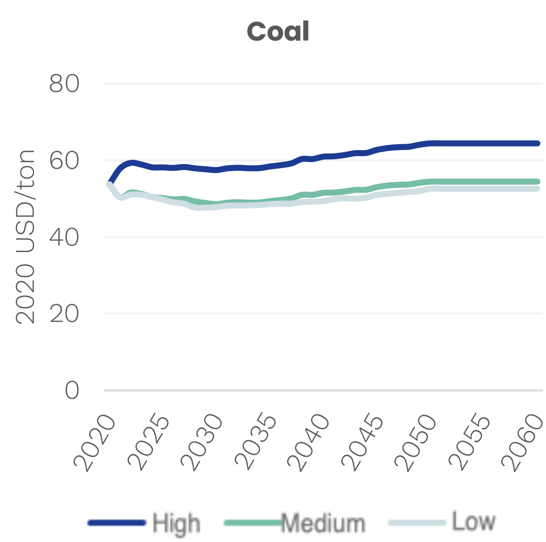
The dotted line in the cost of BESS battery technology represents a low trend, given the typical economies of scale of hybrid Solar PV + BESS, Wind + BESS, or similar solutions. Efficiency improvements and the shared use of transformers, lines, and power converters reduce overall costs by about 10%.



5.5. Fossil fuel prices

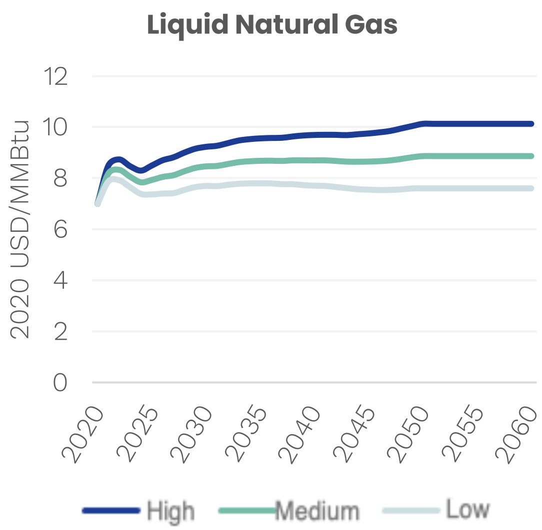
This section presents the projections of fossil fuel prices. The main source of information is the Annual Energy Outlook 2021 of the U.S. Energy Information Administration.

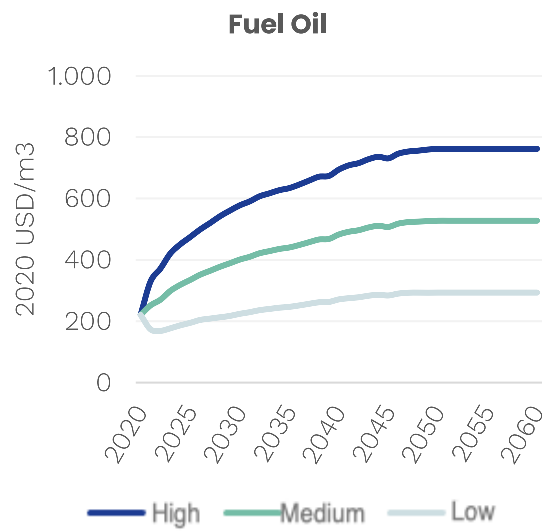


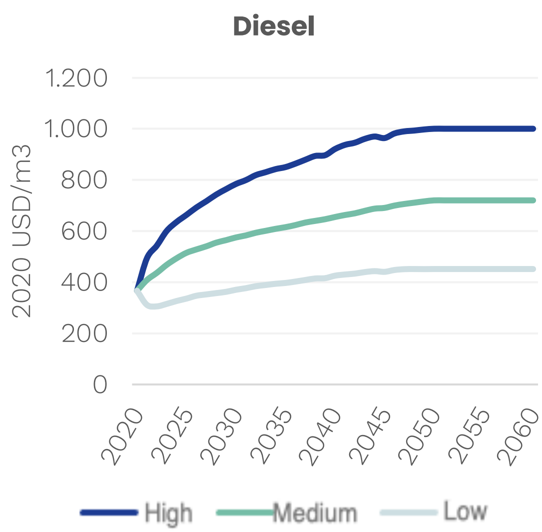


Ministerio de Energía
Gobierno de Chile

PELP
PLANIFICACIÓN ENERGÉTICA DE LARGO PLAZO





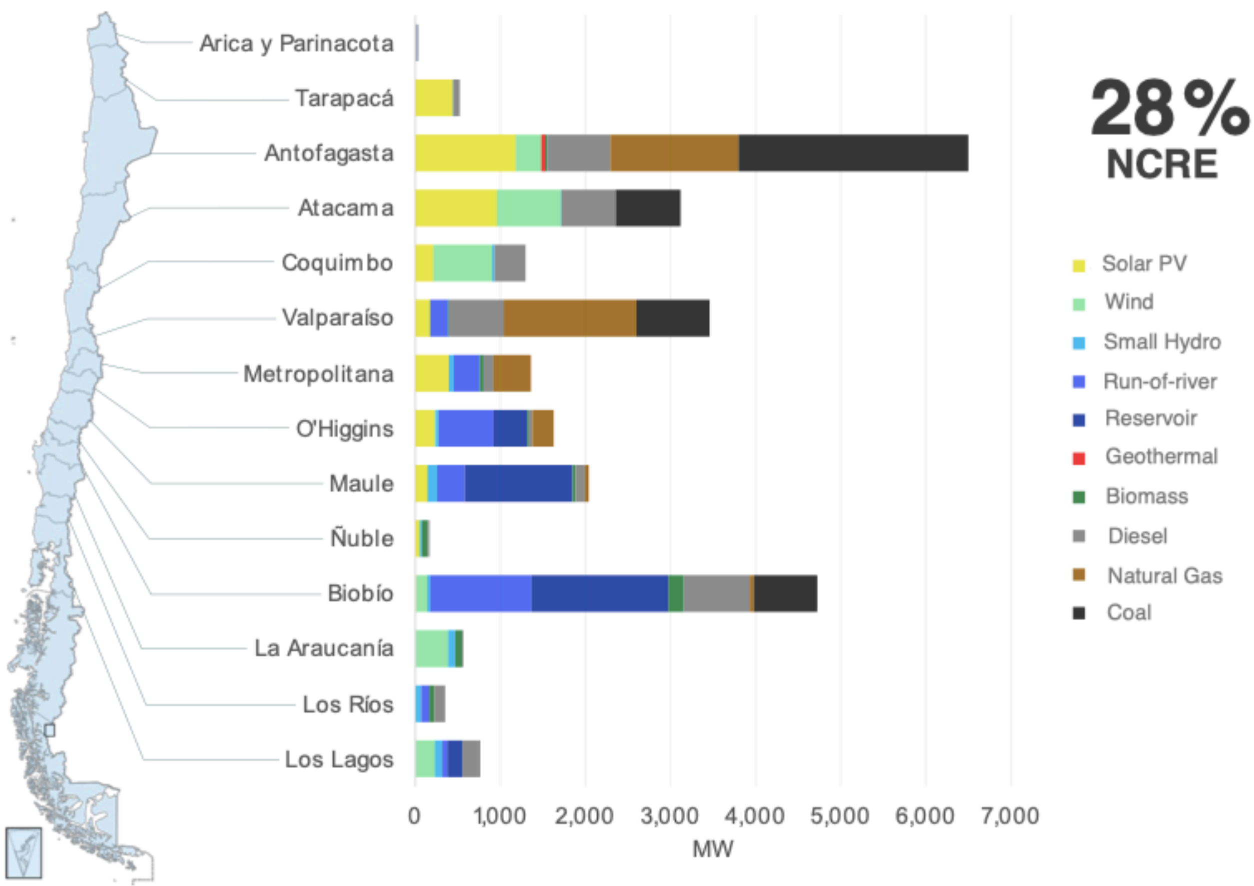


5.6. Current generation in the National Electric System

The current power generating units of the National Electric System are made up of 28% Non-Conventional Renewable Energies, with a total installed capacity of 26,506 MW.

A scheme is presented that summarizes the territorial location of different current generation technologies in the National Electric System.

Current arrangement of power generating plants of the National Electric System

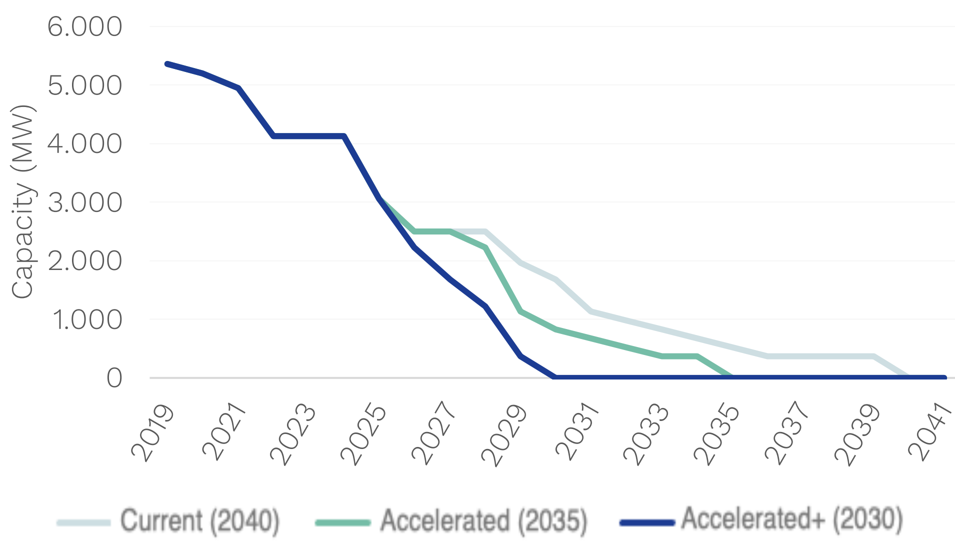


5.7. Paths for Exiting Coal-Fired Power Plants

Three coal-fired power plant exiting paths have been established for the purpose of evaluating the new energy scenarios of the PELP 2023-2027. The new announcement on phasing-out coal-fired power plants shows signs of gradual progress in the exit of coal from the electricity matrix. This, added to a massive integration of renewable energies on a large scale and at a distributed level, an efficient and timely expansion and adaptation of transmission systems and an accelerated technological adaptation and implementation, will allow the total exit of coal to be introduced more and more with respect to the deadline indicated in the Coal Phasing-Out Agreement, held between the Government of Chile and the companies that own coal-fired power plants in June 2019.

In this opportunity, the Recovery scenario considers a total coal exit by the year 2040, the Carbon Neutrality scenario considers the total exit by the year 2035 and the Accelerated Transition scenario considers the total exit by the year 2030, all with a pronounced exit during this decade.

Coal exit enables the direct and indirect consumption electrification, a key piece to achieve the goal of carbon neutrality before the year 2050.

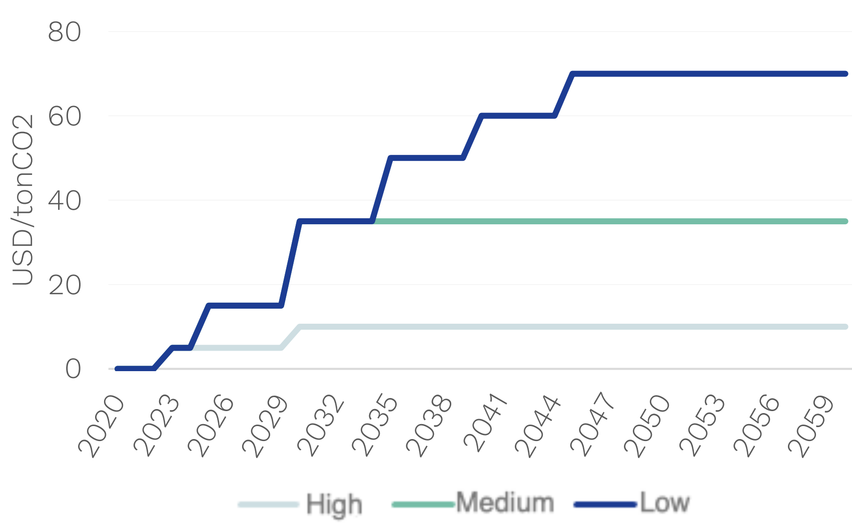


5.8. Green tax path

For purposes of capturing the cost of the externality produced by pollution emanating from polluting generation sources, a growing path of the green tax on stationary and mobile polluting sources is considered.

In this case, the green tax for thermal power plants considers the following assumptions:

- Incorporation of the current green tax of 5 dollars per ton of CO2 equivalent to the variable cost during the year 2023, so that the dispatch of electricity generation is carried out by internalizing the negative externality of the pollution emitted.
- The low tax path maintains this value until 2030, raising the tax rate to 10 dollars per ton of CO2 equivalent.
- On the other hand, the paths of medium and high tax rates gradually increase between 2025 and 2030 until they reach the cost of the externality, which is located at around 35 dollars per ton of CO2 equivalent.
- Finally, the high tax path continues to grow until reaching 70 dollars per ton of CO2 equivalent in 2045.



5.9. Electrical modeling

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

Distributed Generation Projection Study 2021
PELP 2023-2027

Distributed Generation Projections
PELP 2023-2027

5.9.1. Distributed generation

According to a NetBilling-style concept, the projections for the integration of distributed generation in PELP to 2060 are estimated based on an in-house development taking into account the NREL methodology and its Pysam library. This tool considers a model based on agents (ABM) that interact between the residential, commercial and industrial sectors, differentiating each of the regions in the adoption of photovoltaic technology, considering information from previous years, in addition to GDP projections, the price of energy, investment costs, the geo-referenced plant factor and electricity demand.

5.9.2. Transmission expansion criteria

Given the times of development, processing, and construction of new transmission projects, it has been considered that for the 2020-2030 decade, the structural transmission system can only be expanded with technological optimization solutions, extensions, reinforcements and/or with the implementation of storage systems such as GridBooster that allow a more efficient operation in the short term, freeing the N-1 restriction defined in the Technical Security and Quality of Service Standard on those transmission corridors that are limited by capacity.

Starting in 2030, the possibility of developing transmission projects with higher capacity, close to 1,500 MW per alternative, is considered.

5.9.3. Operational 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 minimum inertia restriction and primary and secondary reserve were modeled based on variable renewable energy dispatch, such as solar photovoltaic and wind.

In this sense, a lower limit of 50,000 MVA was set for the contribution of inertia and 10% and 20% of the hourly generation of photovoltaic and wind power plants, respectively.

5.9.4. Block schedule

The dynamics in the daily operation of the electrical power system have an increasing incidence, which has a great impact on future power generating units, the requirements for short-term energy storage for transmission and long-term storage for allocating energy, and the transmission and distribution systems of electrical energy.

For this reason, in order to have a better representation of intraday phenomena, this time a modeling of a typical day per month with an hourly resolution was considered, allowing to study the interactions between variable, manageable and base renewable generation, as well as the activation of the short-term restrictions considered.

Likewise, it allows the integration of short-term storage solutions (1 and 2 hours), as well as the representation of demand profiles with hourly dynamics, which becomes increasingly relevant, since new distributed electrical consumption will take force quickly, such as electromobility and electric heating, whose requirement by society is, in general, highly coincident.

Renewable Resource Analysis Study
PELP 2023-2027

5.9.5. Hydrology

Given the hydrological condition that has occurred in recent years, which is among the driest on record, and according to what was raised in the different participatory workshops of the PELP, on this occasion it has been decided to model a single dry hydrological condition, similar to the record of the hydrological year 1998-1999, considering that the water tributaries are similar to what was observed in the last year.

In this way, PELP identifies dry hydrological conditions for all scenarios to facilitate actions that can overcome the extreme situations that the system may face in the medium and long term.

The hydrological treatment will be a permanent line of work of the PELP, and continuous sensitivity analyzes will be carried out, considering the effect of climate change, both in the water tributaries and generation profiles of solar wind power plants, as well as modifications in the patterns of consumption mainly due to heating, as a result of the effects of climate change.

5.9.6. Wind production profiles[29]

The variability of wind farm production is a relevant factor that must be accompanied by good short, medium, and long-term projection systems, since wind generation is taking on a relevant role in the share of power generating units in the electrical power system.

There are multiple techniques to be able to use this variability in planning models and thus take action on it. In this PELP, a profile of 24 hours per month was considered for each power plant, through the identification of representative days per month using the K-Means mathematical technique with Euclidean distance, as long as it is consistent with the hourly energy generated each month.

5.9.7. Demand profile

Given the important projection of new electricity consumption, such as the electromobility, heating and the production of green hydrogen, whose energy requirement during the day is especially relevant, this time a separate profiles were considered for each demand: base, heating that considers central heating and air conditioning, electromobility and green hydrogen production.

The profiles for heating and electromobility were studied and projected in an undergraduate report from the Universidad de Chile: *"Development of demand profiles at the distribution level for purposes of consideration in Long-Term*

Demand Profiles for PELP Report
PELP 2023-2027

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

Energy Planning."

It was decided to separate and model each of these demands using a different profile, thereby distinguishing them from the base component. In the case of electromobility and heating, information from the master's thesis of a student at the Universidad de Chile was used, and as for green hydrogen, an endogenous modeling of its production was considered, allowing the model to define where and when to produce it based on price signals.

5.9.8. H2V production

The production of green hydrogen, both for local demand and export, is expected to be one of the major uses of electricity in the future, especially in scenarios with better economic prospects.

In this sense, in order to represent the dynamics of its production, the associated demand was incorporated as an optimization variable in the model, in order to define the daily and annual production curve that would optimize the system and production conditions.

In this way, based on a daily and annual green hydrogen production requirement, its production is modulated in order to take advantage of the hours with the best energy prices that, in turn, provides flexibility to the system and reduces operating costs and investment.

5.9.9. Storage

To better determine the fundamental role that storage solutions will have in electrical power systems, various types of technological solutions were modeled.

1. BESS type batteries, whose storage capacity varies between 1, 2 and 4 hours, with an efficiency of 81% in the complete charge cycle.
2. Compressed Air Energy Storage (CAES) that has a storage capacity of 4 hours with an efficiency close to 60%.
3. Reconversion of some of the current coal-fired power plants that are

going to be withdrawn from the system. The conversion alternative to Carnot batteries is modeled, which have a storage capacity of 4 or 12 hours, with an efficiency of 36%.

4. Pumped hydro storage plants in the northern part of the system, based on information that has been collected by the Ministry of Energy on the potential that could be developed in the country.

5.9.10. Configurations for Solar CSP technology[30]

On this occasion, important modifications were implemented in the representation of Solar CSP technology.

Solar CSP Analysis
PELP 2023-2027

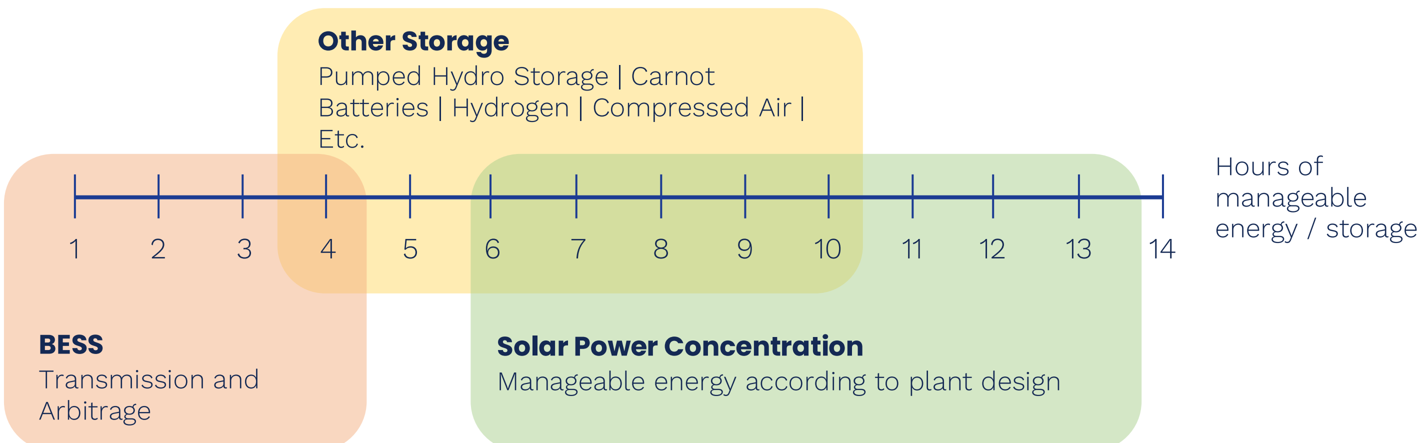
The first is to integrate three configurations, each of which serves a different purpose. The first is a version with 6 hours of storage, exclusively to be available during peak hours of the system, another has 13 hours of storage to be dispatched day and night, and an intermediate one with 9 hours of storage.

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

[30] 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 raise the thermal production profile (under the tower and before salt storage) of these power plants, and for each of the locations where this technology is more efficient, allowing the optimization model to decide the optimal capacity, configuration, location and timing of each project.

5.9.11. Storage for transmission and arbitrage, and manageable energies

A scheme is presented that summarizes the technologies considered in the electrical projections that will be presented in the following section.



5.10. Electrical projections

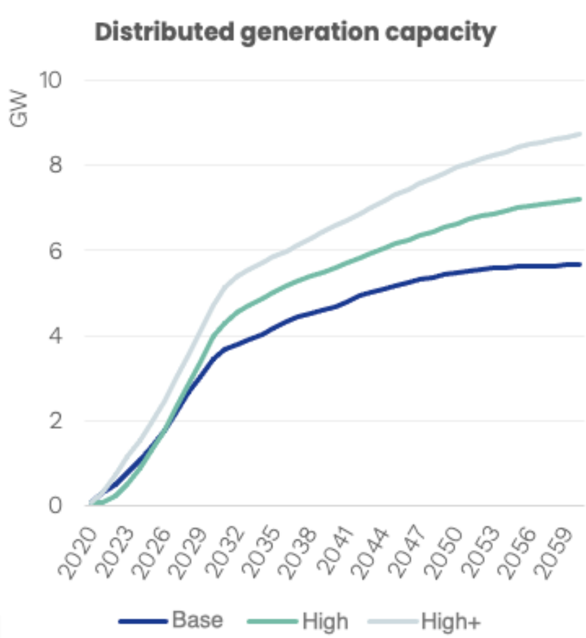
This section presents the results of the electrical projections.

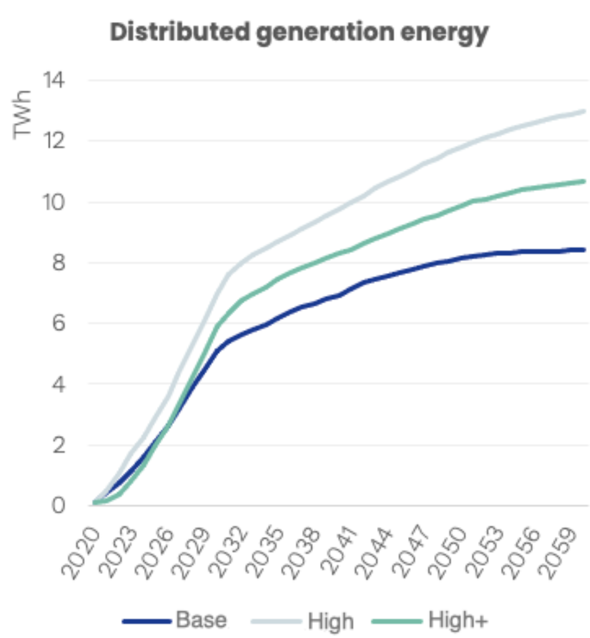
5.10.1. Distributed generation

Capacity and energy projections for distributed generation based on solar photovoltaic technology are presented.

At this time, distributed generation contemplates the residential, commercial and industrial sectors, with projections that exceed 8,000 MW in the High+ scenario.

Given that this technology makes it possible to bring renewable energies closer to the different end uses, it is identified as an option that must continue to be promoted strongly to carry on developing energy from the sun. In addition, they support a more efficient use of the electricity transmission and distribution infrastructure.



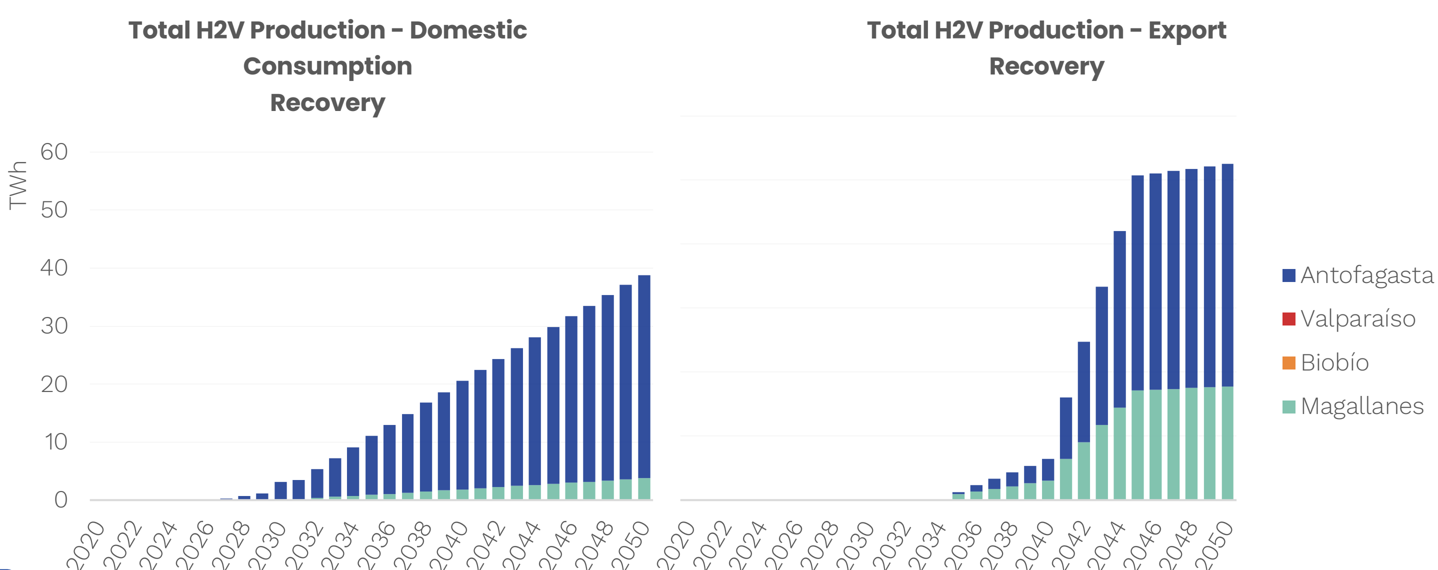


5.10.2. Electricity demand

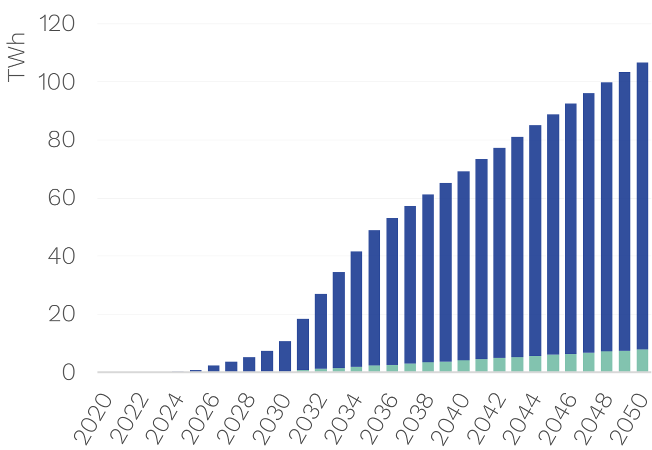
The projection of electricity demand must be carried out with a full understanding of the energy sector as a whole, given that new electricity consumption will gain relevance and even determine the resulting electricity demand. Heating, electromobility and production of green hydrogen (H2V).

In the case of heating and electromobility, their projection is defined based on the energy projection and the identification of the supply needed to supply thermal and mobility consumption. On the other hand, the production of H2V is also obtained from the internal consumption required to replace current polluting energy sources, such as cargo transport, mining uses, motor uses, among others. In addition, the production of H2V will also be required to export this energy vector in the form of hydrogen or its derivatives, such as ammonia to other countries in the world. The H2V production figures in the different scenarios are built based on the National Green Hydrogen Strategy.

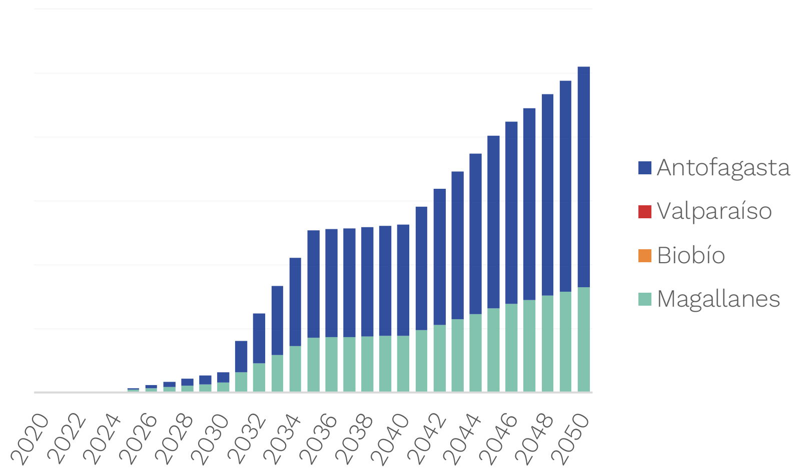
H2V production projections for domestic consumption and export are presented in each energy scenario.



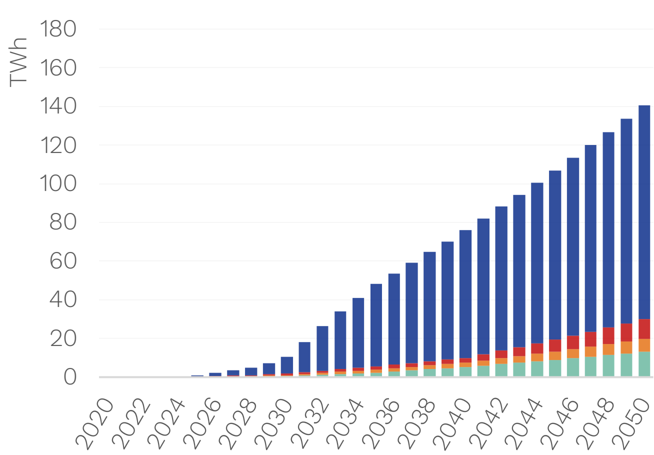
Total H2V Production - Domestic Consumption
Accelerated Transition



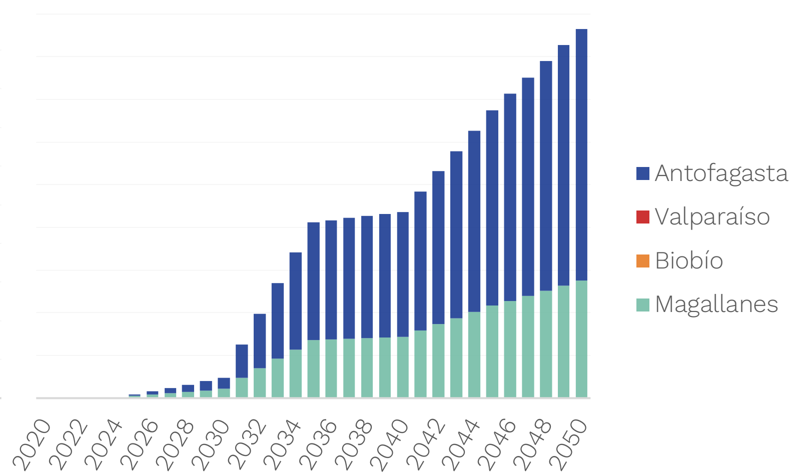
Total H2V Production - Export
Accelerated Transition



Total H2V Production - Domestic Consumption
Accelerated Transition



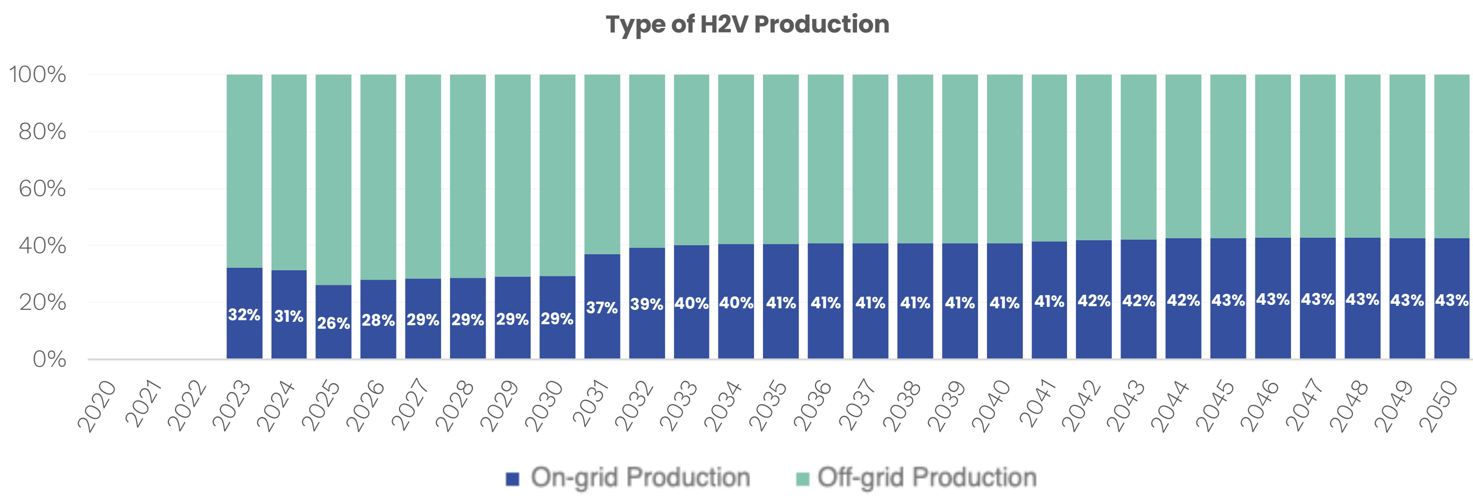
Total H2V Production - Export
Accelerated Transition



On the other hand, H2V is expected to be produced by two types:

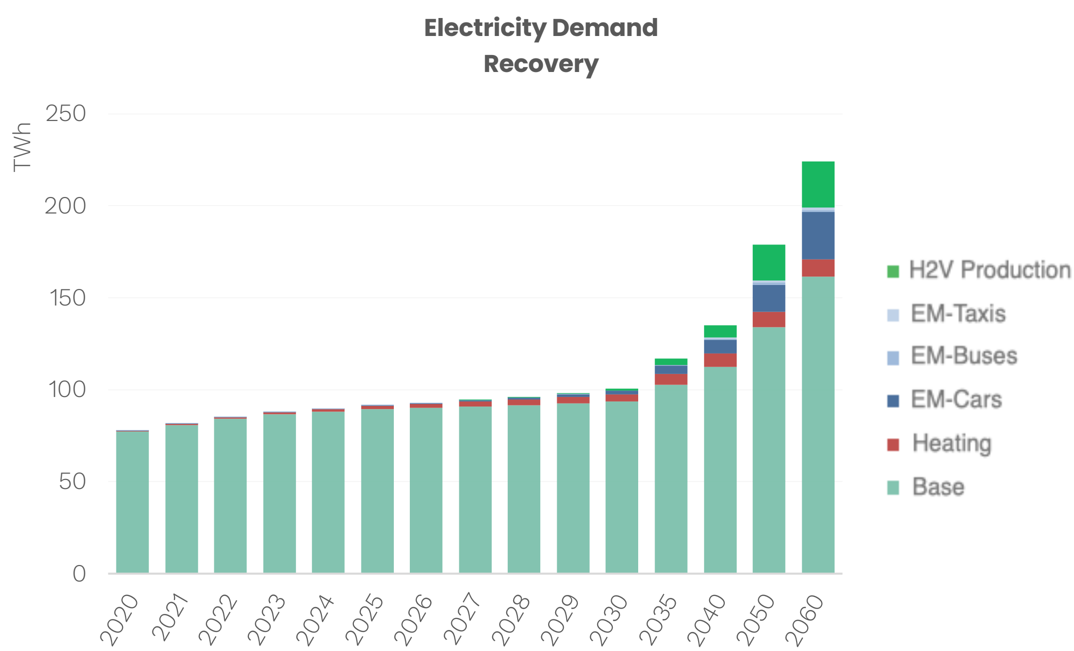
- Off-grid, or disconnected from the electrical power system.
- On-grid, or connected to the electrical power system.

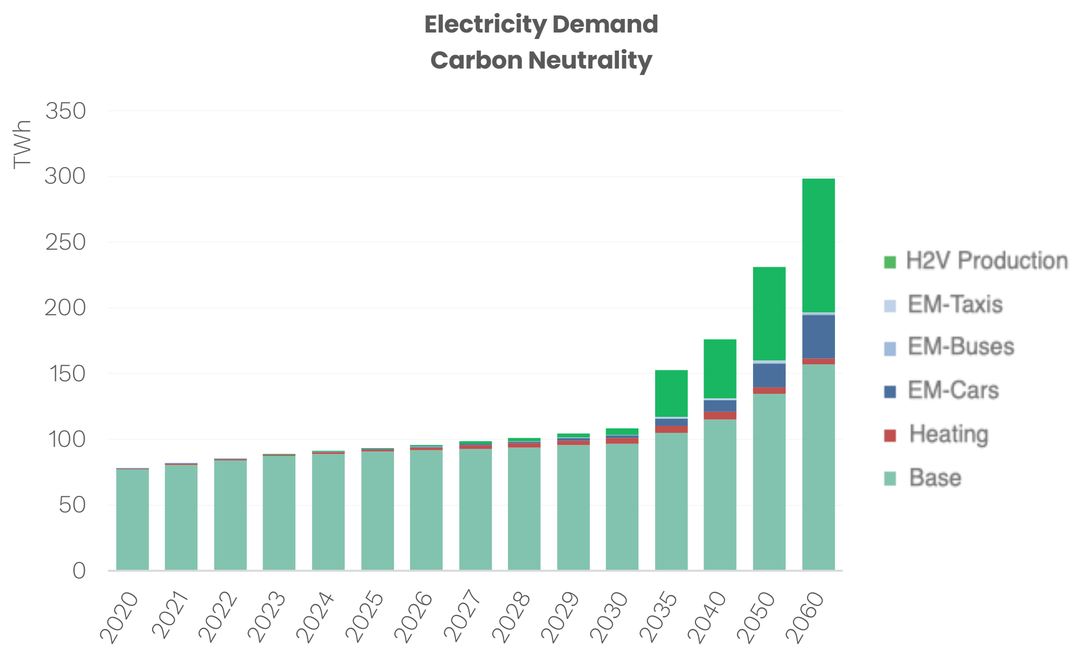
For these purposes, On-grid production levels are expected to be between values close to 30% and 40%, as shown in the graph.

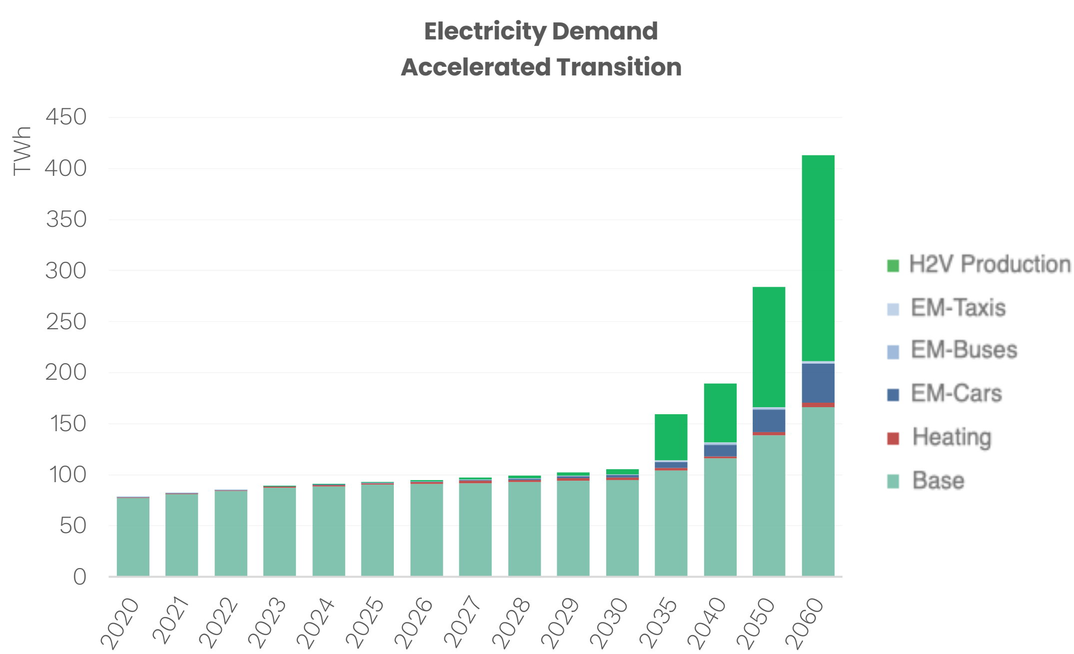


For its part, the demand projection takes into account continued growth over the current decade, influenced by historical consumption. However, towards the end of the decade, the irruption of the new electricity consumption driven by carbon neutrality goals begins to be observed: electric heating (previously considering thermal reconditioning in existing homes), electromobility and green hydrogen production.

In the Recovery scenario, this new electricity consumption will reach a significant proportion by 2050. However, in the Carbon Neutrality and Accelerating the Energy Transition scenarios, electricity consumption shows a substantial increase in the last decades of the analysis horizon, driven mainly by the production of green hydrogen for domestic consumption and export.




Electricity Demand
Carbon Neutrality
TWh
350
300
250
200
150
100
50
0
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2035
2040
2050
2060
H2V Production
EM-Taxis
EM-Buses
EM-Cars
Heating
Base

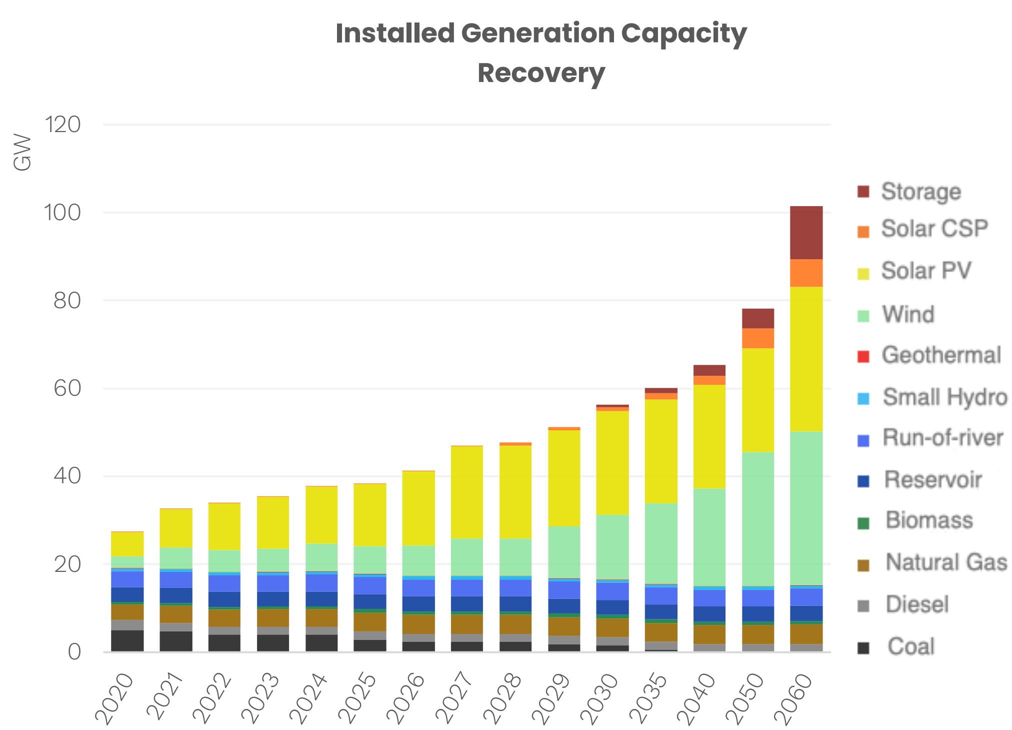

Electricity Demand
Accelerated Transition
TWh
450
400
350
300
250
200
150
100
50
0
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2035
2040
2050
2060
H2V Production
EM-Taxis
EM-Buses
EM-Cars
Heating
Base

5.10.3. Installed capacity

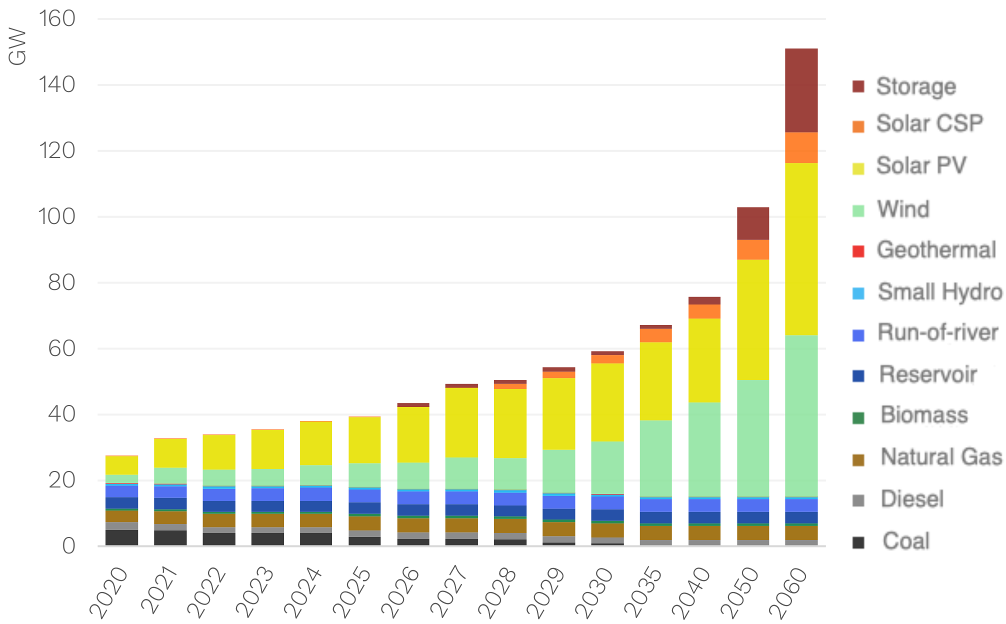
The installed capacity of the National Electric System continues to incorporate renewable energy into its matrix, mainly solar and wind energy.

Nonetheless, in addition to these technologies, as coal exits and more variable renewable energies enter, storage and manageable energies such as Solar CSP have greater advantages. In particular, above 7,000 MW, solar photovoltaic energy needs storage sources or consumption during daylight hours to continue growing, as it reaches the limits imposed by the maximum instantaneous demand, as well as the maximum management capacity of that technology in the operation of the electric system.

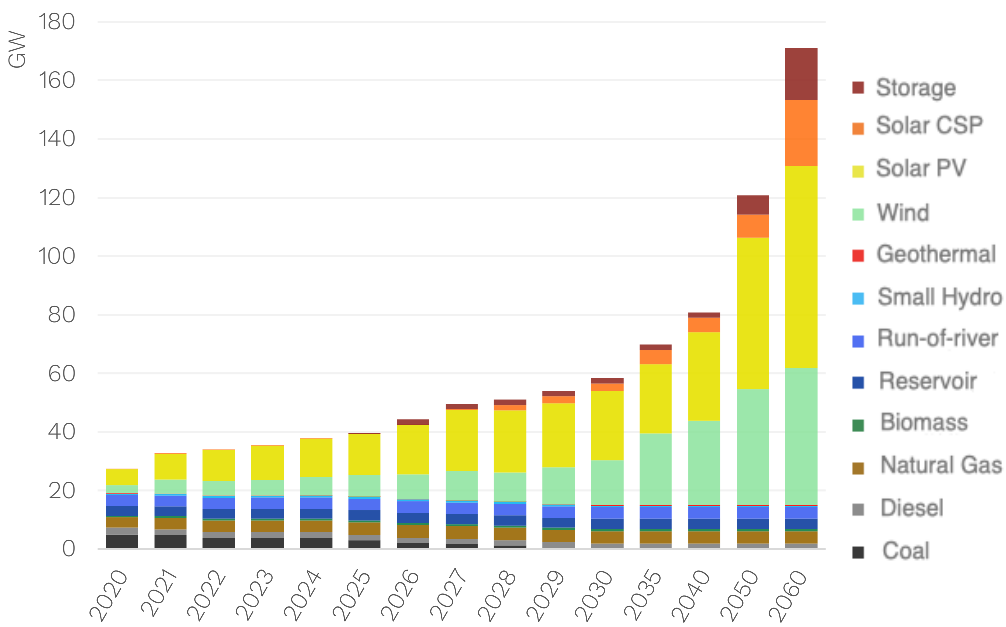
For this reason, between the middle and the end of this decade, storage and manageable energy become a fundamental piece in the growth of the renewable matrix. Projections show that the Accelerating the Energy Transition scenario will require around 2,000 MW of BESS, CAES, Carnot, etc. storage by the end of the decade. In addition to about 3,000 MW of manageable renewable energy such as solar CSP.



Installed Generation Capacity
Carbon Neutrality



Installed Generation Capacity
Accelerated Transition

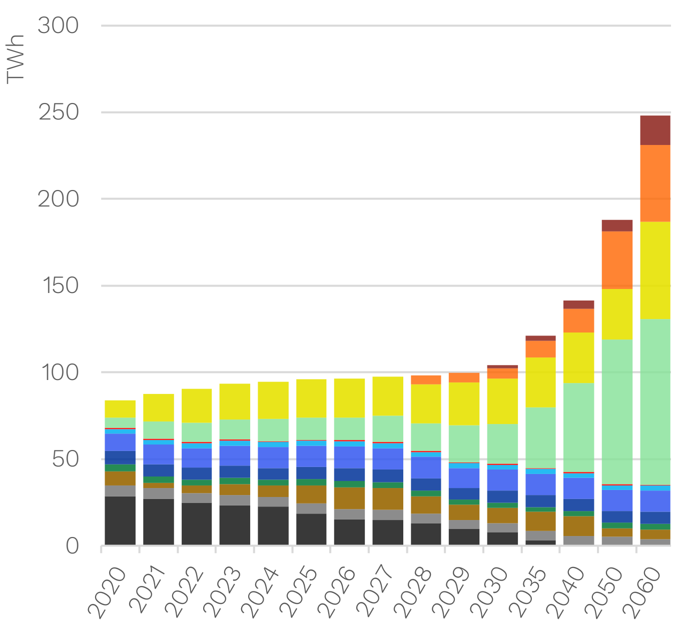


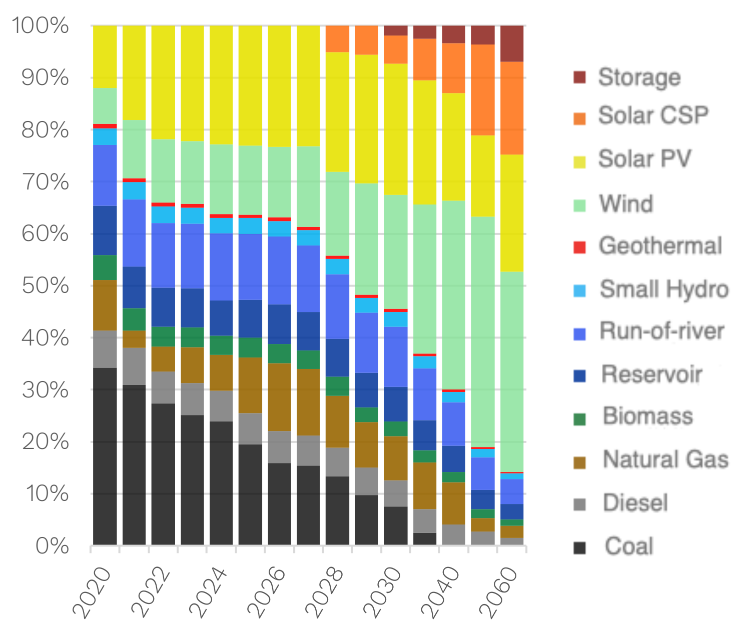
5.10.4. Electricity generation

The levels of electricity generation by technology are presented, both in terms of TWh and percentage share.

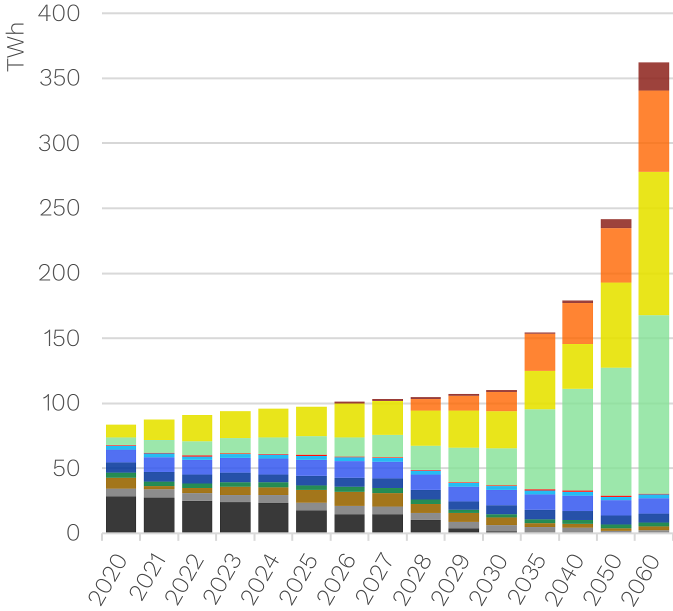
It is clearly identified how the coal-fired power plant phase-out near the end of this decade and the beginning of the next, along with a low availability of water resources, promote in advance the insertion of storage technologies and variable renewable sources with respect to previous PELP projections.

It also identifies how gas assumes an important role in the energy transition, progressively reducing its contribution towards the year 2040, and in advance in scenarios in which a higher green tax is considered, along with favorable conditions for renewable investments of field and energy storage.

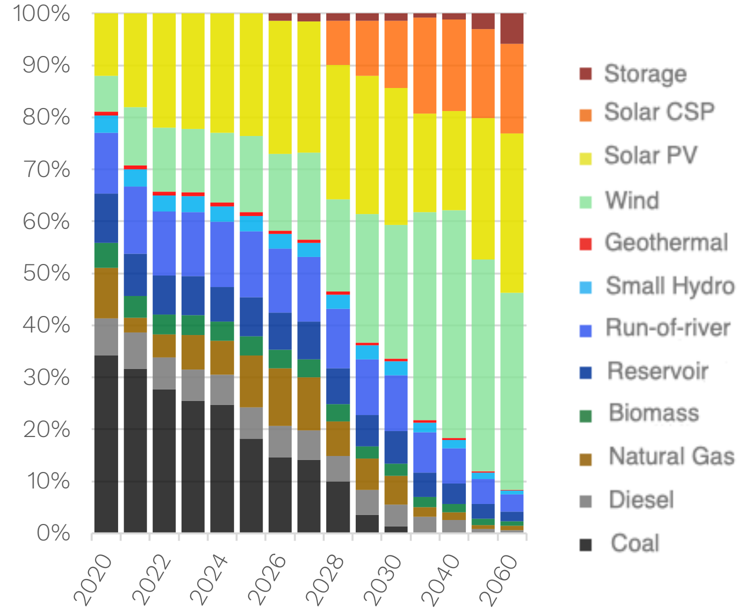




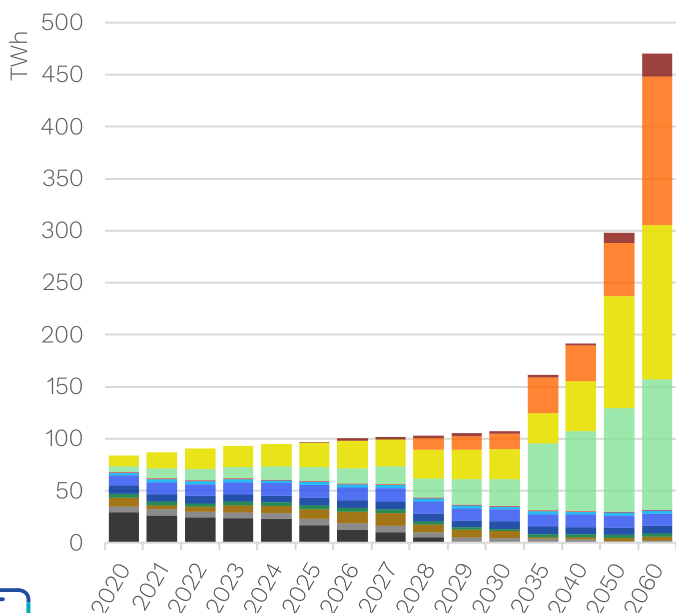
Projected Annual Generation
Carbon Neutrality



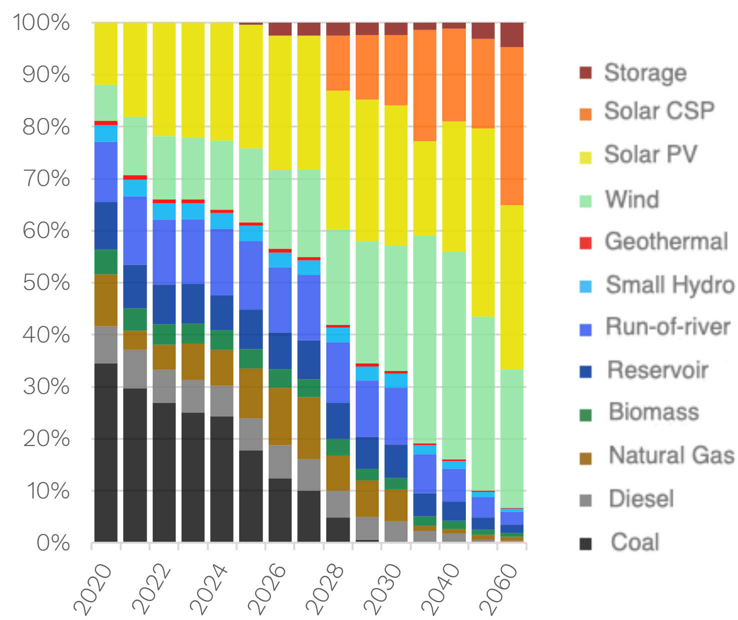
Technology Share of Generation
Carbon Neutrality



Projected Annual Generation
Accelerated Transition



Technology Share of Generation
Accelerated Transition



5.10.5. Daily demand and generation curves

The day-to-day operation of electrical power systems becomes even more important each time more renewable energies are integrated into the grid and larger-scale electricity consumption such as electric heating and electromobility emerges. In addition, the portion of green hydrogen production that is carried out connected to the grid will also set up an interesting dynamic from the point of view of the operation of the electrical grid.

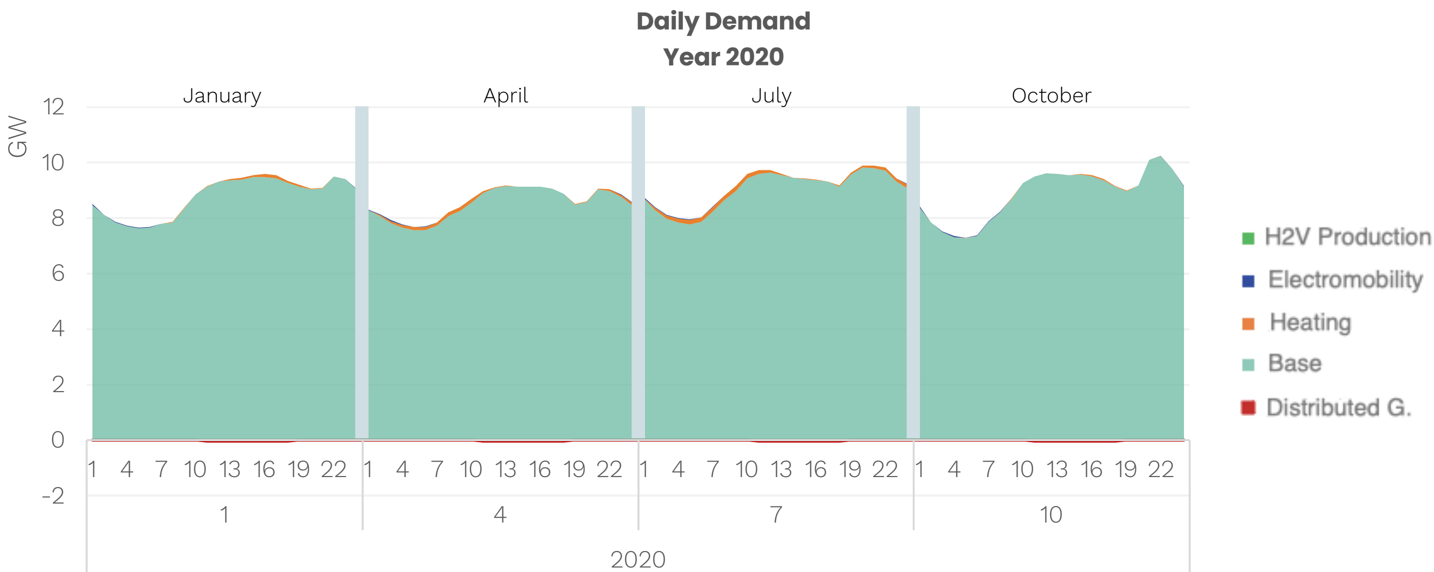
In this context, it is important that technology adoption and implementation at all levels, from the operation of electrical power systems to the provision of automated safety services, characterize this decade.

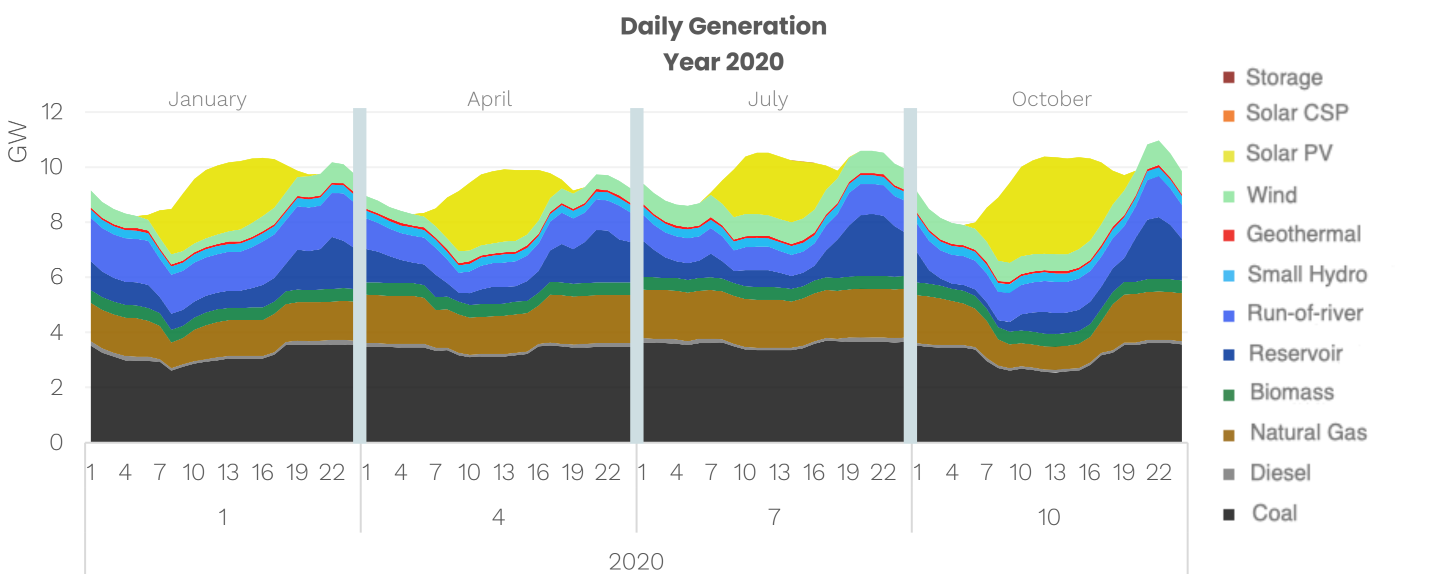
To start the analysis of the projected daily operation, a simulated typical day for the year 2020 will be presented, in order to be able to compare a current operation totally different from what the grid operation will be in a few more years.

Not only will interaction be important from the point of view of generation, but consumption assumes a huge and key role in the relationship of the operation, and its management has a direct implication on the infrastructure required in the medium and long term.

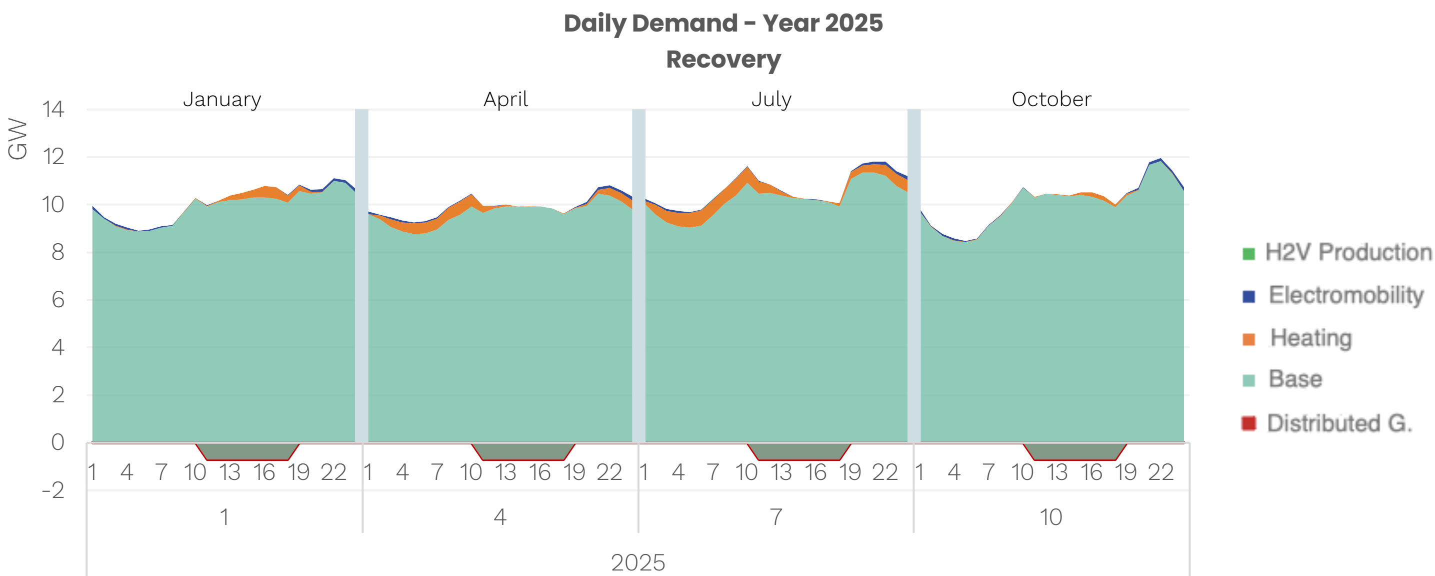
It is worth mentioning that distributed generation has been incorporated into the demand curve with negative values, in such a way that it allows identifying the level of this type of generation and the resulting demand curve that must be supplied from medium and large generating power plants.

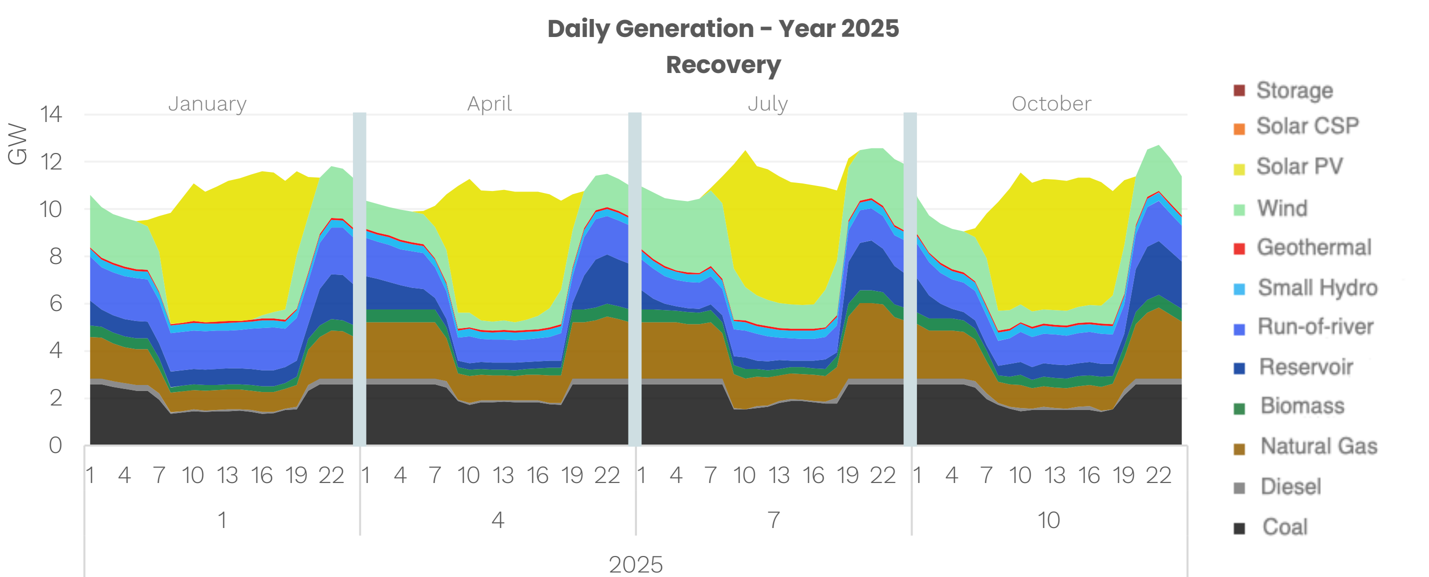
Simulation of the year 2020 as a starting point

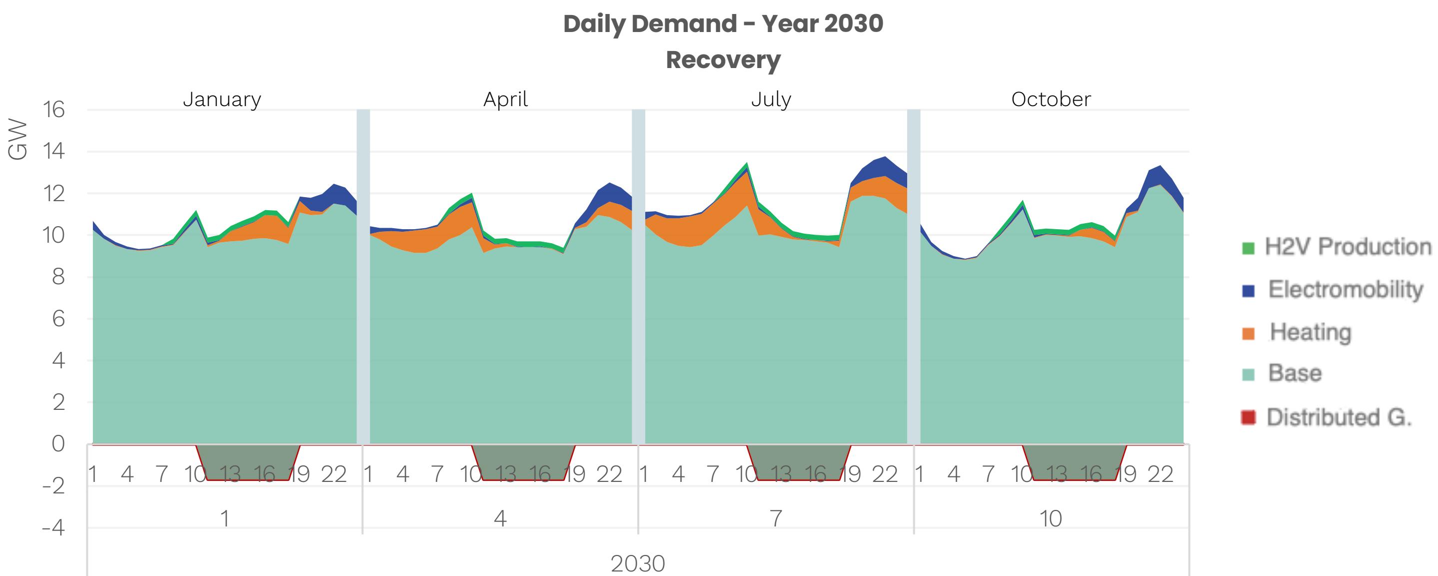




Post Covid Slow Recovery Scenario






Daily Demand - Year 2030
Recovery
January
April
July
October
GW
16
14
12
10
8
6
4
2
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1 4 7 10 13 16 19 22
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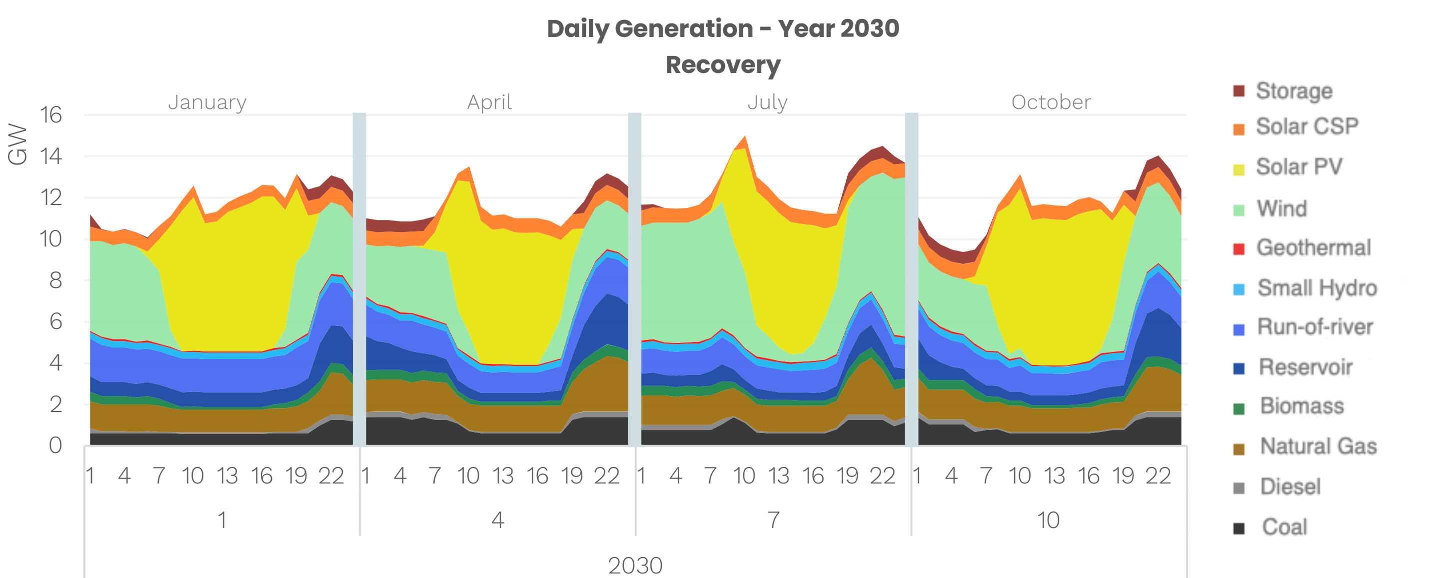
10
2030
H2V Production
Electromobility
Heating
Base
Distributed G.


Daily Generation - Year 2030
Recovery
January
April
July
October
GW
16
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1 4 7 10 13 16 19 22
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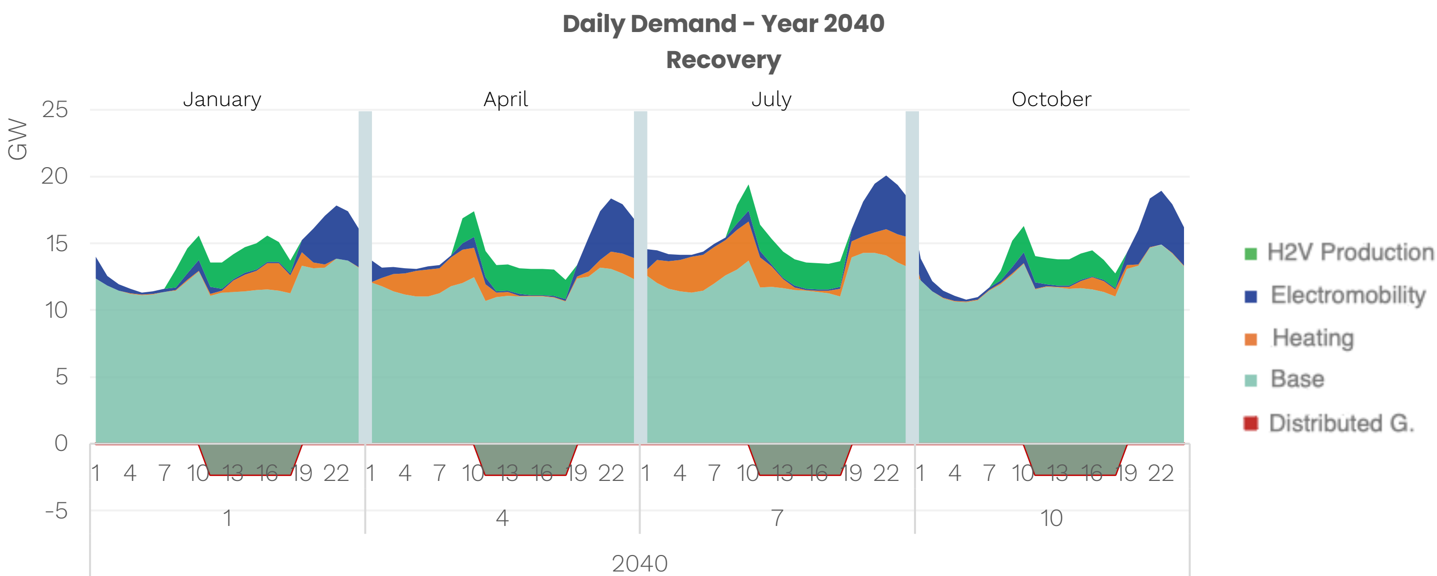
2030
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal


Daily Demand - Year 2040
Recovery
January
April
July
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GW
25
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15
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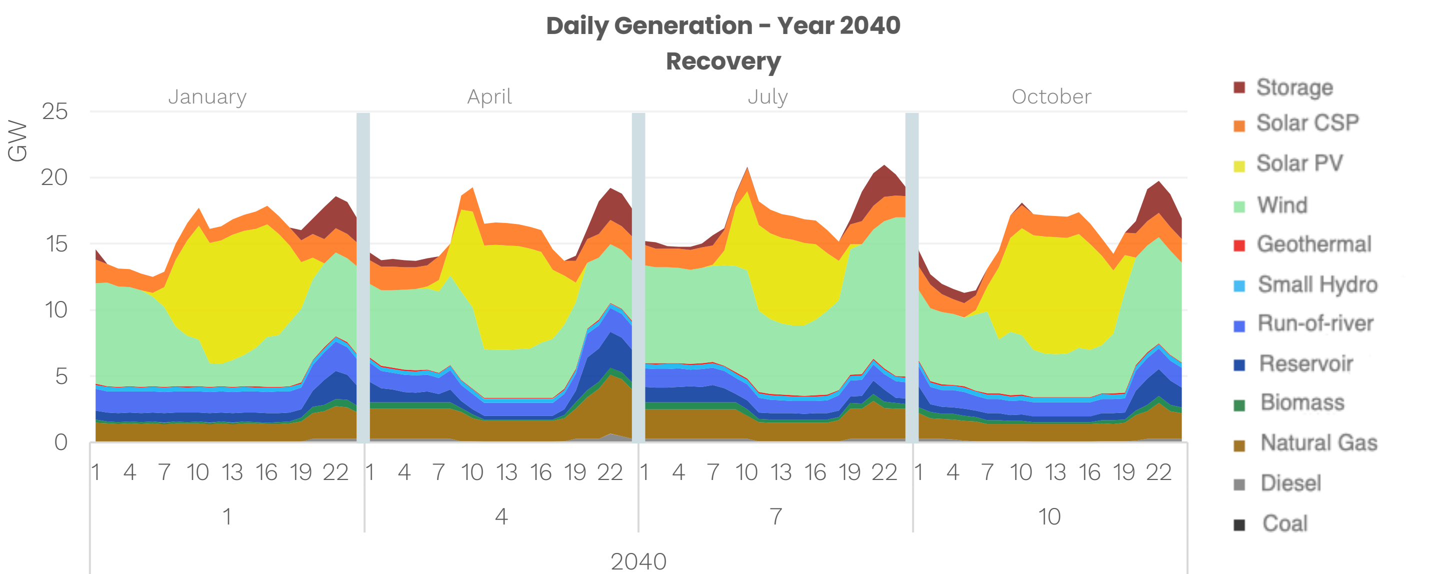
2040
H2V Production
Electromobility
Heating
Base
Distributed G.


Daily Generation - Year 2040
Recovery
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GW
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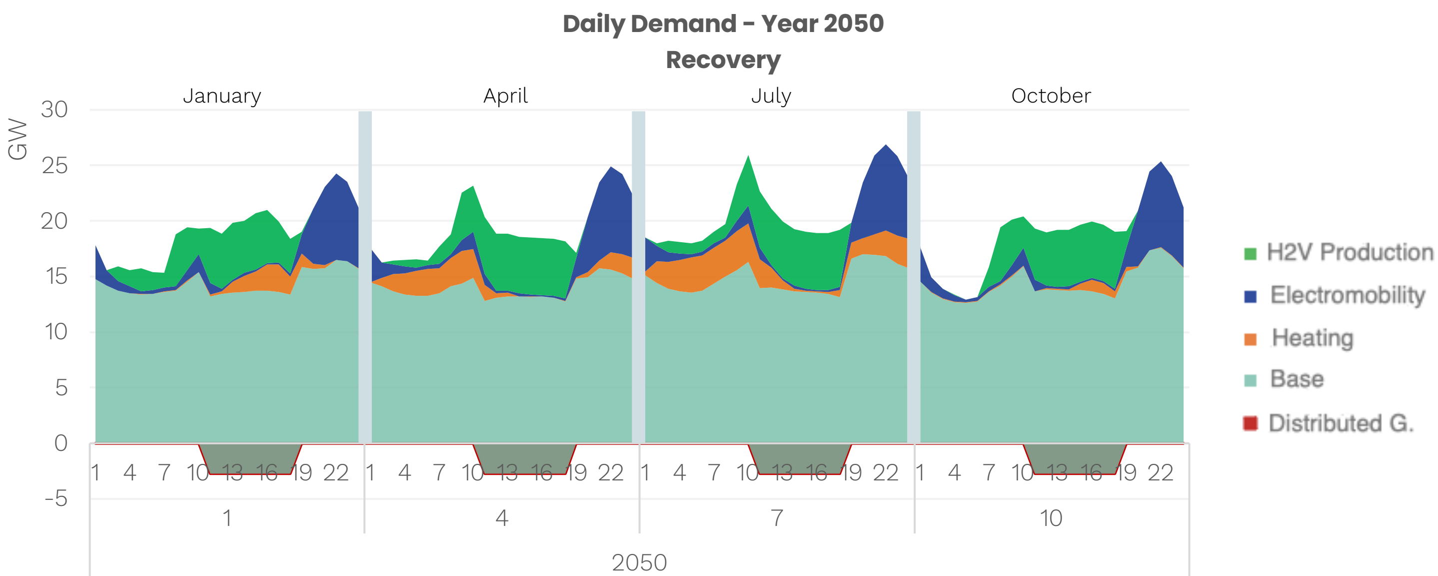
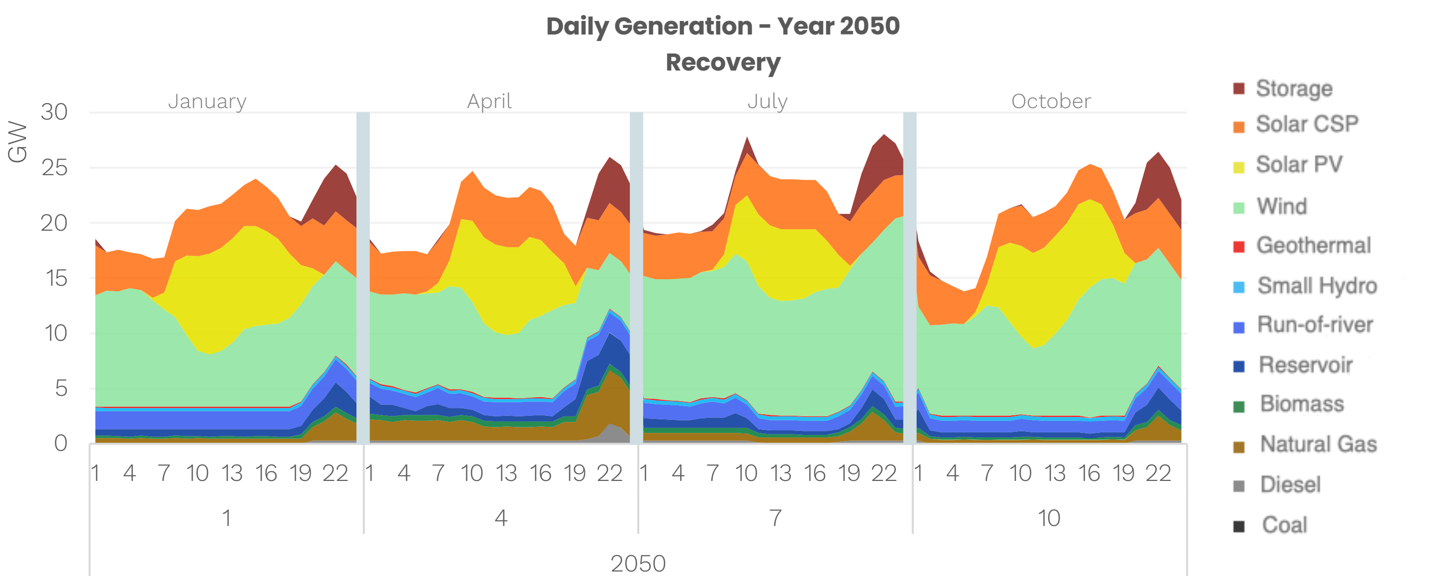
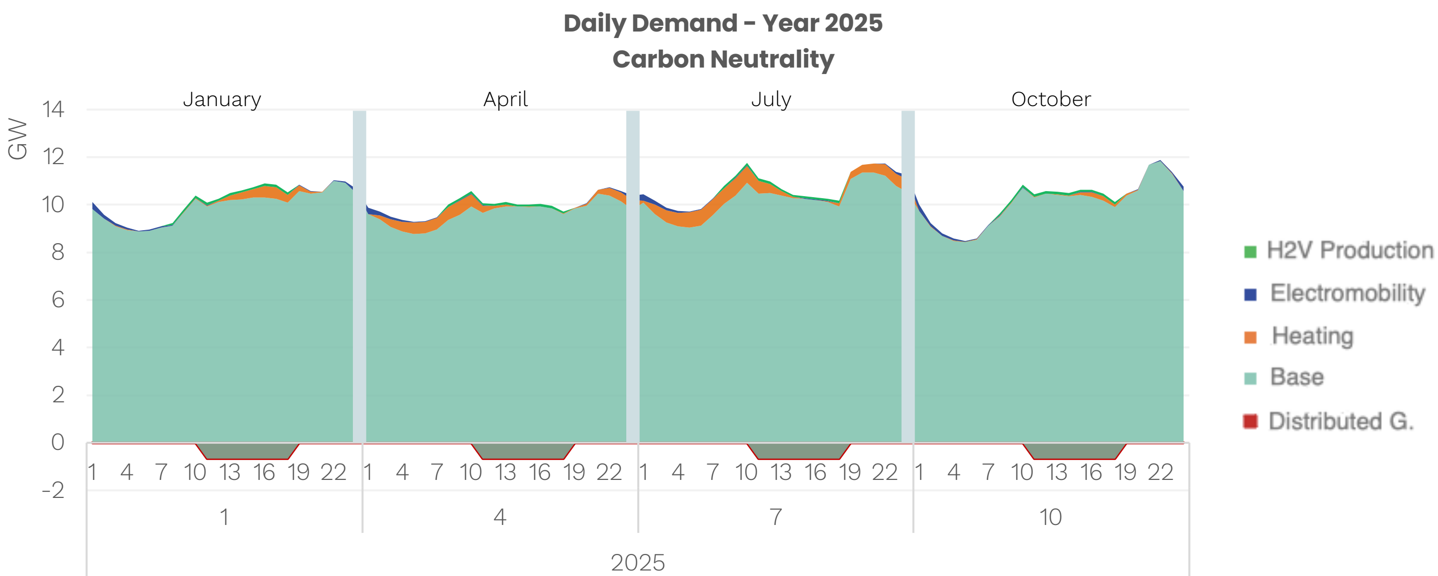
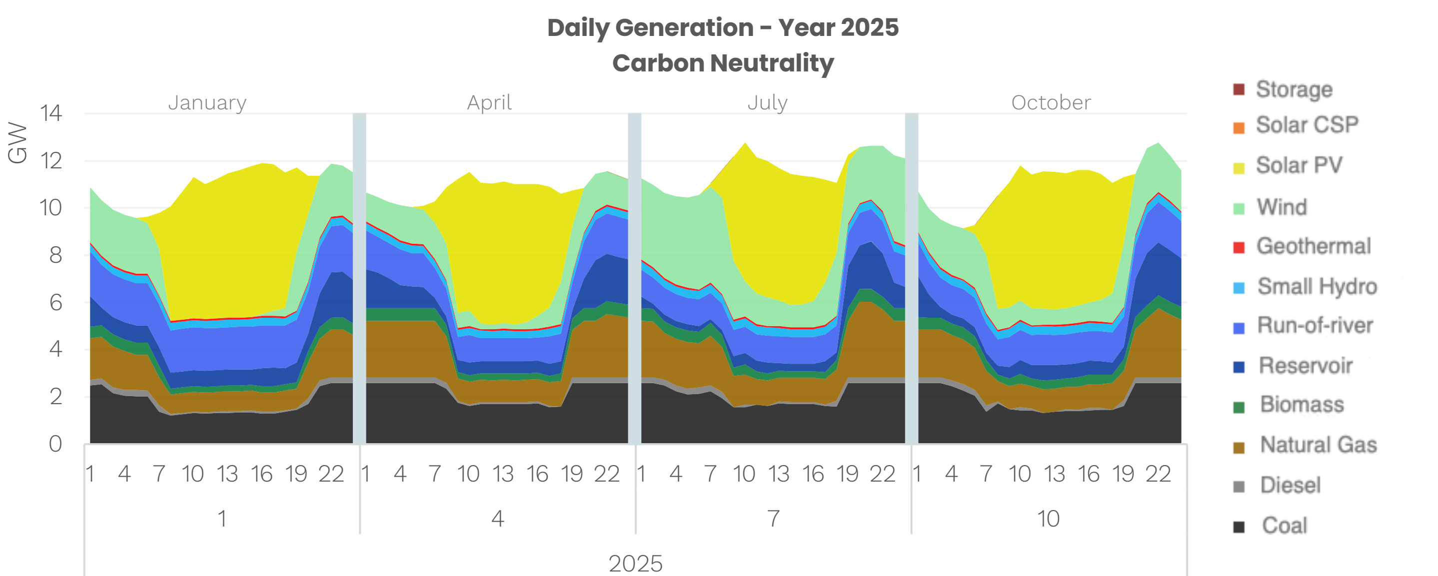
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal

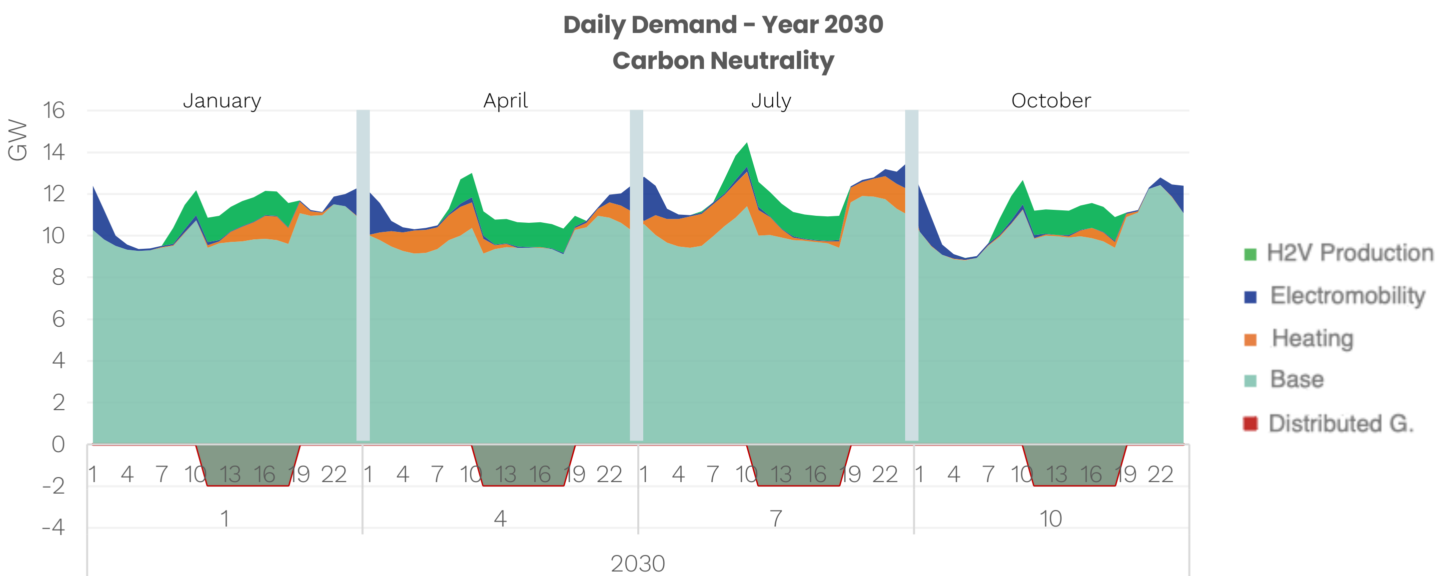

Daily Demand - Year 2050
Recovery
GW
January
April
July
October
H2V Production
Electromobility
Heating
Base
Distributed G.
2050


Daily Generation - Year 2050
Recovery
GW
January
April
July
October
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal
2050

Road to Carbon Neutrality by 2050 Scenario






Daily Demand - Year 2030
Carbon Neutrality
GW
January
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October
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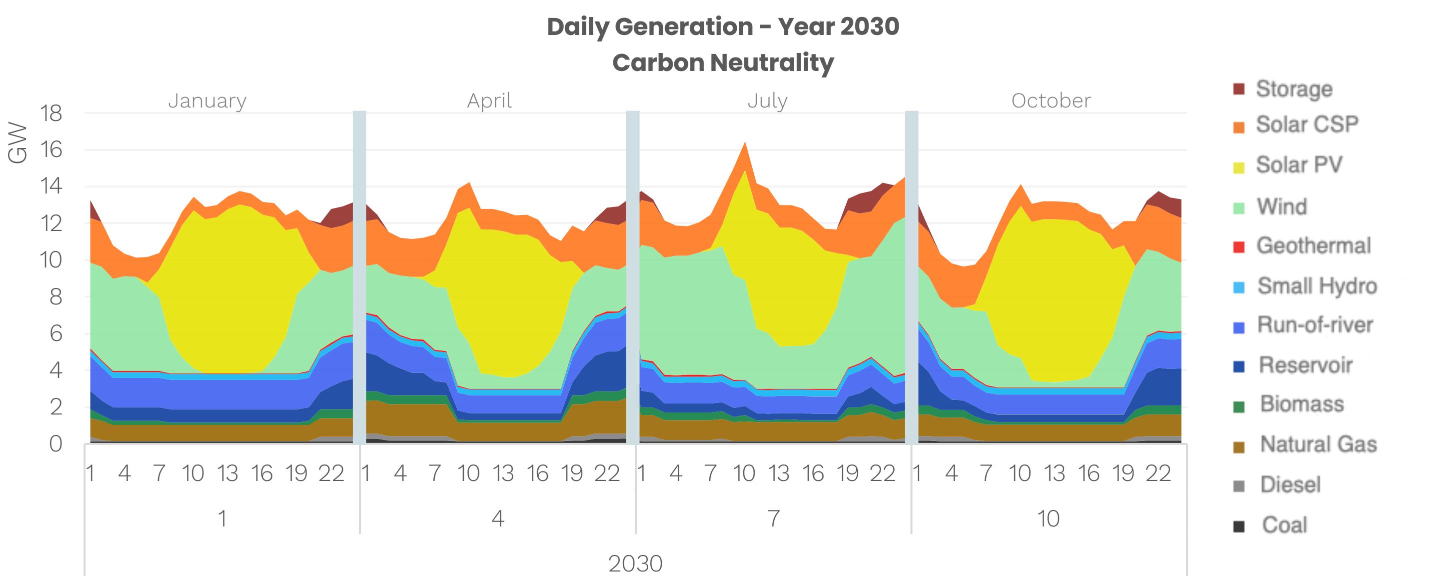
2030
H2V Production
Electromobility
Heating
Base
Distributed G.


Daily Generation - Year 2030
Carbon Neutrality
GW
January
April
July
October
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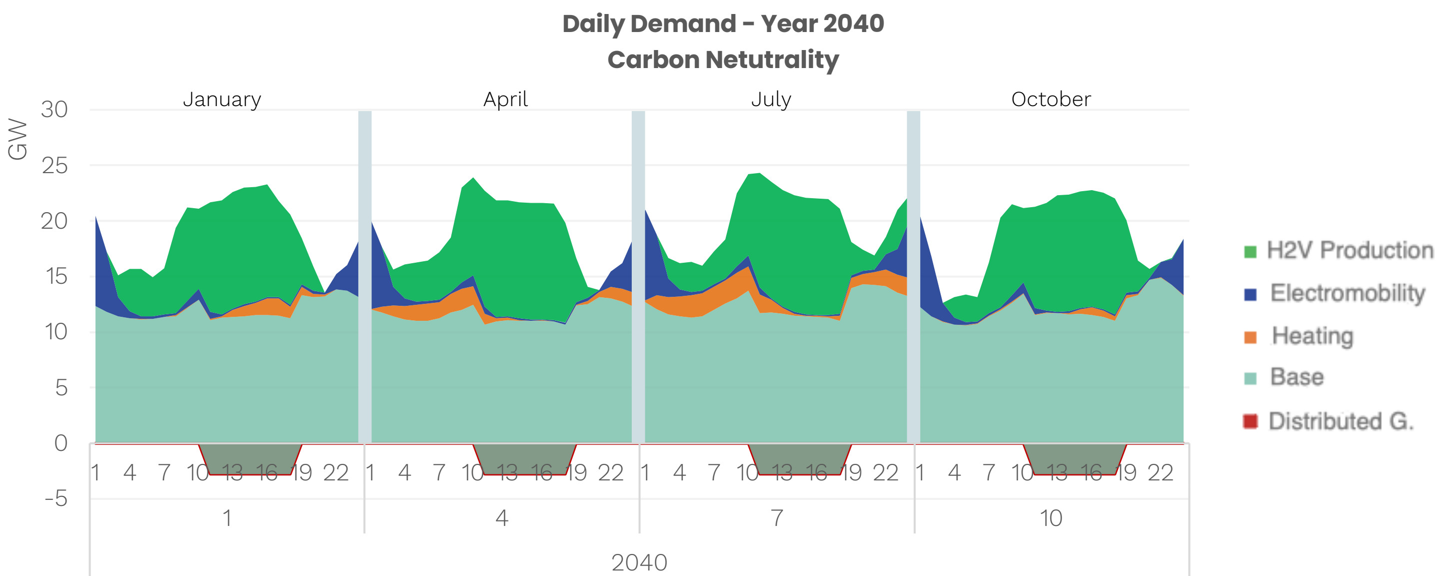
2030
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal


Daily Demand - Year 2040
Carbon Netutrality
GW
30
25
20
15
10
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January
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1 4 7 10 13 16 19 22
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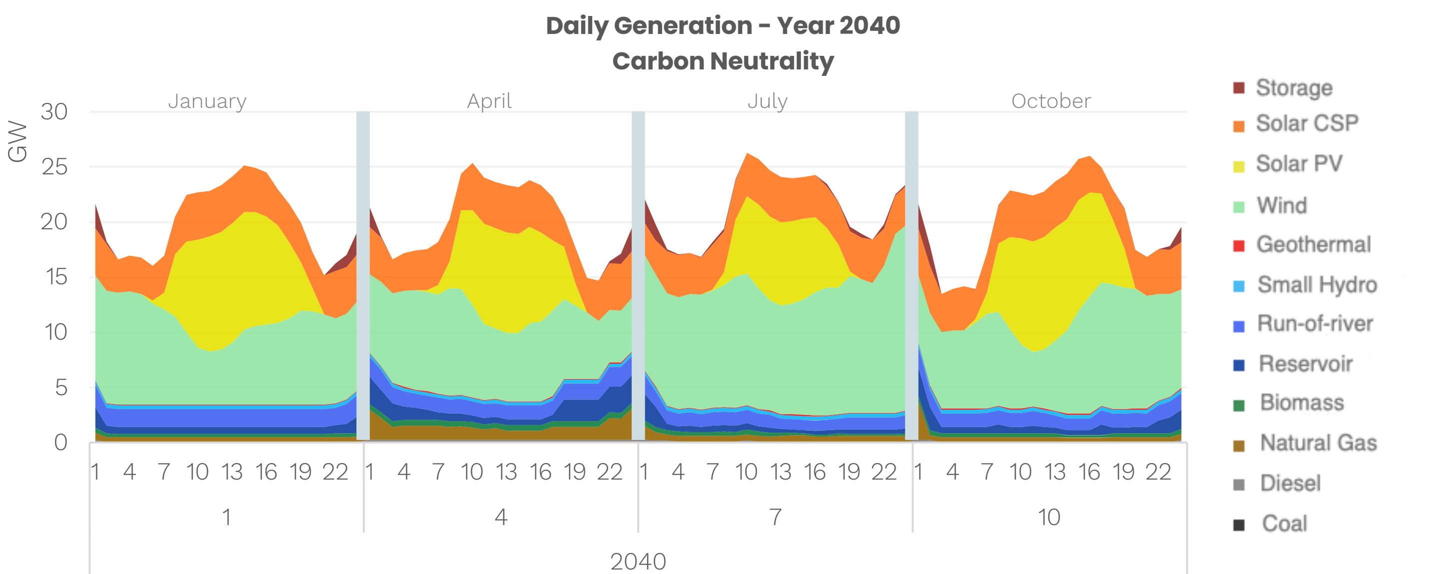
2040
H2V Production
Electromobility
Heating
Base
Distributed G.


Daily Generation - Year 2040
Carbon Neutrality
GW
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January
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July
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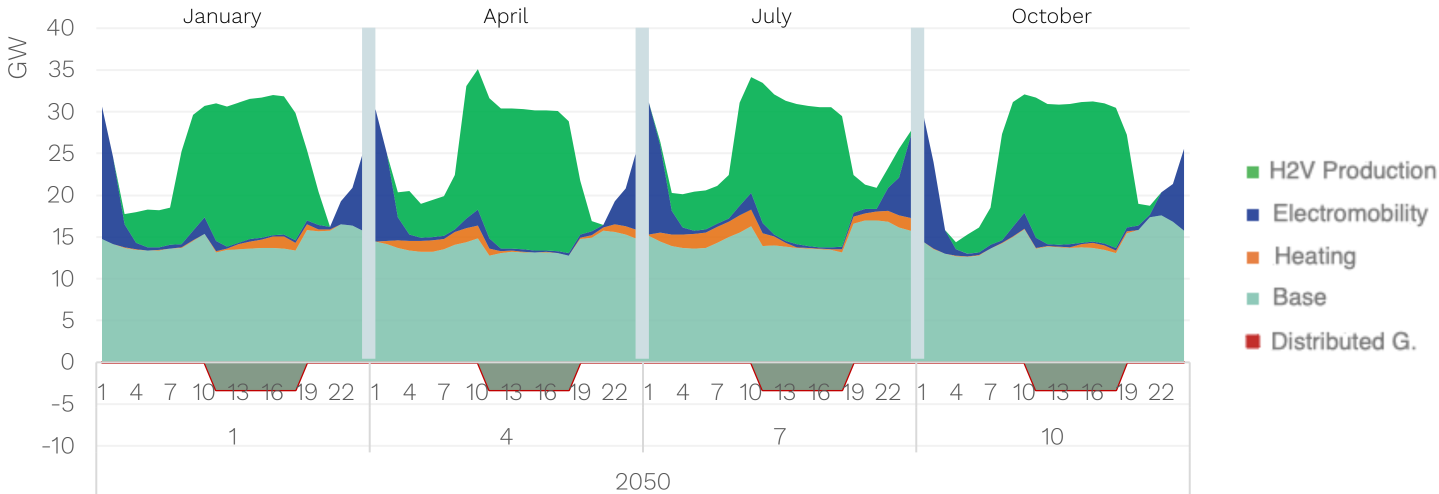
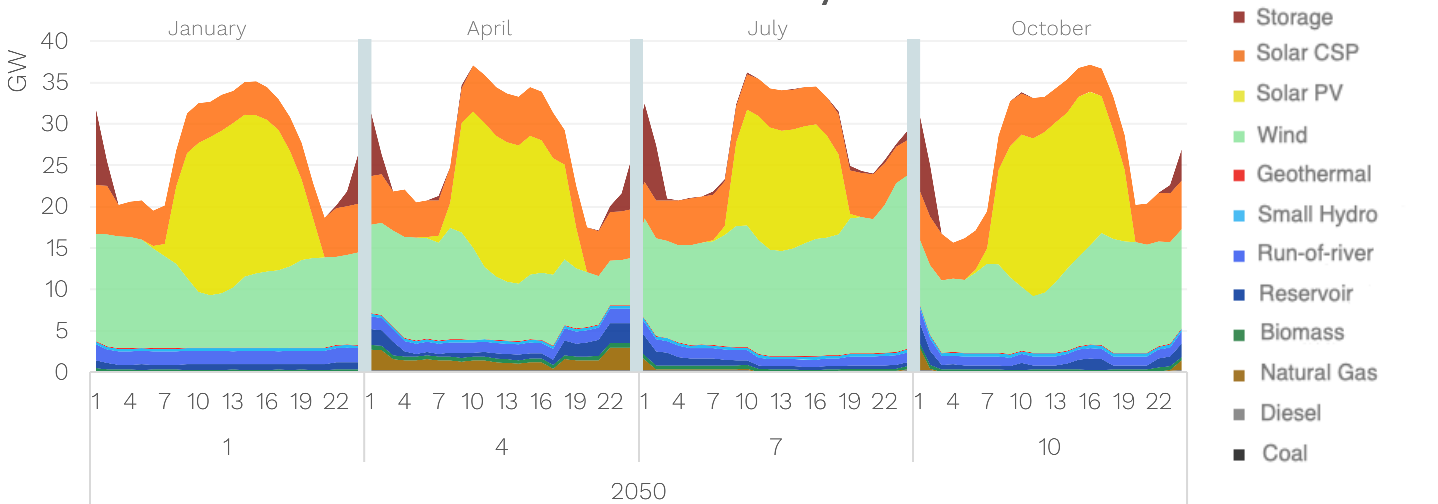
1 4 7 10 13 16 19 22
1
4
7
10
2040
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal

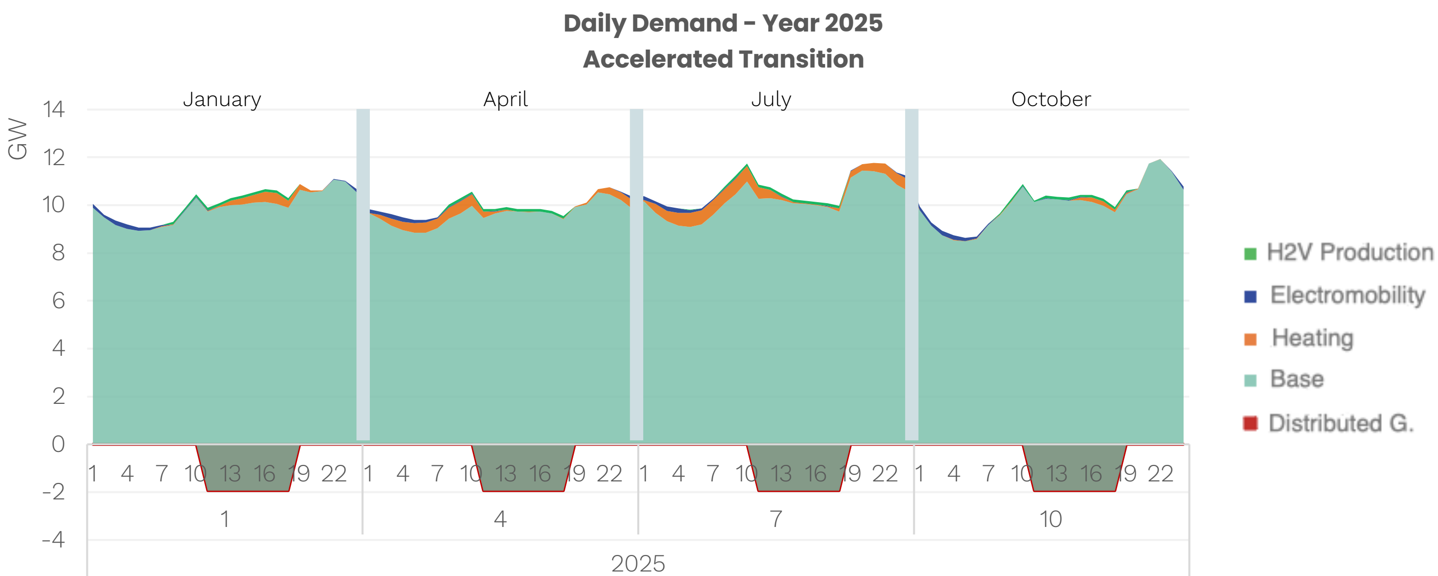
Daily Demand - Year 2050
Carbon Neutrality

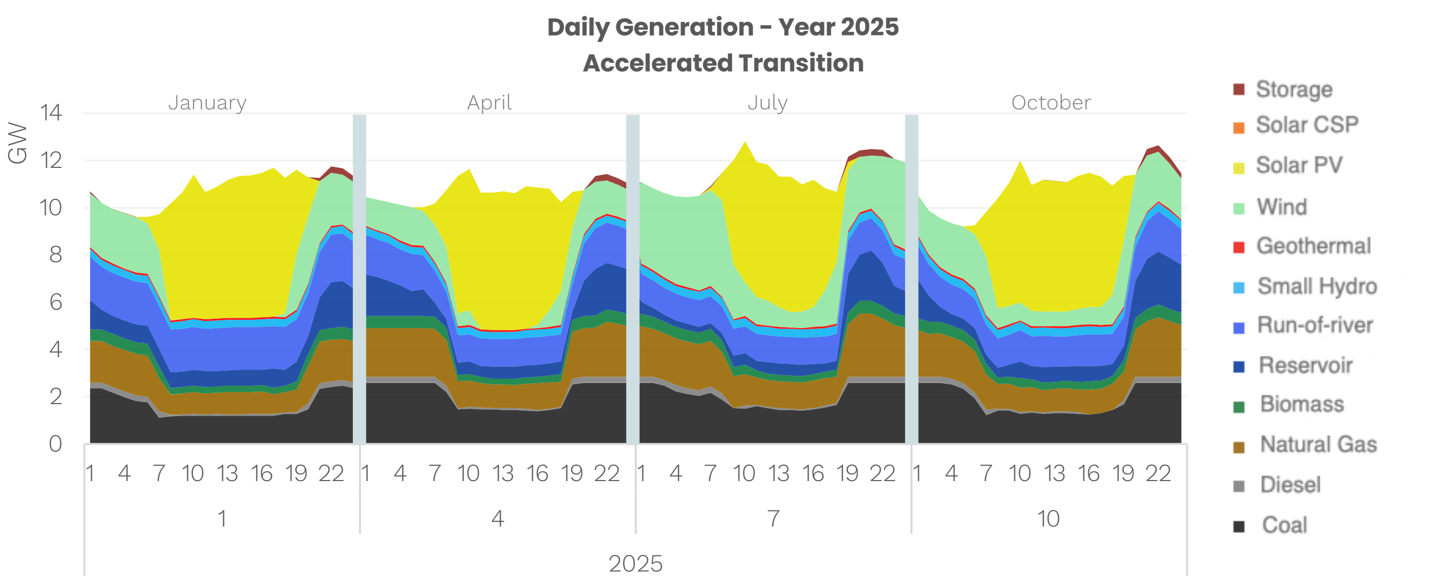


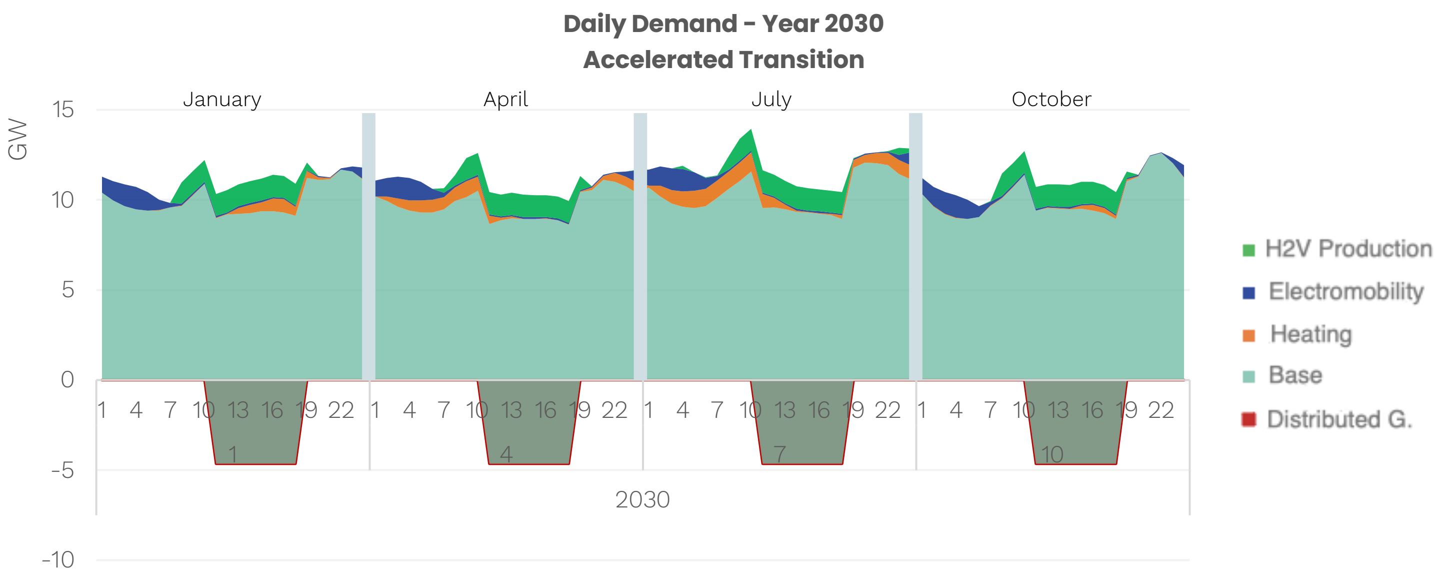
Daily Generation - Year 2050
Carbon Neutrality



Accelerating the Energy Transition Scenario







Daily Demand - Year 2030
Accelerated Transition
January
April
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GW
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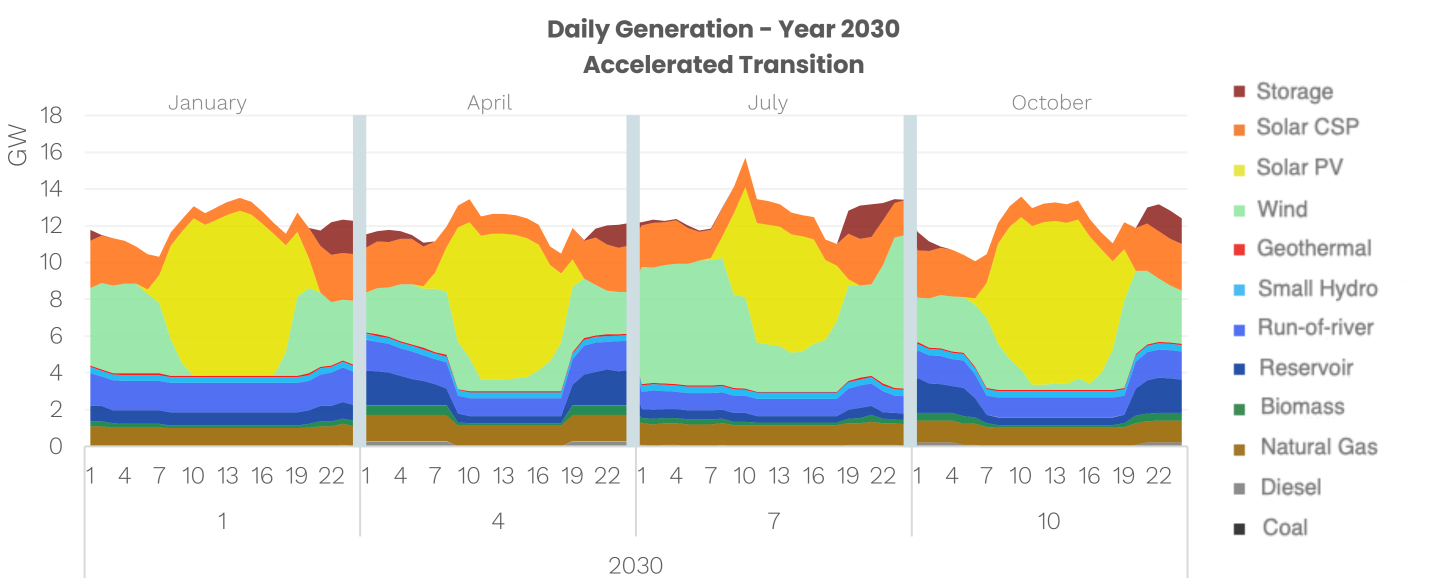
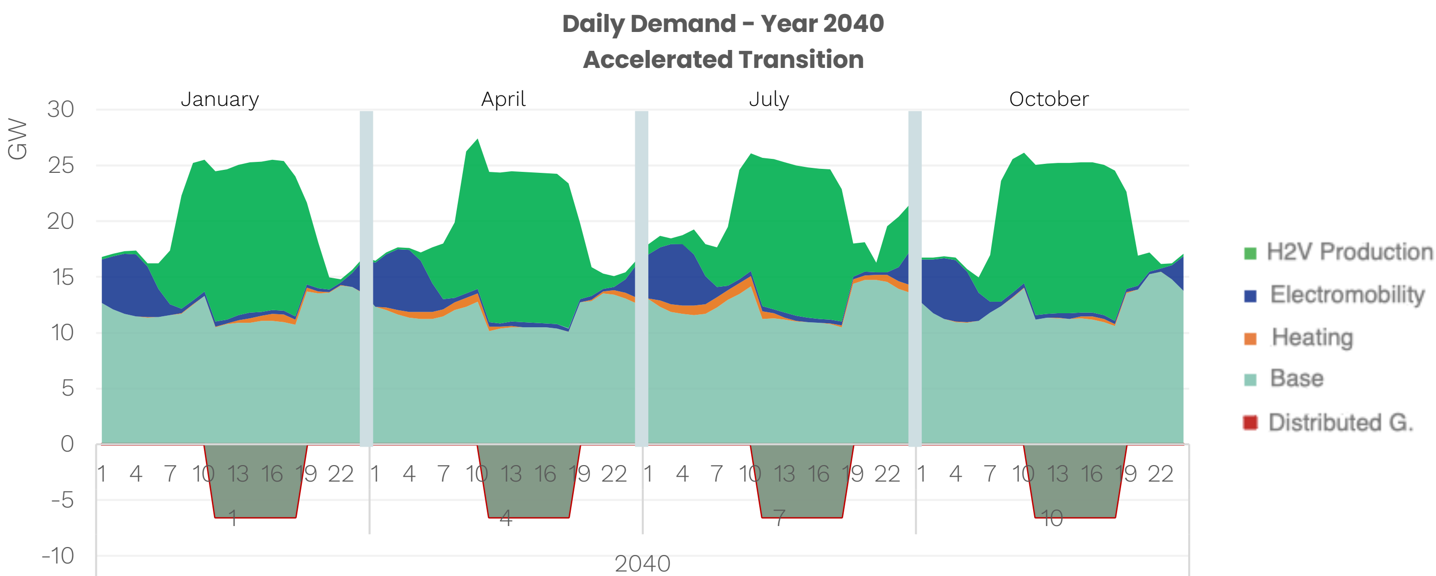
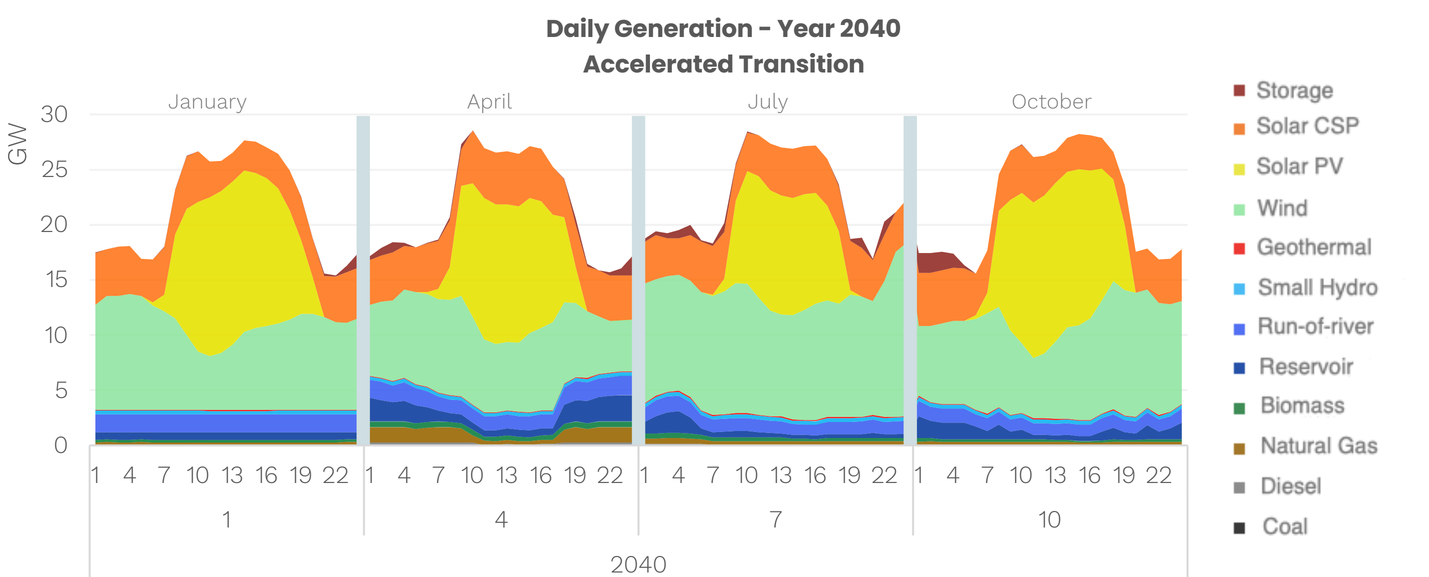
-10
2030
H2V Production
Electromobility
Heating
Base
Distributed G.

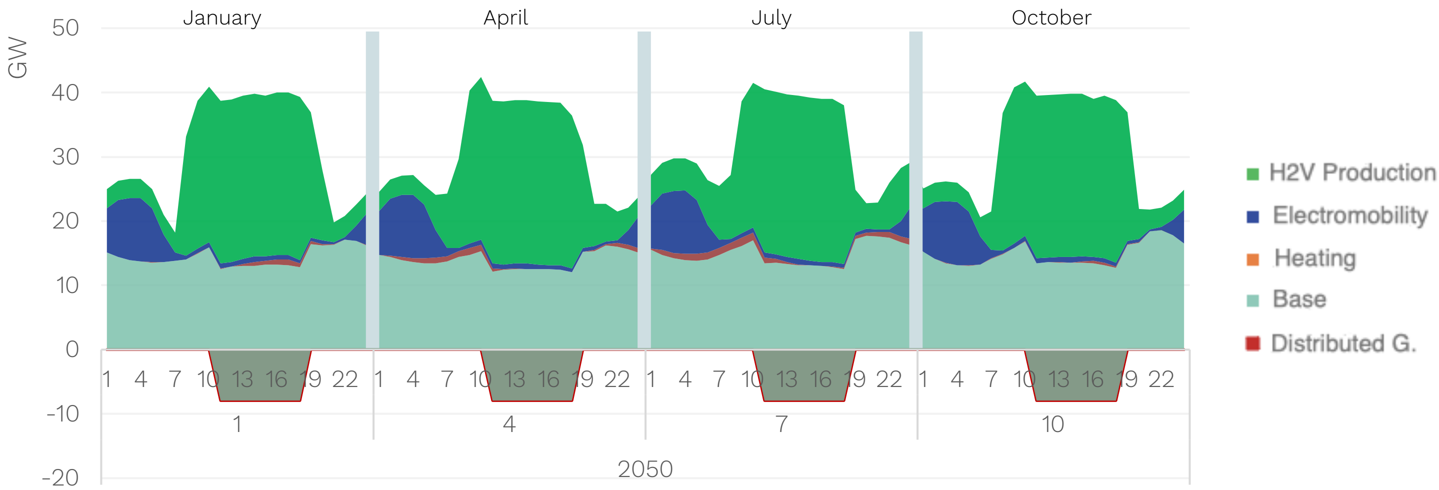


Daily Generation - Year 2030
Accelerated Transition
January
April
July
October
GW
2030
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal

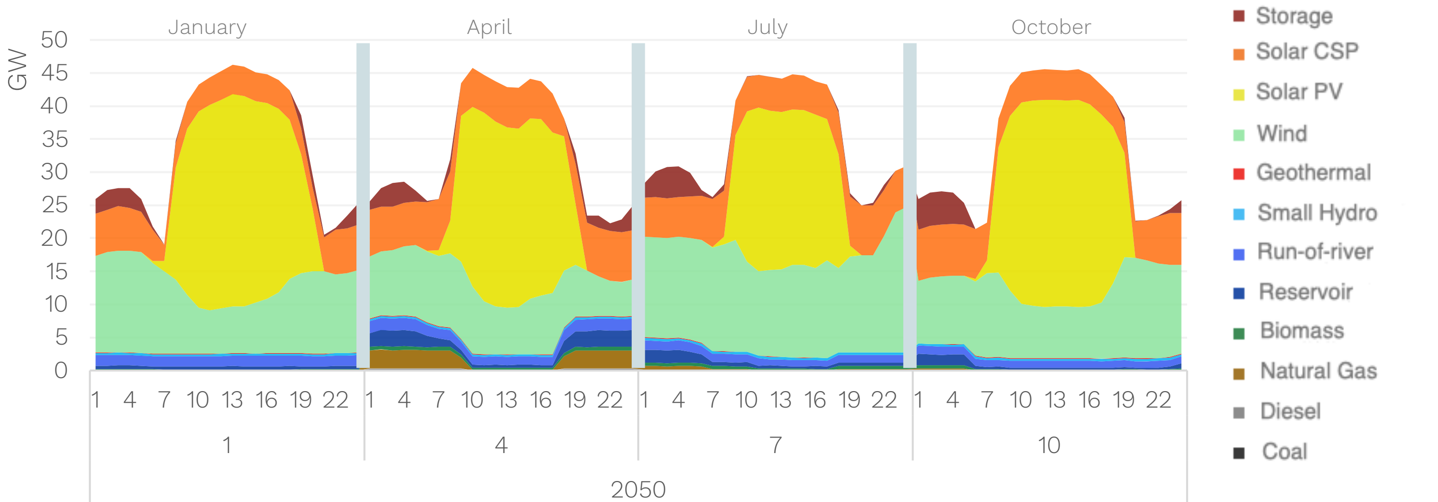

Daily Demand - Year 2040
Accelerated Transition
GW
January
April
July
October
30
25
20
15
10
5
0
-5
-10
1 4 7 10 13 16 19 22
1
4
7
10
2040
H2V Production
Electromobility
Heating
Base
Distributed G.


Daily Generation - Year 2040
Accelerated Transition
GW
January
April
July
October
30
25
20
15
10
5
0
1 4 7 10 13 16 19 22
1
4
7
10
2040
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal

Daily Demand - Year 2050
Accelerated Transition



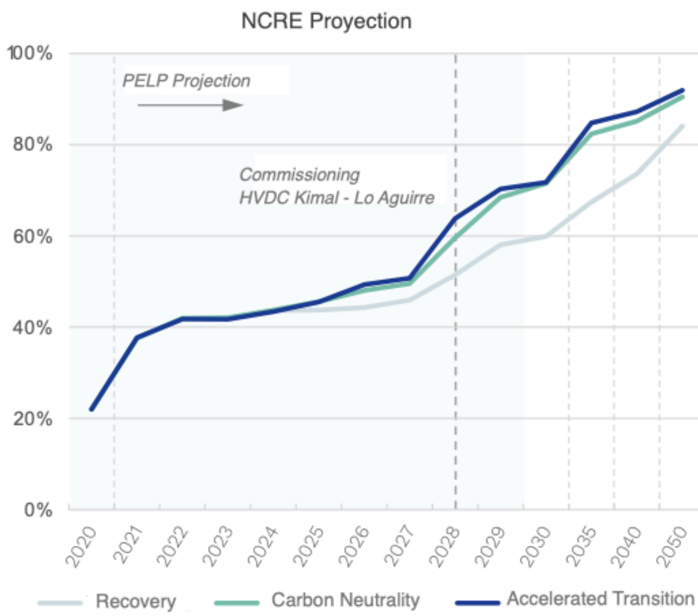
Daily Generation - Year 2050
Accelerated Transition



Main conclusions of the projected daily operation:

- By 2025, the use of electric heating starts to intensify. Likewise, the seasonality of technologies (mainly solar and hydro) allows us to foresee months of the year when technologies must complement each other. This effect makes it necessary to continue enabling the share of variable renewable energies in the security services of the system.
- Since then, it has been important to implement demand management tools that focus on new electricity consumption such as heating and electromobility. The image of an efficient operator in the distribution sector becomes fundamental and an effective incentive for consumers to manage their electricity well. The Carbon Neutrality scenario contemplates hourly management for electromobility, while the Accelerating the Energy Transition scenario considers intelligent management, and it is possible to clearly notice the differences, and the attenuation of hourly consumption, which results in a better use of infrastructure.
- In addition, the irruption of storage and manageable energies such as Solar CSP at the end of this decade, allow us to conclude that storage becomes a key element for the development of the electricity sector since renewable energies require this type of energy sources to continue entering to the grid.
- Natural gas continues to play a relevant role in the system in the long run, primarily as a supplement during months when water availability is low.
- The daily and seasonal variability of solar, wind, and water resources reveal the need to establish mechanisms for continuous improvement of projection systems. These are also essential for the projection of electricity demand.
- Optimized green hydrogen production considering short-term market signals has positive implications for the insertion of more variable renewable energies, particularly solar photovoltaics. Tools that promote management in the production of large electrical consumption, generate better conditions for the safe operation of the electrical grid and efficiencies in the use of infrastructure.

5.10.6. Storage and manageable energy



A sustained increase in non-conventional renewable energies (NCRE) is projected in the electrical power system.

Period from 2020 to 2022

The significant growth in the period from 2020 to 2022 is largely explained by the commissioning of the projects awarded in supply tenders for regulated customers.

This reinforces the role of the long-term contract market as an investment driver. Renewable and manageable energy attributes will allow investments associated with optimal portfolios required by the electrical power system, safeguarding the safety conditions in the operation.

Period from 2023 to 2027

Later, for the period from 2022 to 2027, NCRE projects continue to enter to a large extent. The incremental capacity of the period is close to 15 GW of investments in projects. For its part, electricity demand continues to grow during this period at a rate that fluctuates between 3% and 5% on average, depending on the scenario, which can be explained by plant growth and the gradual adoption of new electricity consumption.

Extremely dry hydrological conditions and the progressive phase-out of coal-fired power plants require more NCRE investment. Natural gas, in turn, plays an important role, tapering off as green taxes are projected to increase, depending on the scenario.

For its part, the connection to substations of the electrical power system is a very relevant challenge, as well as solutions for expansion and extension of the existing grid.

Period from 2028 to 2030

The commissioning of the HVDC Kimal-Lo Aguirre provides an important investment signal that translates into the start-up of a train of projects, mainly solar and wind energy in the north of the country. In this context, technologies such as solar CSPs and storage can play an important role in inserting more variable renewable sources.

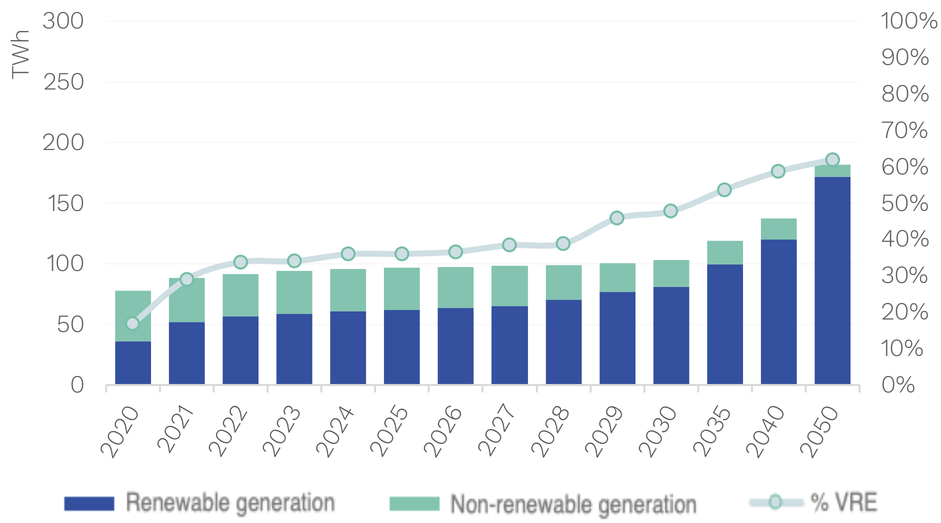
To incorporate higher levels of NCRE to more than 50% by 2030, significant levels of storage are required, greater than 2 GW. Higher consumption electrification to reduce pollution levels requires more NCRE investment, and the start of large-scale production of green hydrogen also encourages more NCRE investment.

Structural transmission works should be recommended in the short term. A portfolio of structural transmission works must be established that allows us to achieve carbon neutrality, as well as promote alternatives for optimization and reinforcement of the existing grid, enhancing the use of technologies.

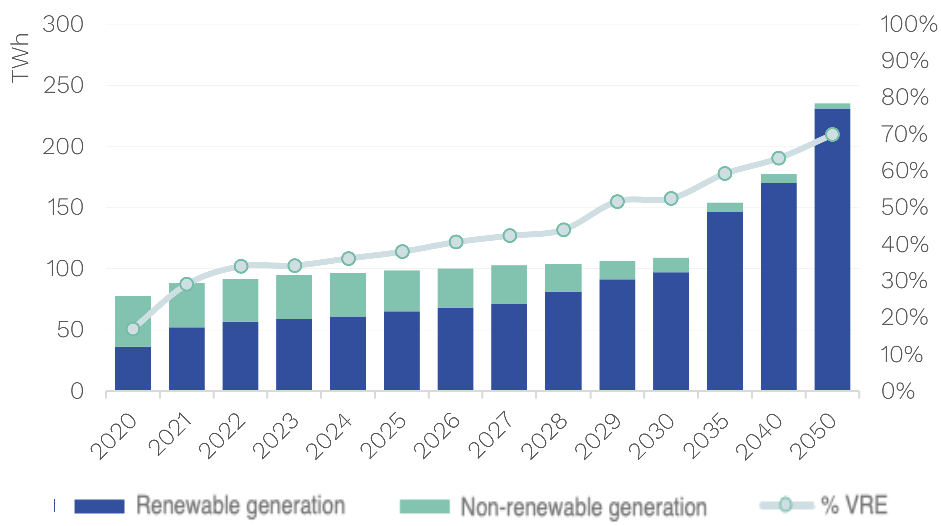
Renewable energy levels and VRE

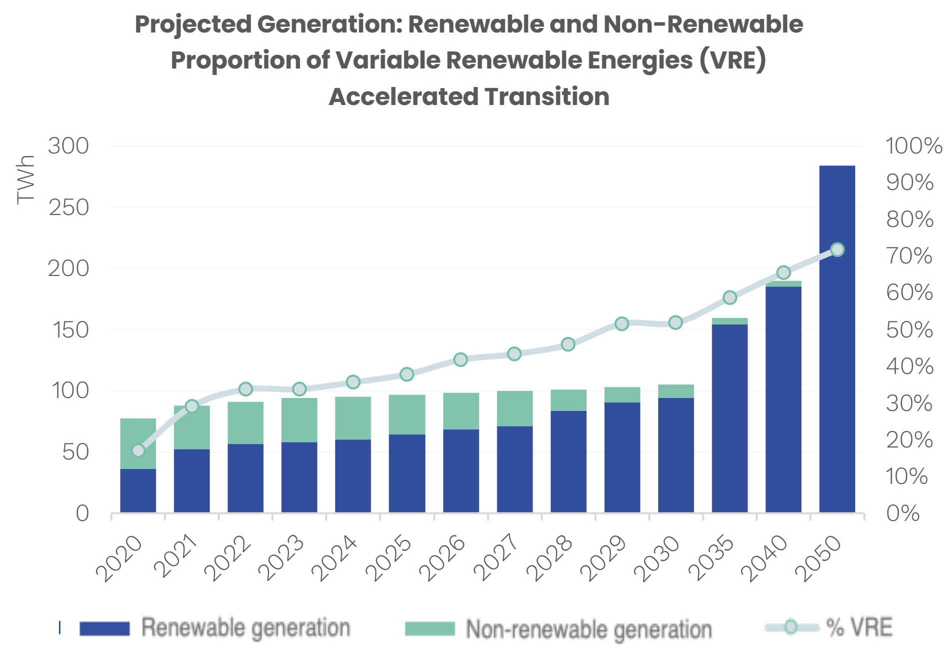
Below are the projected levels of renewable energies, and the percentage of variable renewable energy (VRE).

Projected Generation: Renewable and Non-Renewable Proportion of Variable Renewable Energies (VRE) Recovery

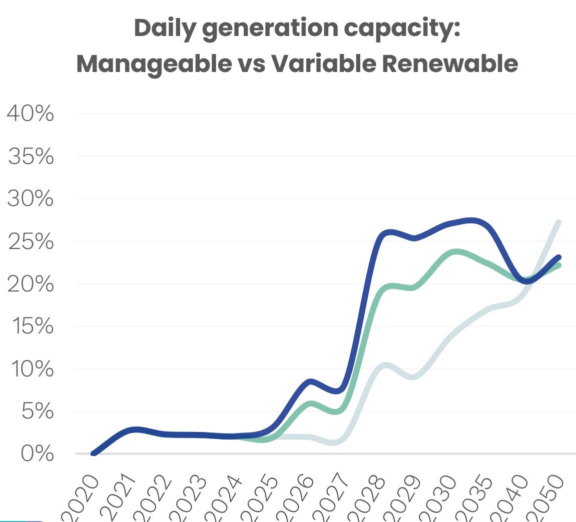


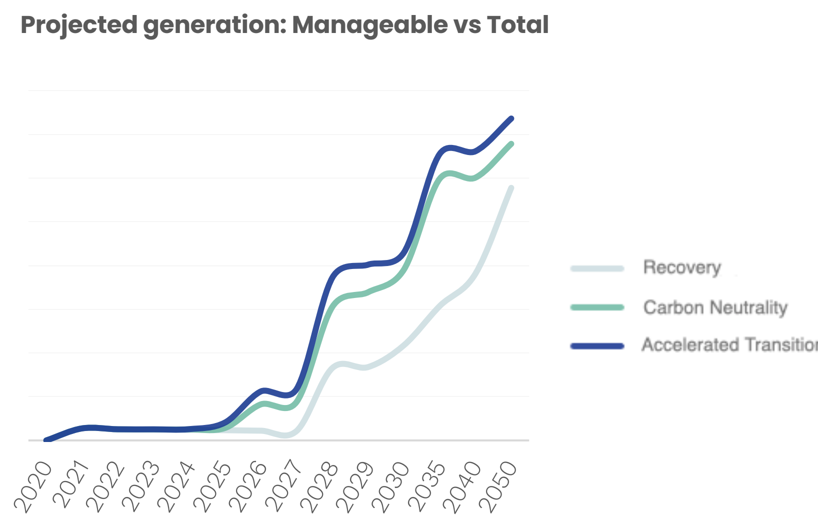
Projected Generation: Renewable and Non-Renewable Proportion of Variable Renewable Energies (VRE) Carbon Neutrality





Finally, the projections show that a level of manageable energy and/or storage close to 30% of the total energy generated by VRE sources is required. As such, the total manageable energy or storage capacity (in MW) multiplied by its available storage hours must be 30% of the total projected VRE.





5.10.7. Integration of power electronics in the electrical grid

The integration of renewables and BESS-type storage will provide the electrical power system with a large number of converters based on power electronics.

Given the levels of renewable insertion, it is expected that Chile will be one of the first countries to achieve a simultaneous operation of more than 75% of generation by variable renewable sources in some hours of the day, which is detailed in the international literature as a path *unexplored*.

This challenge opens up a great opportunity for innovation in the country. This is the decade of technology adoption and implementation. These technologies are rapidly evolving, but their implementation and use is a major task.

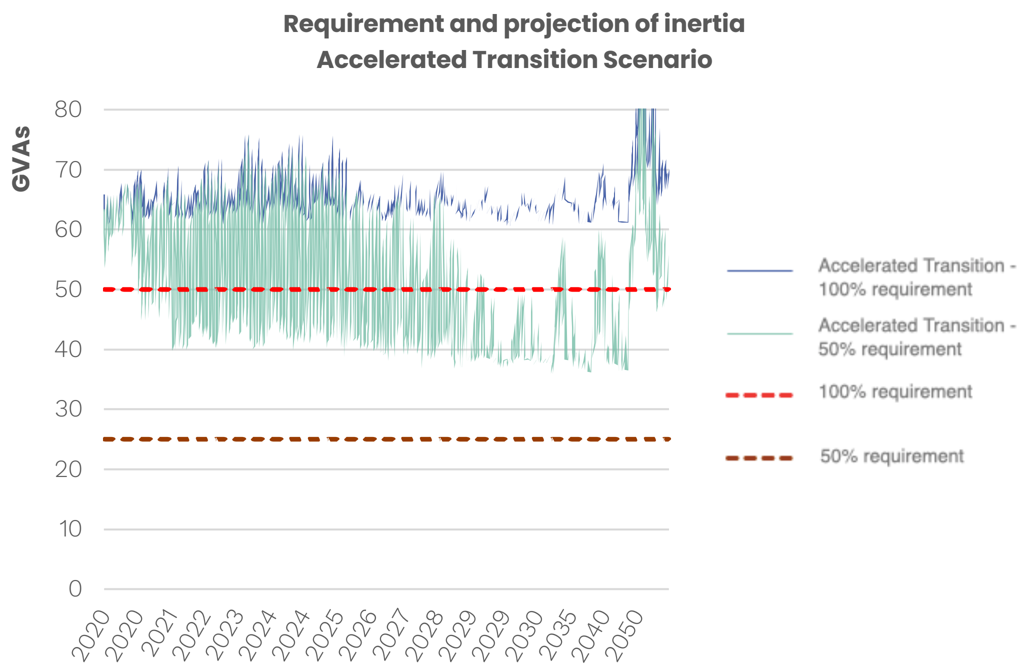
Synthetic Inertia Study
GIZ | PELP 2023-2027

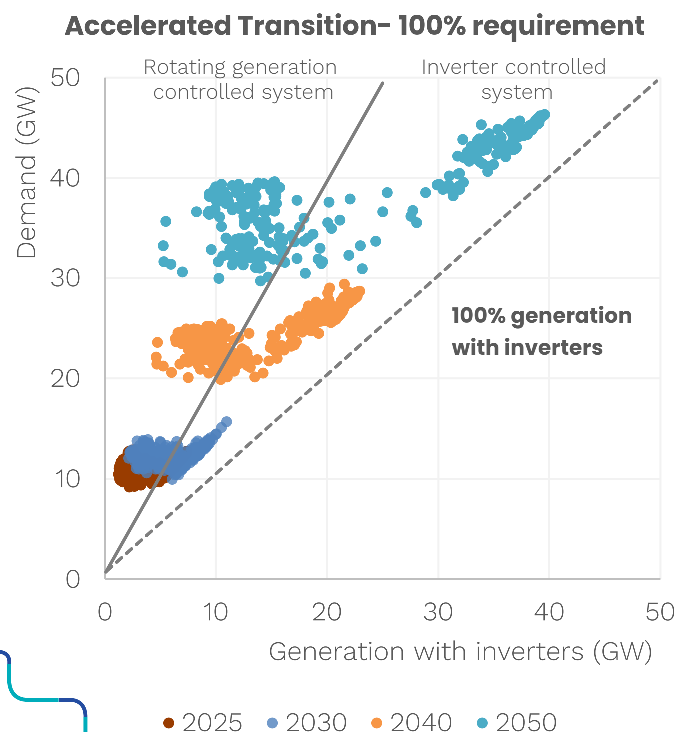
Inertia, reserves and short-circuit requirements become relevant as coal-fired power plants are phased out. There was a natural fulfillment before that, but it's less obvious today.

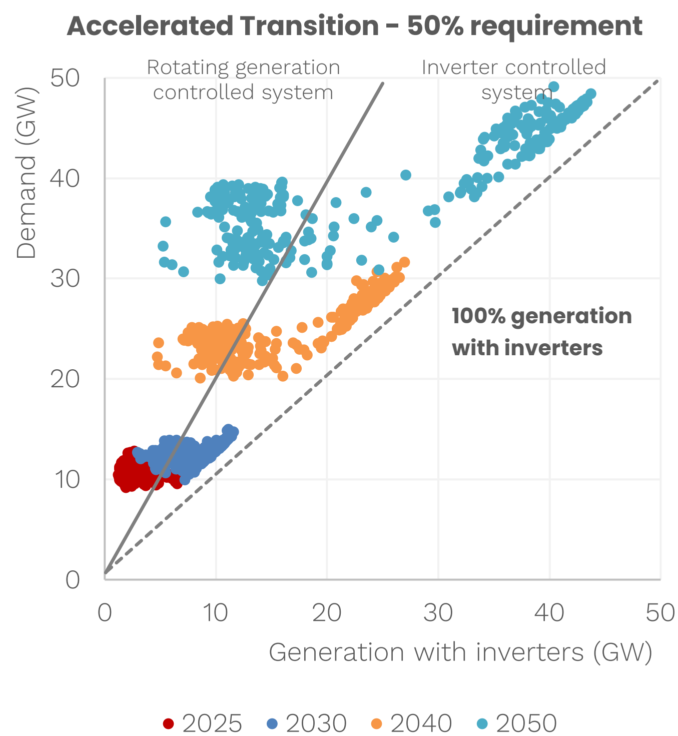
However, technological advancements have enabled solutions that provide a paradigm shift in how the electrical power system operates. Power electronics can provide security conditions to the electrical grid, but this requires a technological adoption that must already begin to take place, through pilot projects, and the digitalization and progressive automation of the operation of the electrical power system, thus directing the electrical grid of the future.

Inertia levels

Power electronics is a solution that will coexist with the traditional security measures historically provided by rotating sources. Next, comparisons are presented between an expansion considering conservative operating requirements (100% requirement) versus a situation in which said requirements are reduced by half due to the contribution to the grid security that converters based on power electronics (50% requirement) can provide. Any intermediate situation will be between both evaluations.


Requirement and projection of inertia
Accelerated Transition Scenario
GVAs
80
70
60
50
40
30
20
10
0
2020
2020
2021
2022
2023
2024
2024
2025
2026
2027
2028
2029
2029
2030
2035
2040
2050
Accelerated Transition - 100% requirement
Accelerated Transition - 50% requirement
100% requirement
50% requirement


Accelerated Transition- 100% requirement
Rotating generation controlled system
Inverter controlled system
100% generation with inverters
Demand (GW)
Generation with inverters (GW)
0
10
20
30
40
50
2025
2030
2040
2050


Accelerated Transition - 50% requirement
Rotating generation controlled system
Inverter controlled system
100% generation with inverters
Demand (GW)
Generation with inverters (GW)
0
10
20
30
40
50
2025
2030
2040
2050

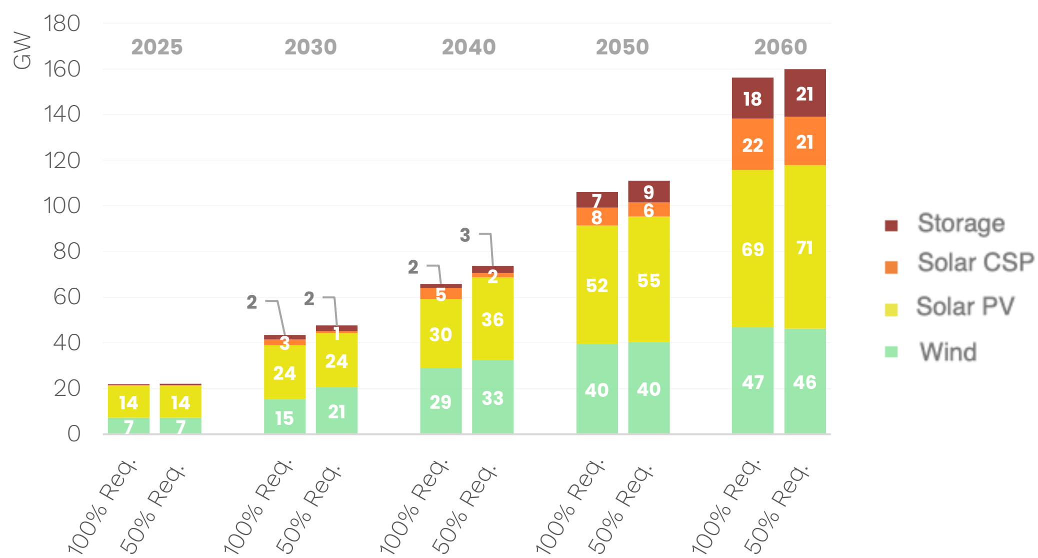
The systemic behavior is observed when the security requirements decrease because part of them are provided by converters based on power electronics, for the Accelerated Transition scenario.

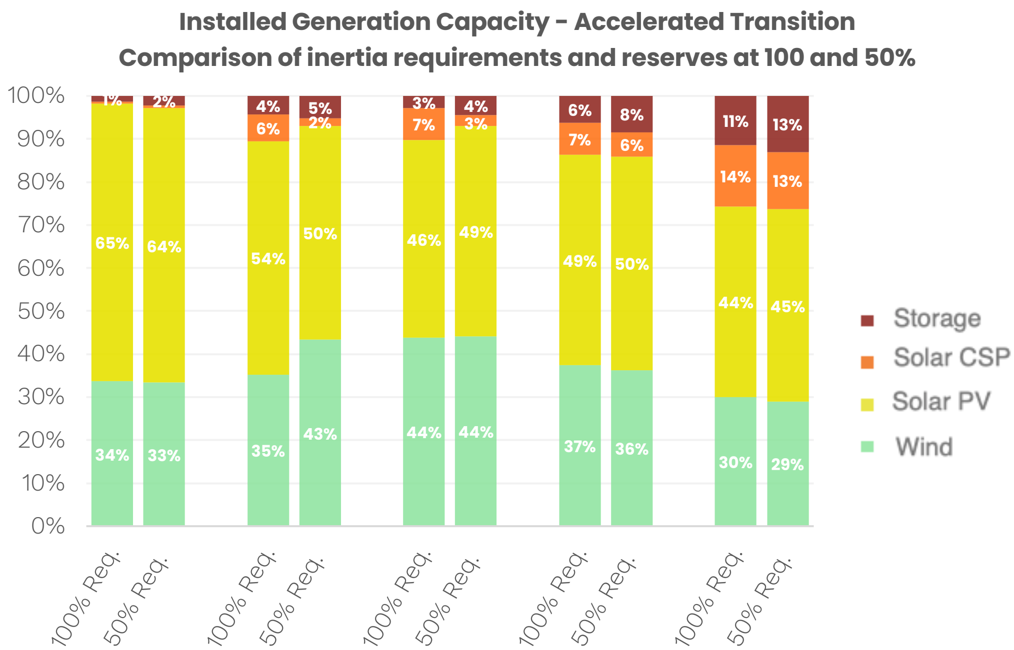
In the case of a 50% security requirement, a higher simultaneous share of VRE is observed, and the systemic inertia is always maintained over the 25 GVAs considered.

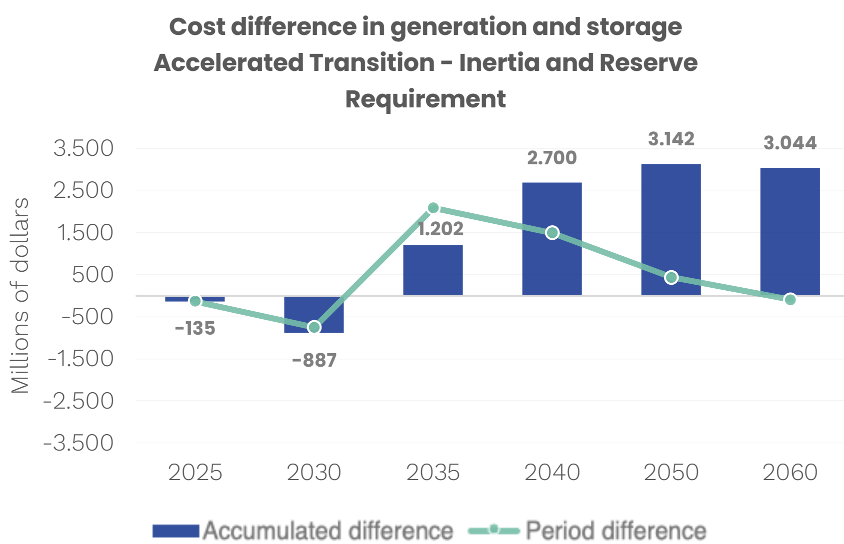
The resulting extensions of the two situations are reviewed for comparative assessment of the impact on generation investment. A condition with security provided from power electronics converters encourages greater investments in storage during the first decade, along with a more gradual installation of manageable energies, such as Solar CSP, which responds to a greater extent to a signal of operational requirements of the grid. Later, when power electronics-based converters can safely contribute to the system, wind and solar PV can enter more fields.

Finally, the economic benefits accumulated in the period could reach values close to 3,000 million dollars.

Installed Generation Capacity - Accelerated Transition
Comparison of inertia requirements and reserves at 100 and 50%



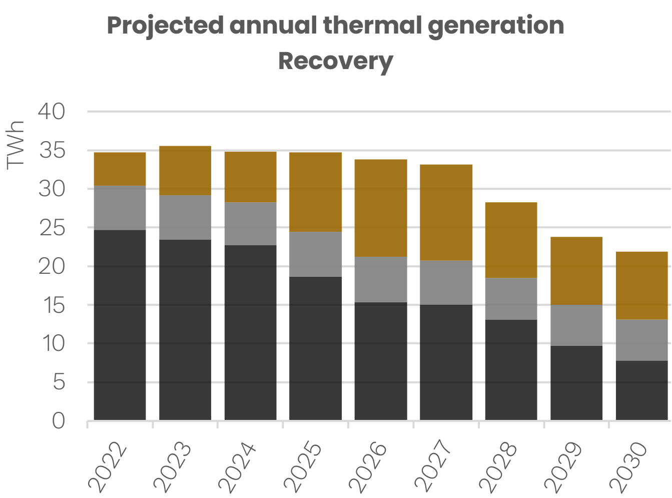

Installed Generation Capacity - Accelerated Transition
Comparison of inertia requirements and reserves at 100 and 50%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Storage
Solar CSP
Solar PV
Wind
100% Req.
50% Req.

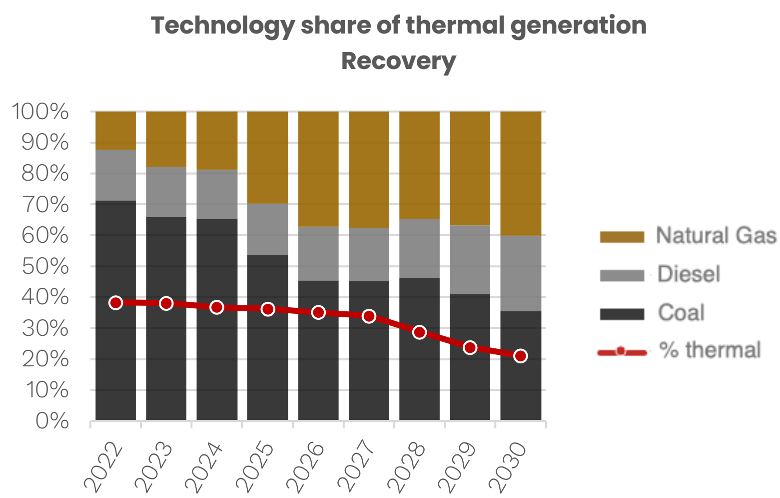

Cost difference in generation and storage
Accelerated Transition - Inertia and Reserve Requirement
Millions of dollars
3.500
2.500
1.500
500
-500
-1.500
-2.500
-3.500
-135
-887
1.202
2.700
3.142
3.044
2025
2030
2035
2040
2050
2060
Accumulated difference
Period difference

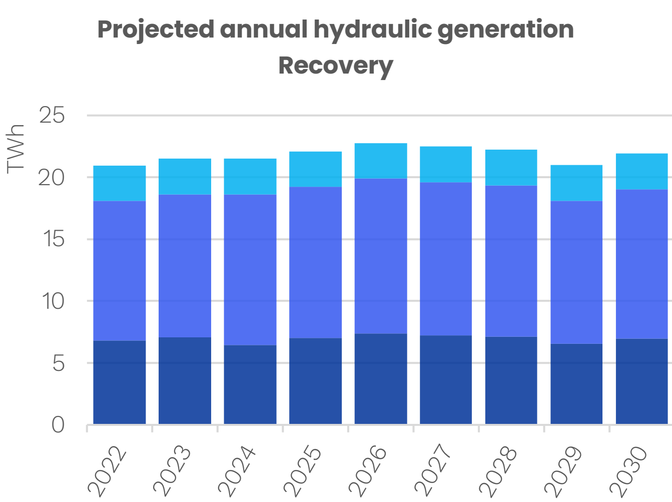
5.10.8. Thermal and hydropower generation

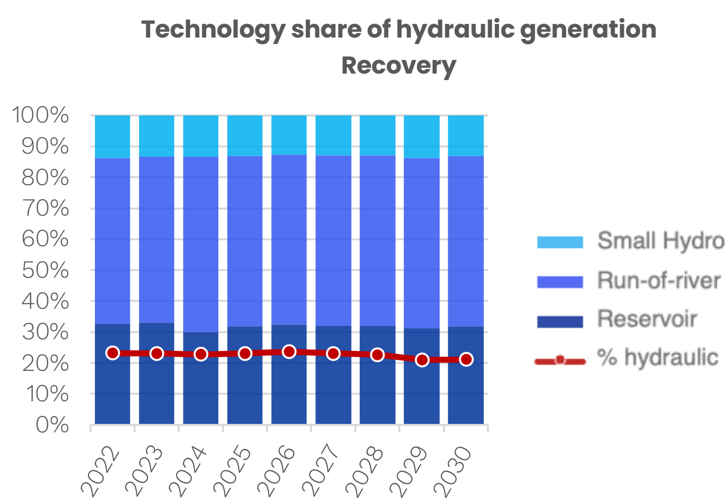
This section presents the projected generation of thermal and hydropower plants for the current decade.

Recovery Scenario

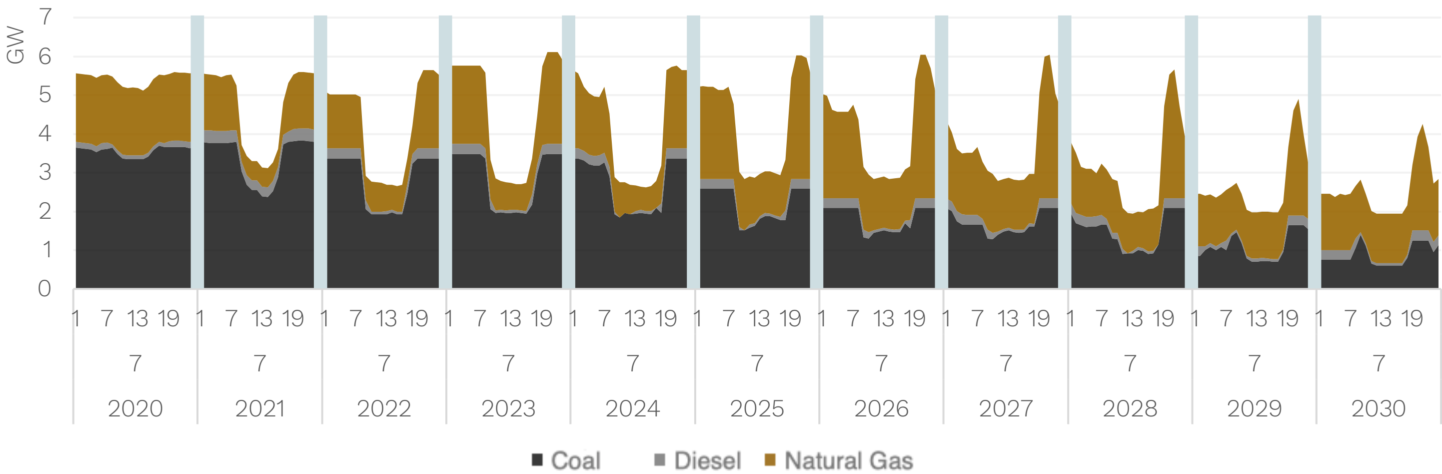




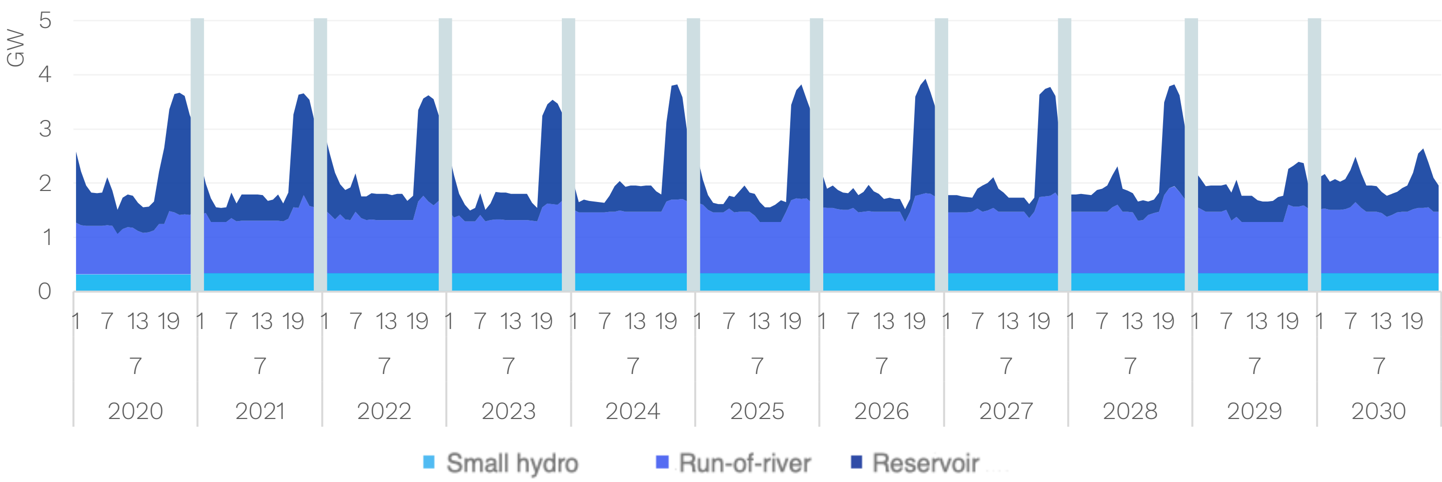




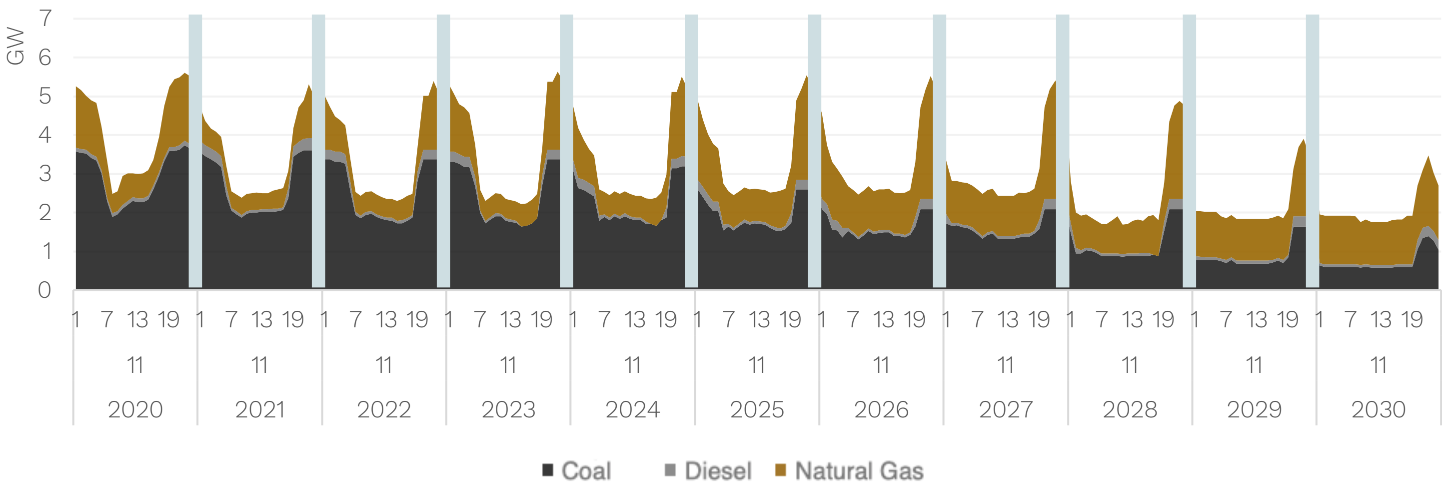
Annual thermal generation- Typical day in July
Recovery



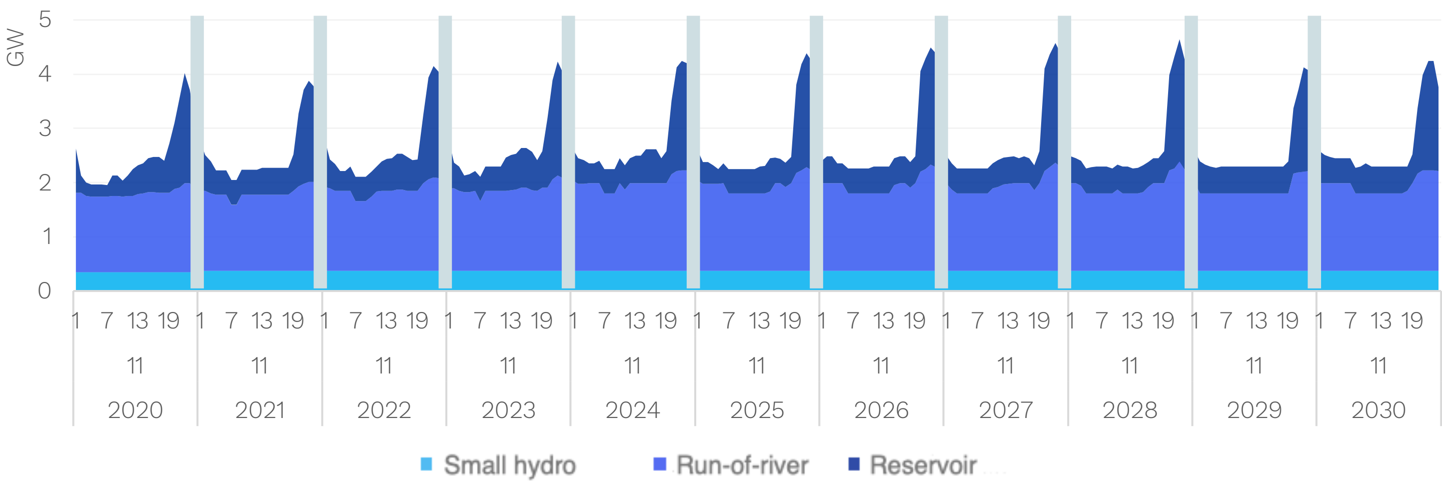
Annual thermal generation - Typical day in July
Recovery



Annual thermal generation - Typical day in November
Recovery

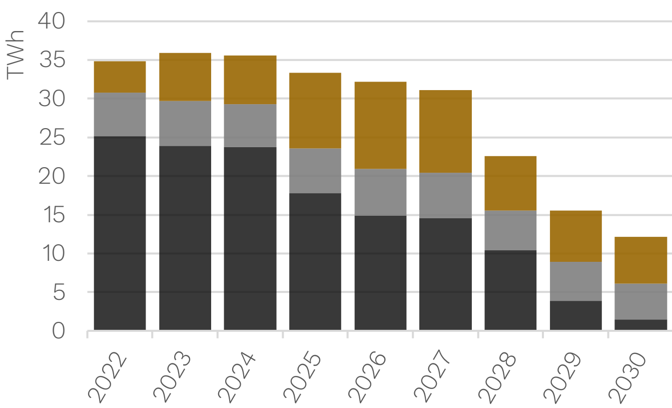


Annual thermal generation - Typical day in November
Recovery

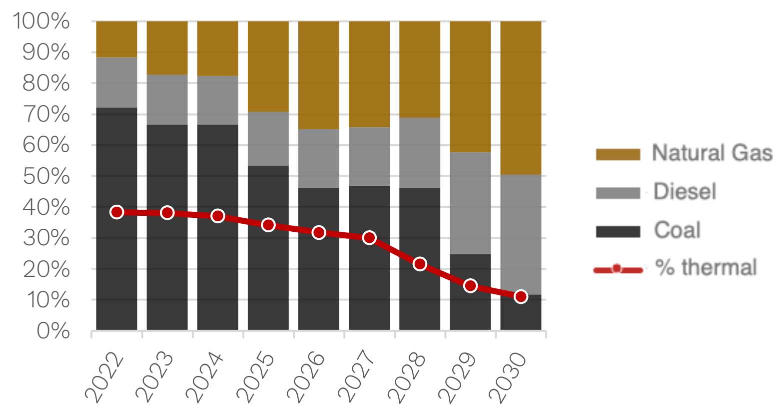


Carbon Neutrality Scenario

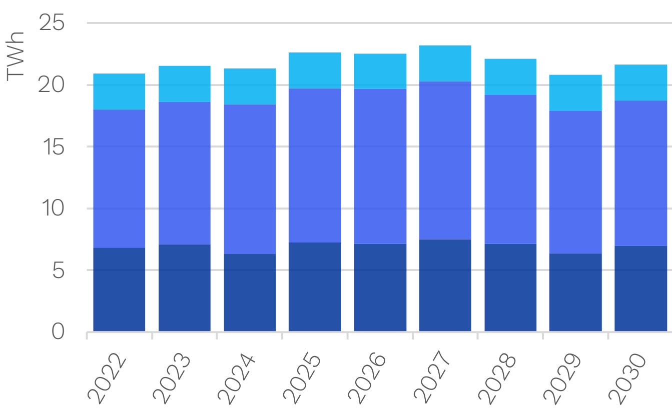
**Projected annual thermal generation
Carbon Neutrality**



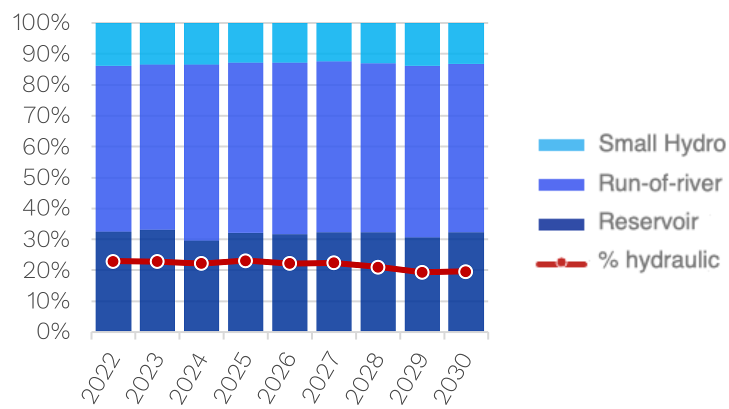
**Technology share of thermal generation
Carbon Neutrality**



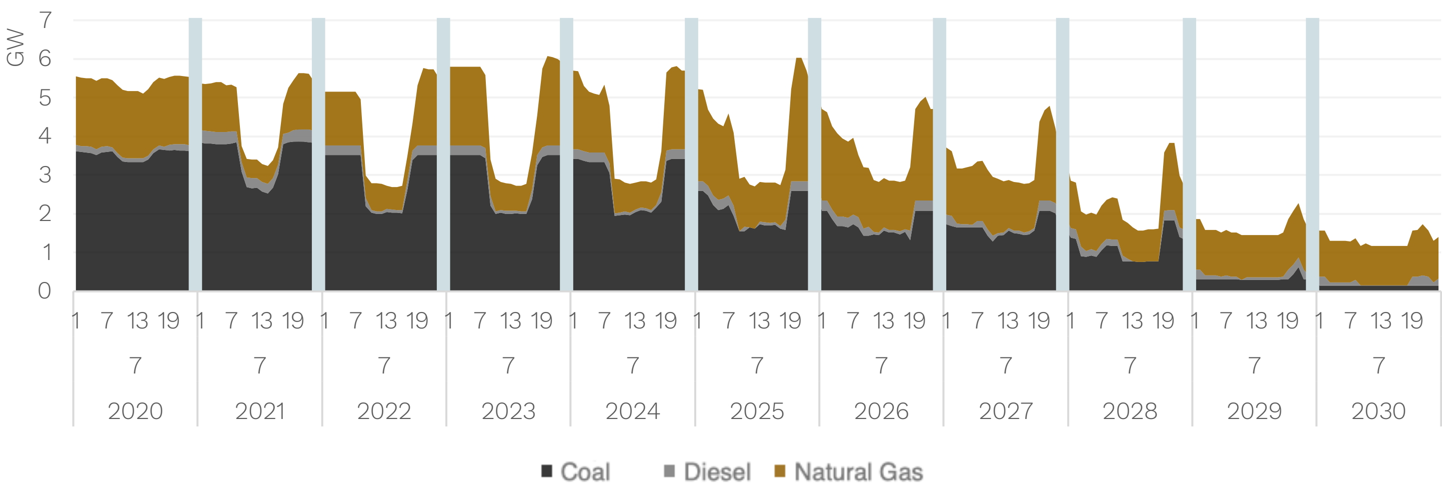
**Projected annual hydraulic generation
Carbon Neutrality**



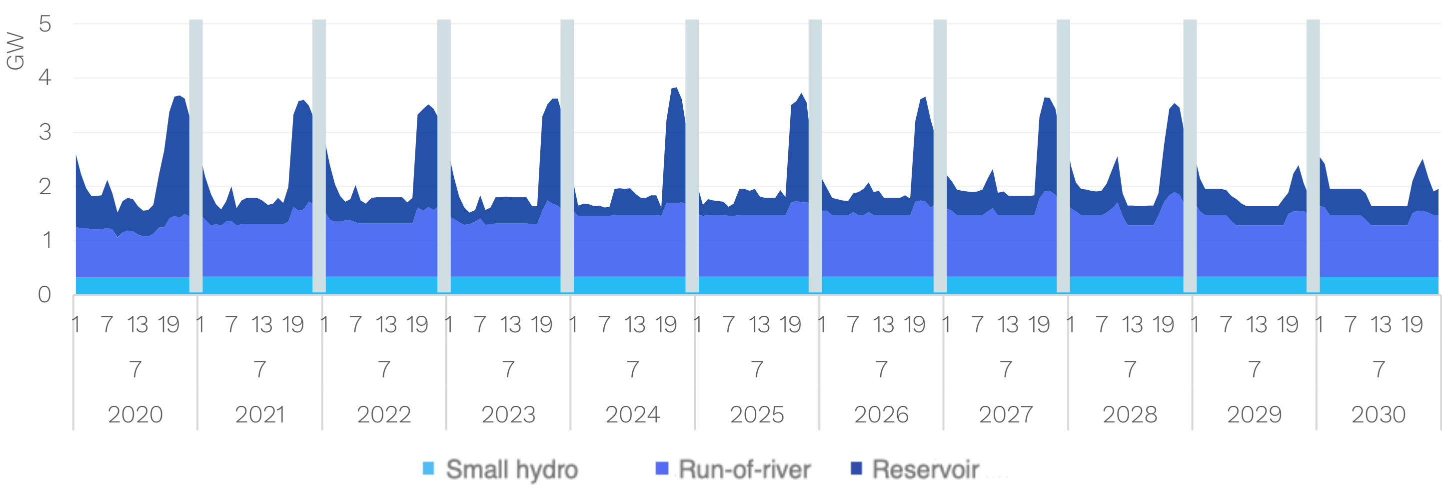
**Technology share of hydraulic generation
Carbon Neutrality**

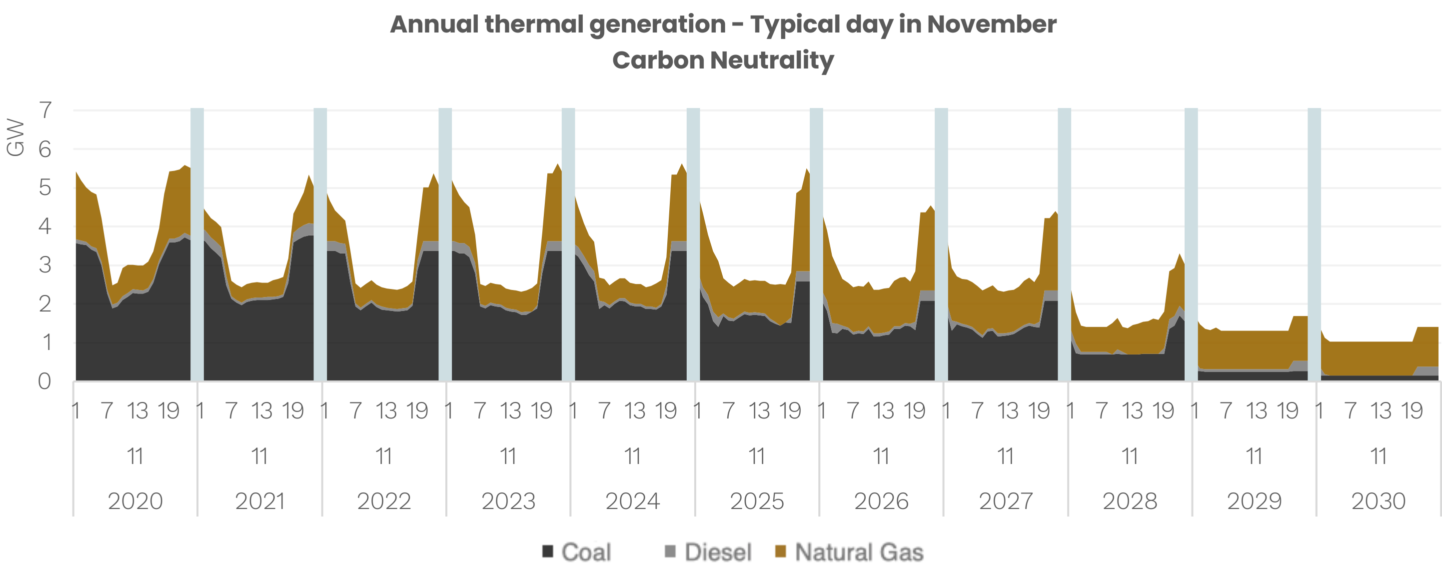


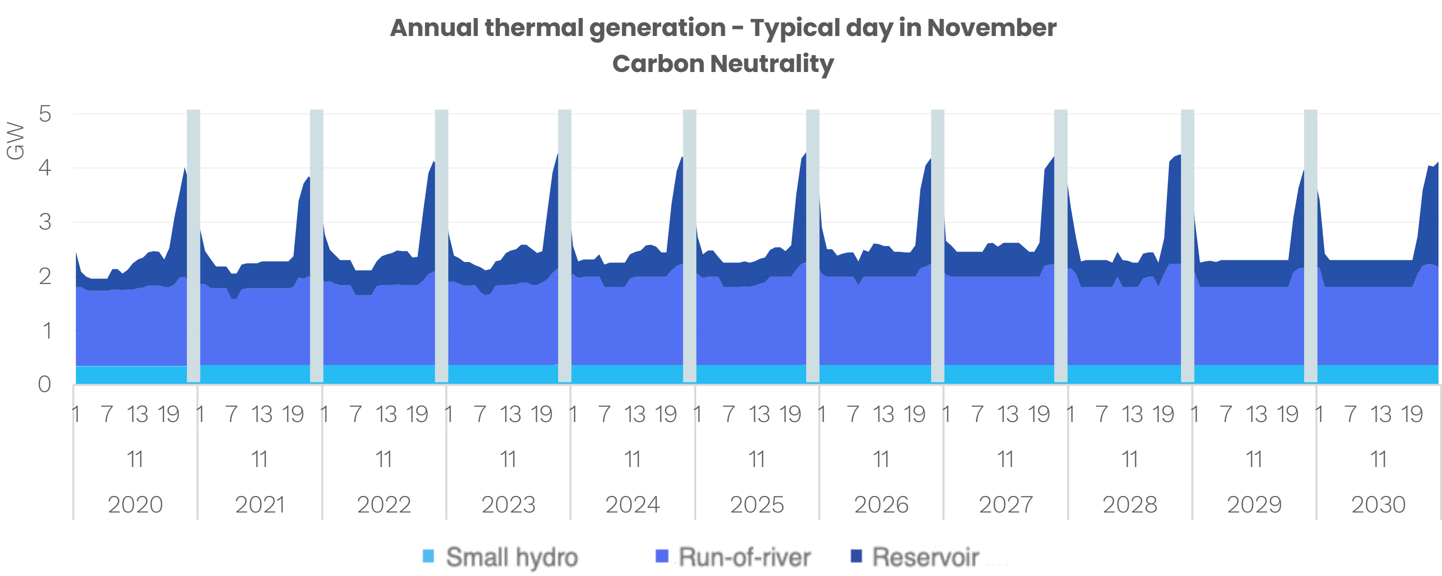
Annual thermal generation - Typical day in July
Carbon Neutrality



Annual thermal generation - Typical day in July
Carbon Neutrality

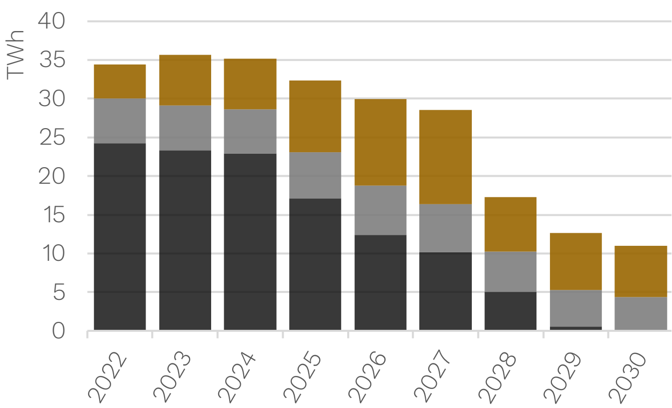



Annual thermal generation - Typical day in November
Carbon Neutrality
GW
0
1
2
3
4
5
6
7
1 7 13 19
11
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Coal
Diesel
Natural Gas

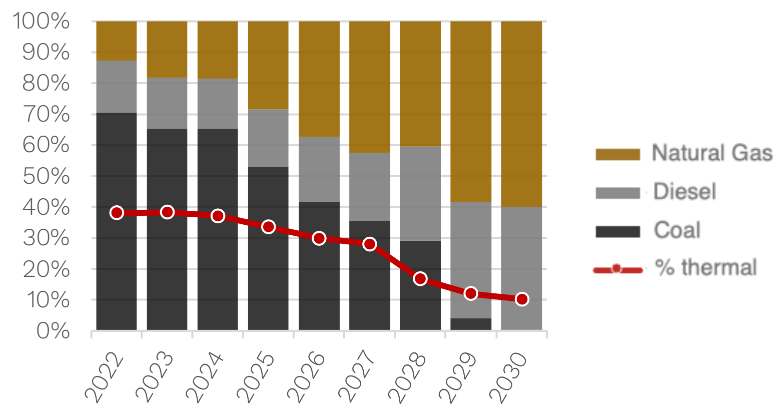

Annual thermal generation - Typical day in November
Carbon Neutrality
GW
0
1
2
3
4
5
1 7 13 19
11
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Small hydro
Run-of-river
Reservoir

Accelerated Transition Scenario

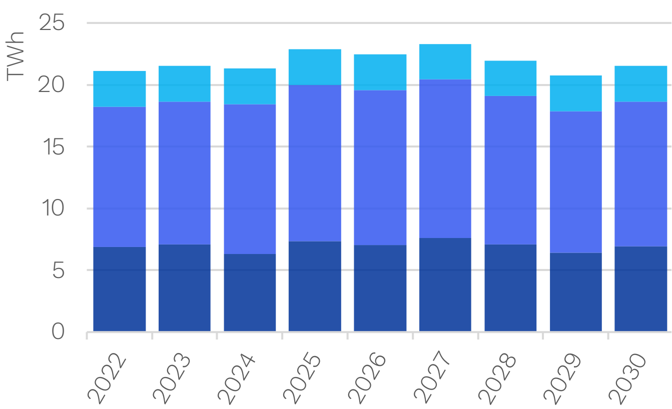
Projected annual thermal generation
Accelerated Transition



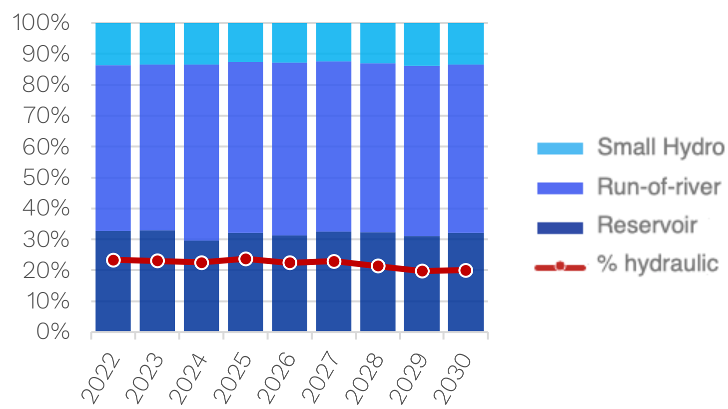
Technology share of thermal generation
Accelerated Transition



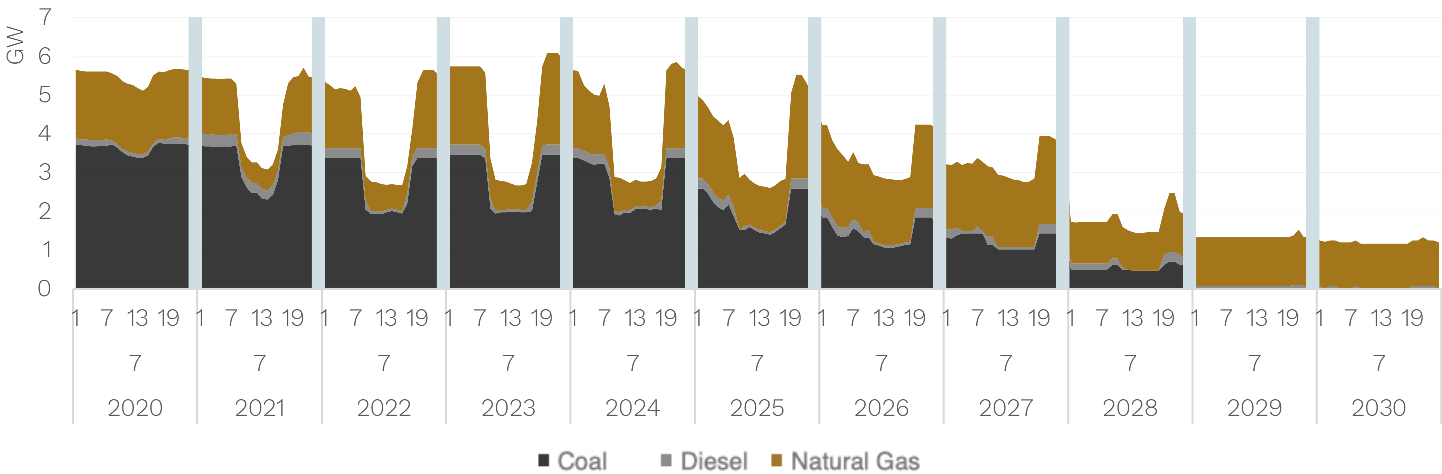
Projected annual hydraulic generation
Accelerated Transition



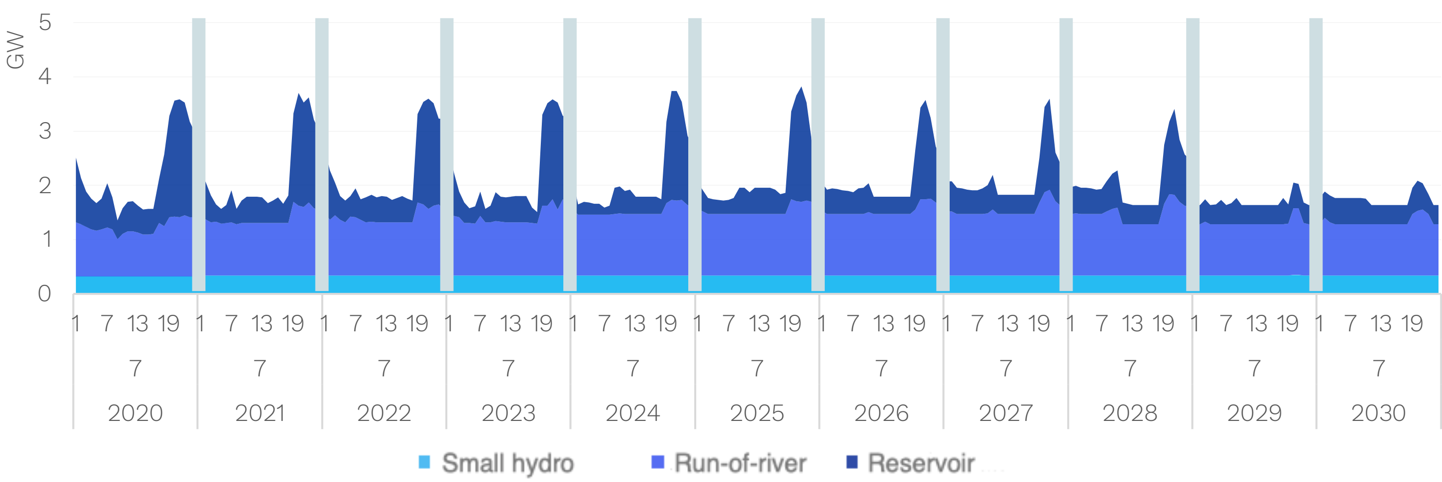
Technology share of hydraulic generation
Accelerated Transition



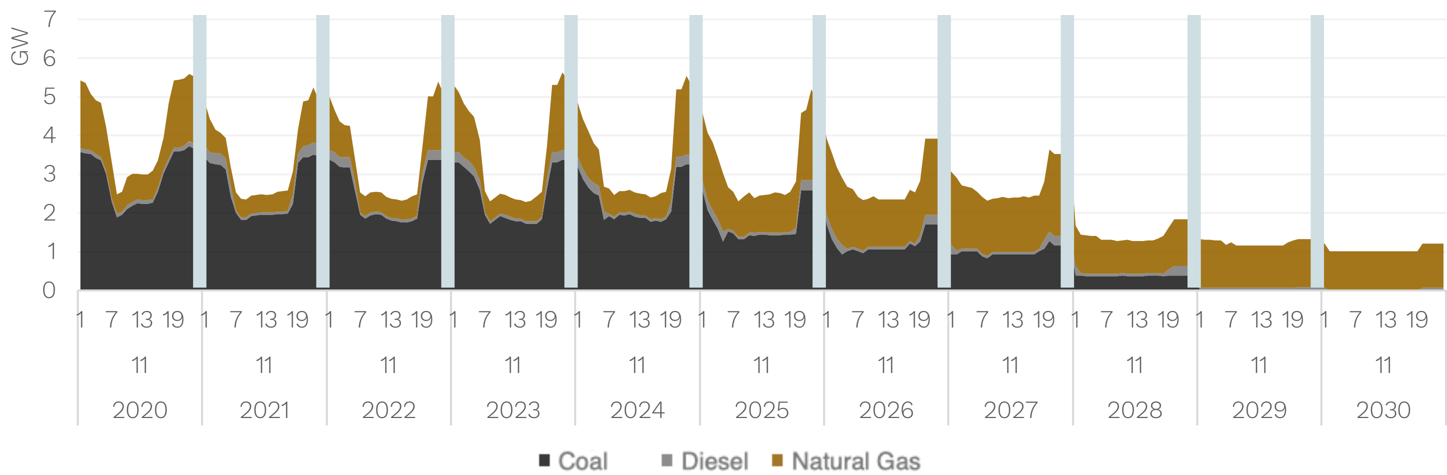
Annual thermal generation - Typical day in July
Accelerated Transition



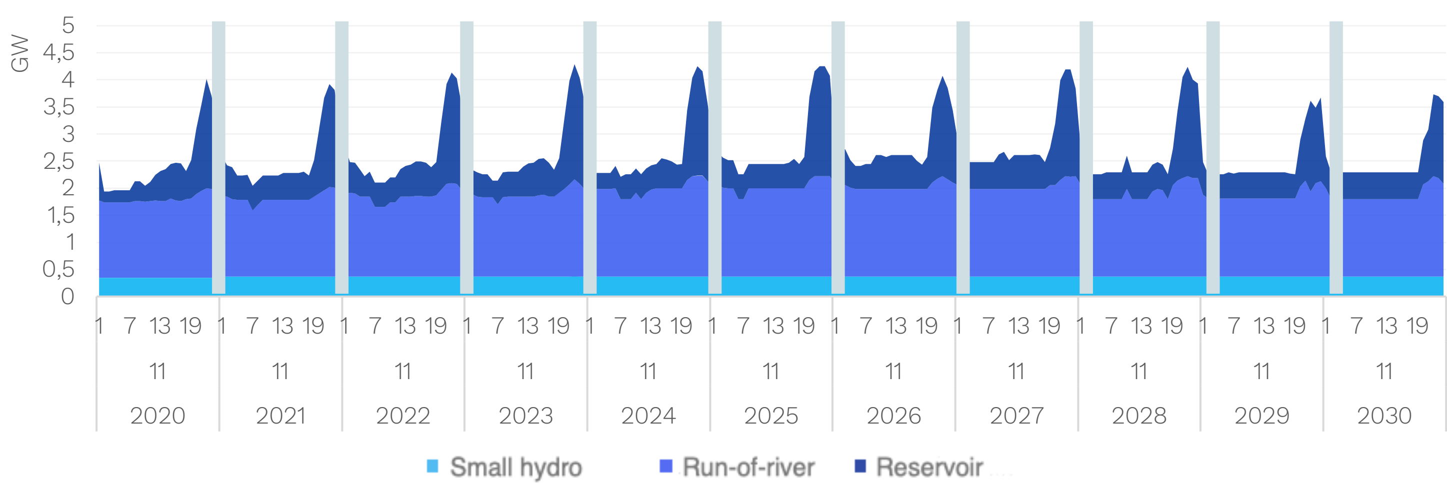
Annual thermal generation - Typical day in July
Accelerated Transition



Annual thermal generation - Typical day in November
Accelerated Transition



Annual thermal generation - Typical day in November
Accelerated Transition



The important role played by natural gas and hydroelectric energy, operating in a complementary manner, is observed. Natural gas continues to run continuously, and they support the reservoirs as demand increases and solar photovoltaic power dwindles. In addition, a seasonal complementarity is looming that may require even more natural gas in the face of drier conditions in the future.

5.10.9. Transmission

To meet the transmission requirements in the short term, different technologies and alternatives must be considered to expand the transmission capacity in the different corridors.

The PELP projections are carried out through a cooperative optimization between generation, storage and transmission. In the current decade, some sections of the electrical power system have shown signs of expansion. Owing to construction deadlines, optimization or reinforcement solutions must be promoted.

The following diagram outlines the different options for expanding the electrical power system, considering the experience of electricity operators in Germany.

Expansion of the Electric Transmission System		
OPTIMIZATION	**REINFORCEMENT**	**EXPANSION**
Short-life battery *Grid Booster*	Voltage rise	New national transmission lines
FACTS Devices	Conductor change	New zonal transmission lines
DLR Devices	Uprating	

In this way, transmission is an enabler of public policy to meet the challenge of becoming a carbon neutral country before the year 2050. To do this, considering this PELP process, it is necessary to:

1. Define **portfolio of structural transmission works** required to achieve the carbon neutrality goal considering the new energy scenarios, and the territorial location of the candidate power generating plants emanating from the PELP analysis, considering the year 2050 as the evaluation horizon.

2. Review the **grid requirements at the zonal transmission level**, and their coherence with the increases in electricity consumption at the level of consumers connected to the distribution network, driven mainly by electric heating and electromobility.

3. Define the **sections of the system that can increase capacity by optimizing or reinforcing solutions**, and those that are limited for other reasons such as system stability or others.

4. Identify **optimization or reinforcement works to increase the corridor's capacity in the short and medium term** while completing the structural works currently underway.

5. Incorporate the quantitative analysis to the economic evaluation methods of transmission works, allowing the consideration of different **transmission attributes as specified in Article 87** of the General Law of Electric Services (GLES).

5.10.10. International interconnections

To date, Chile-Peru and Chile-Argentina interconnection analysis studies have been carried out, which are not affected by the new energy scenarios.

In any event, the technical demands needed to achieve each assessed project will be reviewed in the update as progress is made in terms of regulatory conditions with neighboring countries.

Chile-Peru Interconnection Study
Inter-American Development Bank

6. Transmission Strengthening

Poles for sustainable development

6.1. Definition of development poles

In general, electricity generation projects are connected to the electrical grid using dedicated transmission systems i.e., lines that are planned and executed privately, and that connect the respective projects with the national and/or zonal transmission systems.

Therefore, the expansion plan of the National Energy Commission does not contemplate transmission solutions aimed at collecting electricity generation to connect it to the National Electric System. However, this can be changed using the regulatory tool set out in the General Law of Electric Services (GLES) in 2016: transmission systems for electricity generation development poles.

Infographics
"Development Poles"
PELP 2023-2027

This is how, in those territorial areas of the provinces that are identified as development poles, the transmission expansion plan can incorporate transmission solutions that allow the collection of renewable generation in areas where significant development of these projects is expected, hand in hand with several development companies.

To this end, PELP identifies provinces as potential development poles and then analyzes the best sustainable development options through a Strategic Environmental Assessment (SEA) to incorporate renewable energies in those provinces.

Importance of a development pole

Energy planning has the potential to identify in advance areas that will have significant development of renewable energy projects over time. This situation should be reflected in the reality with several development companies locating renewable energy power units in the above-mentioned areas, facing the challenge of connecting their respective projects to the National Electric System.

This is where two situations can be identified:

1. **Without poles:** In a province that has not been declared a development pole, the transmission solutions that connect the projects with the rest of

the electrical power system will be planned and developed by the respective promoting companies.

In this case, two situations may arise: a) each project is independently connected to the grid through its own transmission solution, or b) different projects develop transmission solutions to be connected to the grid together.

In general, the most efficient from an economic and territorial point of view, in the case where there are different renewable projects located in neighboring areas, is to seek joint solutions so that a single transmission system can connect multiple projects: less land is used, fewer connection positions are used in the existing substations of the National Electric System and solutions with less territorial impact are promoted.

These situations can be achieved through agreements between different companies; however, in some territories, national planning may be required to promote efficiency, order and competition in the connection of renewable energy projects to the electrical grid.

2. **With poles:** In provinces that are declared a development pole according to the definition of the General Law of Electric Services (GLES), a Strategic Environmental Assessment (EAE) will be carried out in the first instance that allows defining the best sustainable solutions for the connection of renewable energy projects to the National Electric System.

   After that, these provinces are enabled so that the National Energy Commission can plan and propose transmission solutions that allow the collection of renewable generation with the National Electric System in the best possible way, making efficient use of the transmission and the territory, as well as promoting greater competition in the development of electricity generation projects.

   The transmission solution will facilitate the connection of different renewable projects located in adjacent areas through a single transmission system rather than multiple separate ones.

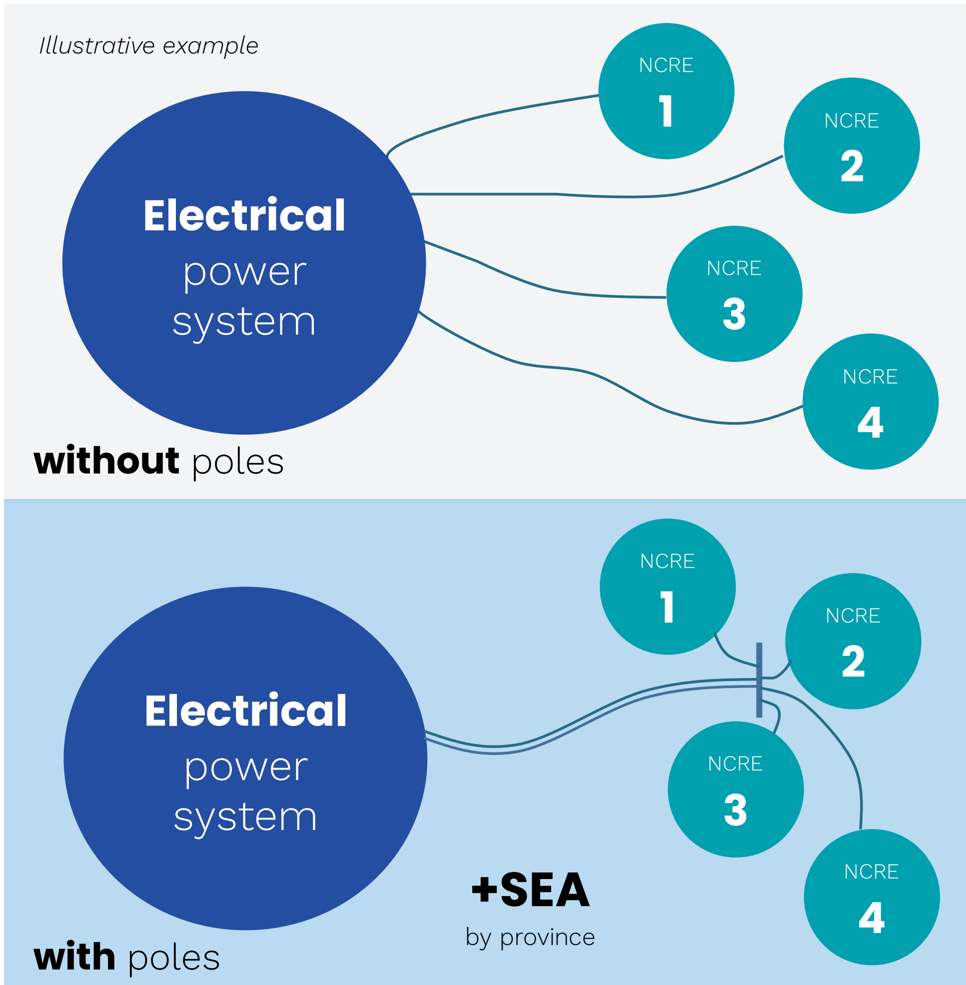
   A transmission system for poles is planned by the State and built by tender. Once the renewable energy projects are connected, transmission costs will be endorsed in proportion to the total capacity of the transmission solution in proportion to the capacity used.

   Of course, a transmission solution for development poles will present attributes that will make it more efficient for the payment of the projects that use it and for the resulting rate for clients: economies of scale, promoting greater competition in the electricity generation sector, making efficient and sustainable use of the territory, promote renewable investments in zones and/or areas that aim at sustainability.

Illustrative example

The following figure presents two cases to illustratively exemplify the benefit of development poles. Four renewable projects located in the same area must be connected to the electrical grid: without poles (and without coordination between the different development companies), and with poles. In the first case, each project is connected to its own transmission solution, while in the second, the connection is facilitated through a single, stronger and more efficient transmission system, which minimizes the number of kilometers of connection lines between the four renewable projects and the National Electric System.

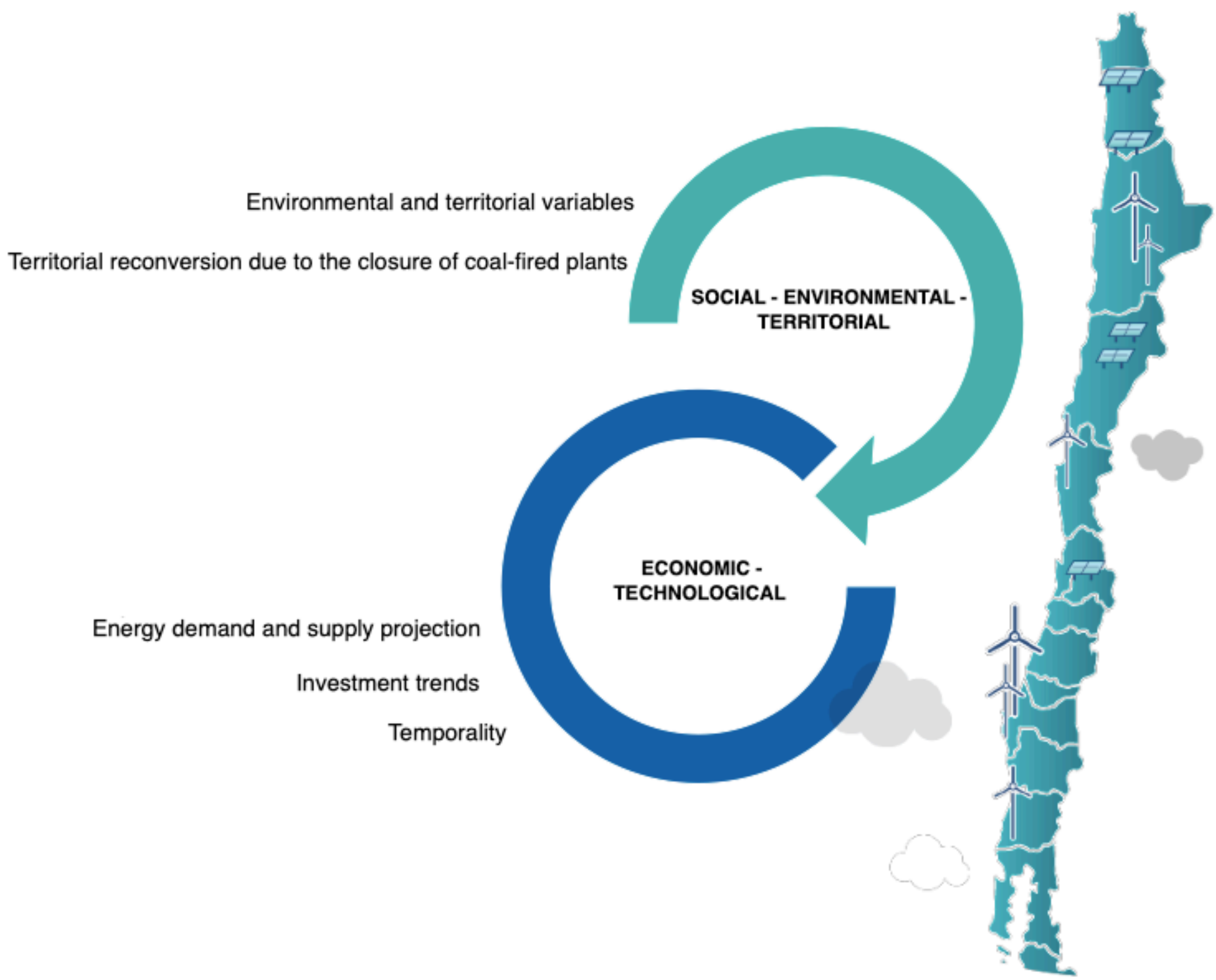
The territory is used in a better way and a more efficient use is made of the positions available in existing substations of the National Electric System.


Illustrative example
Electrical power system
NCRE 1
NCRE 2
NCRE 3
NCRE 4
without poles
Electrical power system
NCRE 1
NCRE 2
NCRE 3
NCRE 4
+SEA
by province
with poles

6.2. Selection criteria of candidate provinces for power generation development poles

In order to identify candidate provinces for Generation Development Poles, criteria that respond to two dimensions were used:

1. Social-environmental-territorial.
2. 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 times of 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 from natural renewable sources. Likewise, it is a criterion that will be deepened later in the framework of the planning of each one of the Development Poles of Electric Power Generation.

- **Territorial reconversion due to the closure of coal-fired power plants:** This criterion considers the Ministry of Energy's Phase-Out and/or Reconversion Plan for Coal-fired Power Plants to prioritize those territories involved in the closure processes and where there are significant challenges, but also great opportunities such as 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 role of the Just Transition Strategy of the energy sector prepared by the Ministry of Energy and now in public consultation [31] is highlighted, where the generation of renewable energies contributes to economic development and local employability, being able to mitigate what the closure of a power plant could cause.

The economic-technological dimension addresses the effectiveness and feasibility of implementing renewable projects in different provinces of the country. To this end, the work was carried out according to three general criteria:

- **Projection of energy supply and demand:** This criterion considers the growth of renewable capacity so that the projected energy supply in the provinces must be relevant in a medium-term time horizon and the projected capacity levels must point to the development of multiple

[31] https://energia.gob.cl/consultas-publicas/estrategia-de-transicion-justa-en-el-sector-energia-parte-i-acompanando-el-cierre-yo-nuevos-usos-de-centrales-carbon-en-chile

projects in the same area, and the probable project development i.e., that the projected growth in a territory should be contained in all PELP scenarios.

- **Investment trends:** This criterion addresses, on the one hand, the public 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 a current RCA (Environmental Qualification Resolution) as a signal from the investment, and the needs of new capacity and number of projects interested in connecting to the grid, integrated through information from the open access process of the National Electricity Coordinator.

- **Temporality:** 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 PELP five-year 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.

This definition uses the proposals that were collected in the participatory processes as input. In particular, within the framework of Workshop 1 devoted to this issue, the criteria proposed by the participants were presented, which were divided into the two dimensions shown. To define the treatment of the proposed elements, a proposal was drawn up, collected at different points in the planning process according to the scale and scope of their application. In this way, as can be seen in the following table, only some of the proposals that emerged in the social-environmental-territorial dimension could be directly included in the selection criteria of provinces candidate for Generation Development Poles:

Dimension	Criterion	Workshop 1 Proposals - Poles
Social-environmental-territorial	Environmental and Territorial Variables	• Energy potential • Presence of protected population • Limit areas with visual impacts (e.g., ZIT) • Protection sites of cultural significance • Demographic development (sufficient population distance)
	Territorial reconversion due to the closure of coal-fired power plants	• Closure zones of coal-fired thermoelectric plants (case-by-case analysis)
Economic-technological	Projection of energy supply and demand	• Plant factor of energy potential • Long-term demand projections • Economic efficiency of the transmission solution • Capacity of the existing transmission system in the territory
	Investment Trends	• Capacity of the existing transmission system in the territory • Demand for private projects in the sector
	Temporality	• There were no proposals

For their part, matters were identified that will be addressed in the framework of the planning of each Generation Development Pole, either in the base analysis, in the planning itself and/or in the Strategic Environmental Assessment, as can be seen in the following table:

Workshop 1 Proposals Development Poles	**Territorial Analysis**	**Pole Planning**	**SEA of the Pole**
Presence of protected population	-	Territorial valuation objects	
Limit areas with visual impacts (e.g., ZIT)	-	Territorial valuation objects	
Demographic development (sufficient population distance)	-	Distance from rural human settlements	
Social and environmental territory saturation (e.g., MW installed/area; or maximum limit of projects)	Distribution of loads and efficient use of the territory		
Harmony with existing territorial planning instruments	Territorial planning framework		
Areas (vocation) with opportunities for productive development	Land uses and trends		
Participation of inhabitants of the territory		Citizen consultation	
Positive impact it could have on local development	-	-	Environmental effects
Cost-benefit analysis considering socio-environmental effects	-	-	Environmental effects
Consistency with criteria of other State agencies	-	-	Coordination with State Administration Organizations

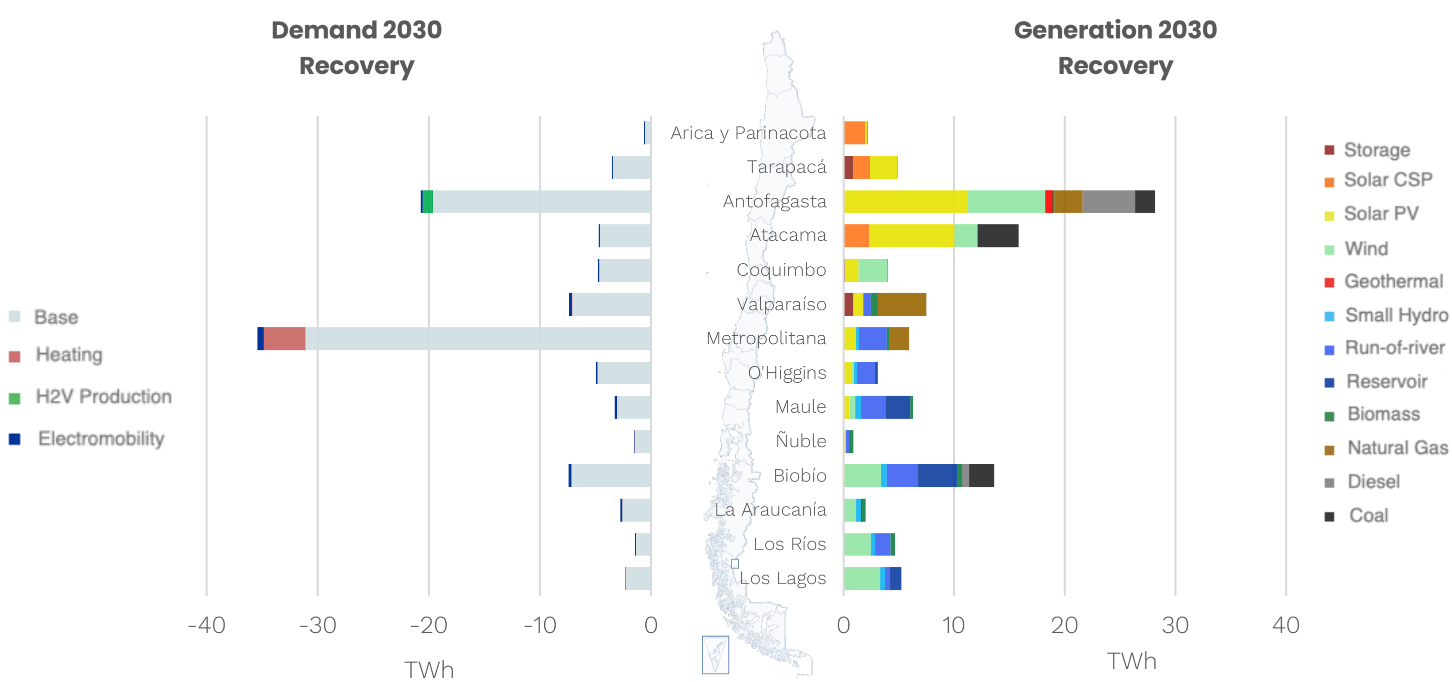
Finally, there were 2 proposals that could not be considered. One refers to "Where it is necessary to improve the quality of service for end customers", which was not considered since it does not correspond to the scope of competence of the Generation Development Pole. Likewise, the proposal to "Prioritize those territories where the largest population benefits" also exceeds the scope of action of the instrument, but it is also in contrast to the proposal for "Demographic development (sufficient population distance)" that was accepted.

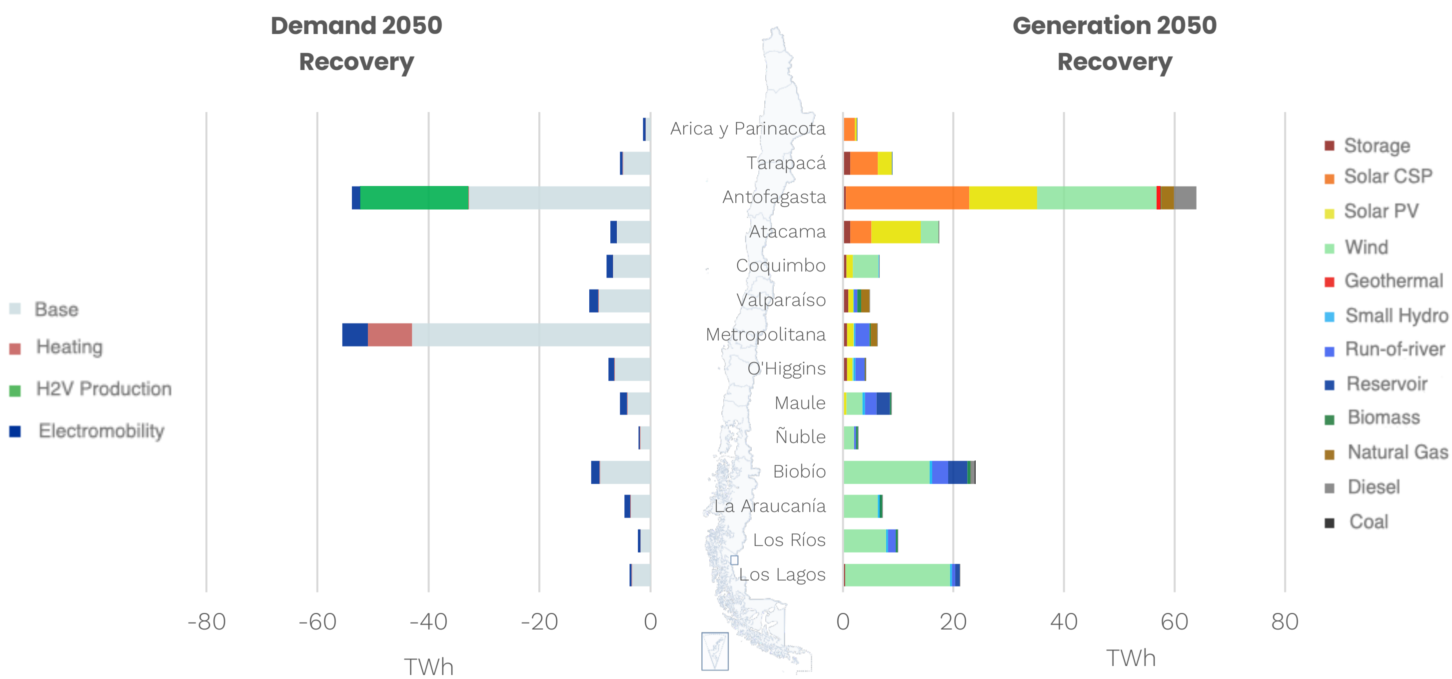
6.3. Projection of energy supply and demand

This section presents the projected electricity demand and generation by region, in order to identify those regions in which there will be a greater connection of renewable projects.

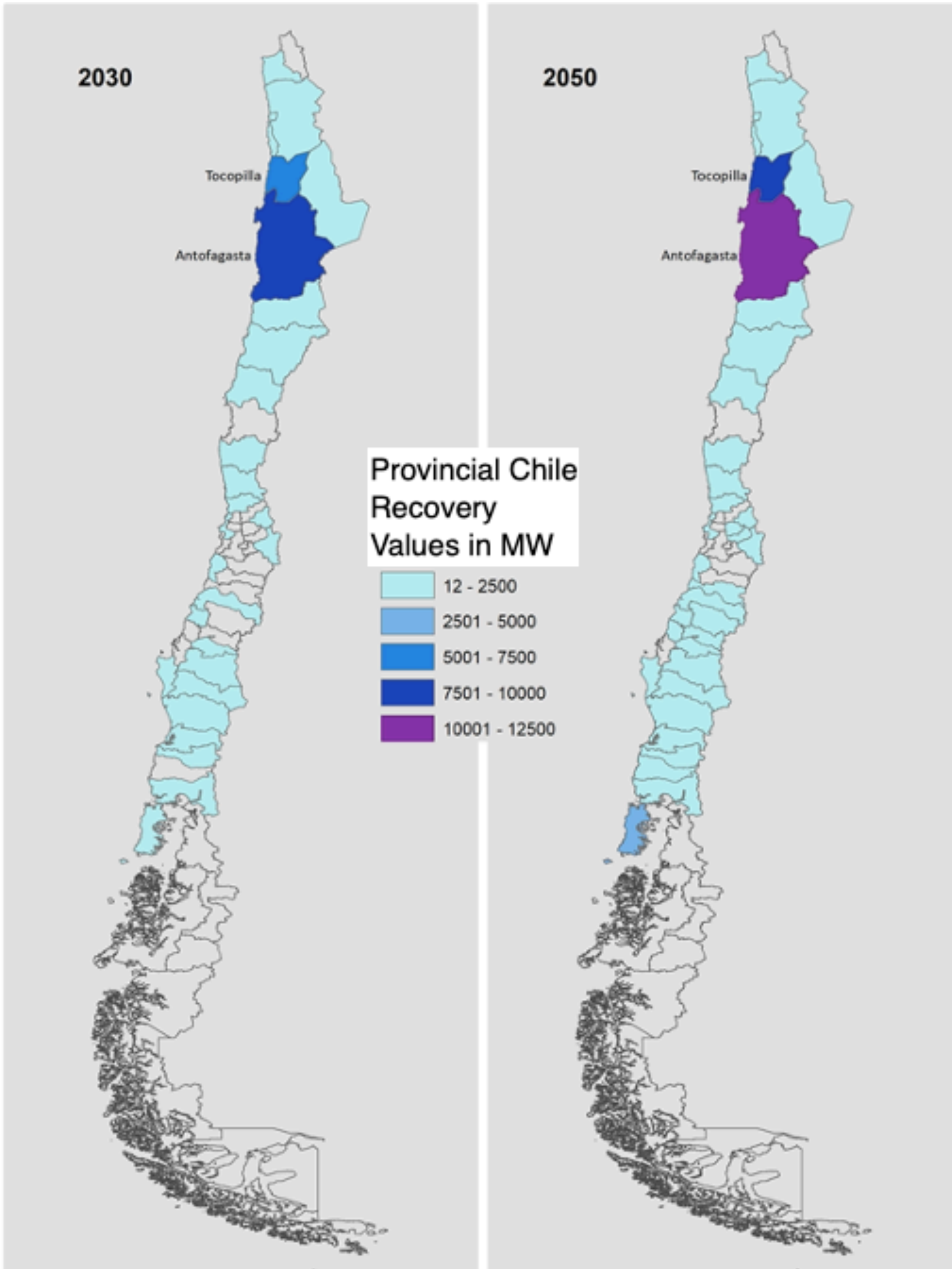
In turn, for each scenario, a color map is presented, identifying those provinces that concentrate a greater number of new renewable projects between 2022 and 2030, and between 2031 and 2050.

6.3.1. Recovery Scenario

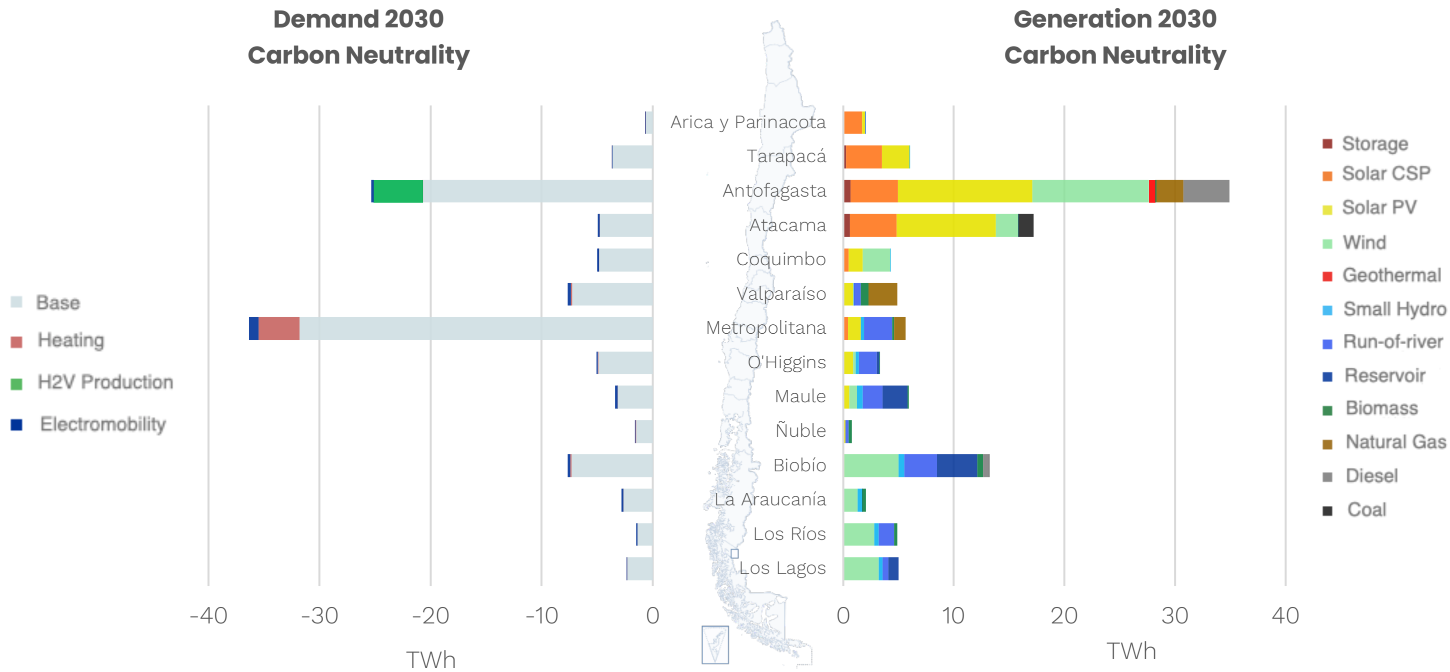


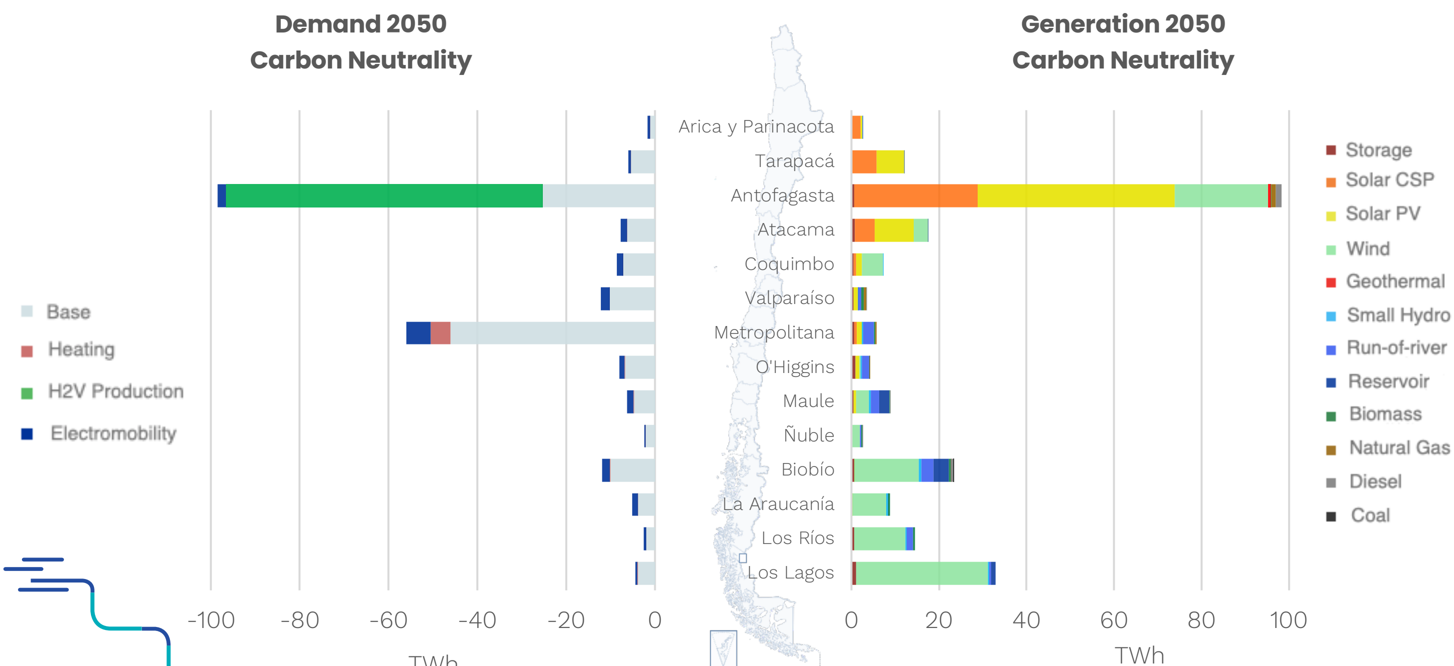


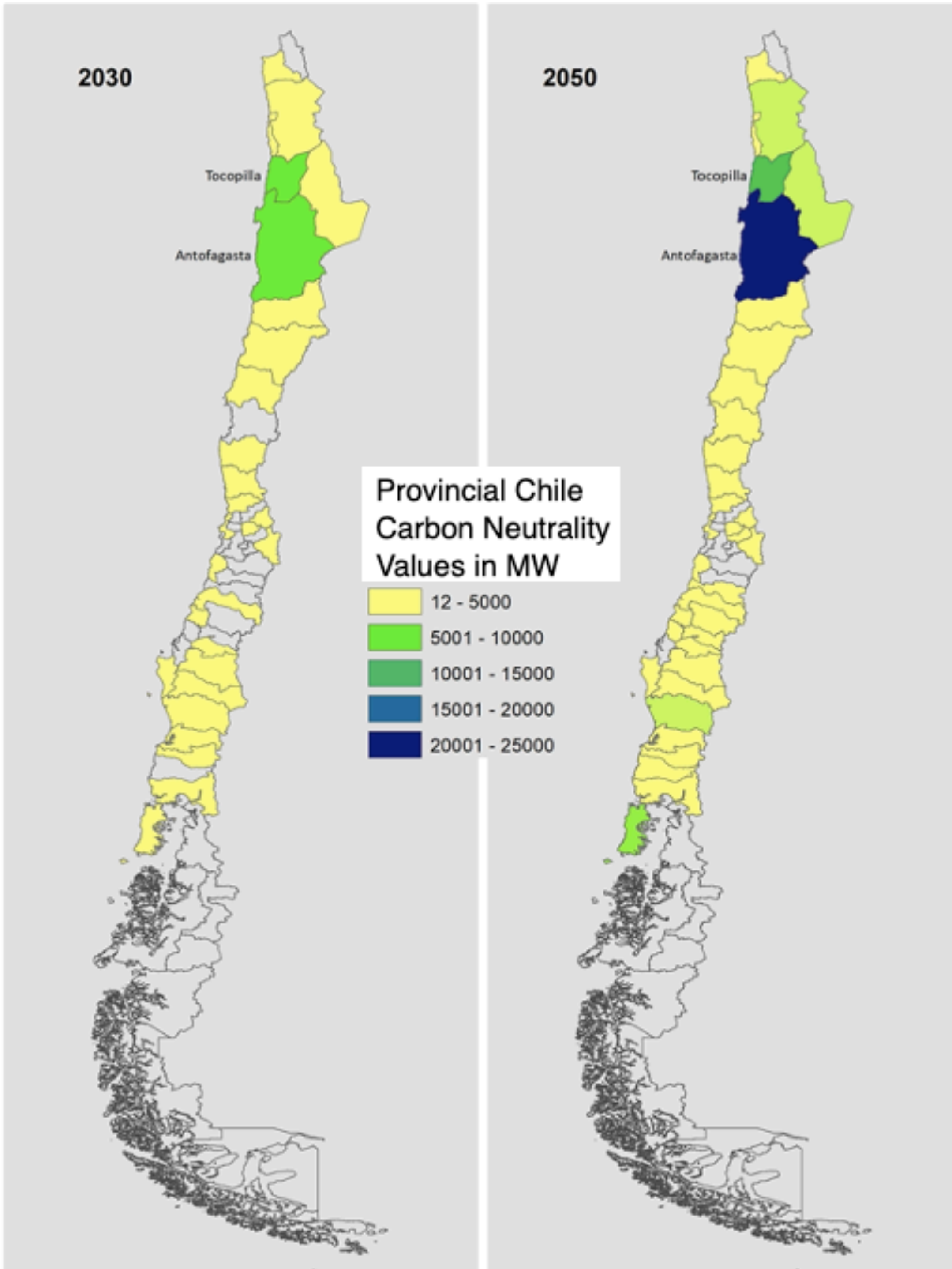
Demand 2050
Recovery
Generation 2050
Recovery
Base
Heating
H2V Production
Electromobility
Arica y Parinacota
Tarapacá
Antofagasta
Atacama
Coquimbo
Valparaíso
Metropolitana
O'Higgins
Maule
Ñuble
Biobío
La Araucanía
Los Ríos
Los Lagos
Storage
Solar CSP
Solar PV
Wind
Geothermal
Small Hydro
Run-of-river
Reservoir
Biomass
Natural Gas
Diesel
Coal
-80
-60
-40
-20
0
0
20
40
60
80
TWh
TWh


2030
2050
Tocopilla
Antofagasta
Provincial Chile Recovery Values in MW
12 - 2500
2501 - 5000
5001 - 7500
7501 - 10000
10001 - 12500

6.3.2. Carbon Neutrality Scenario

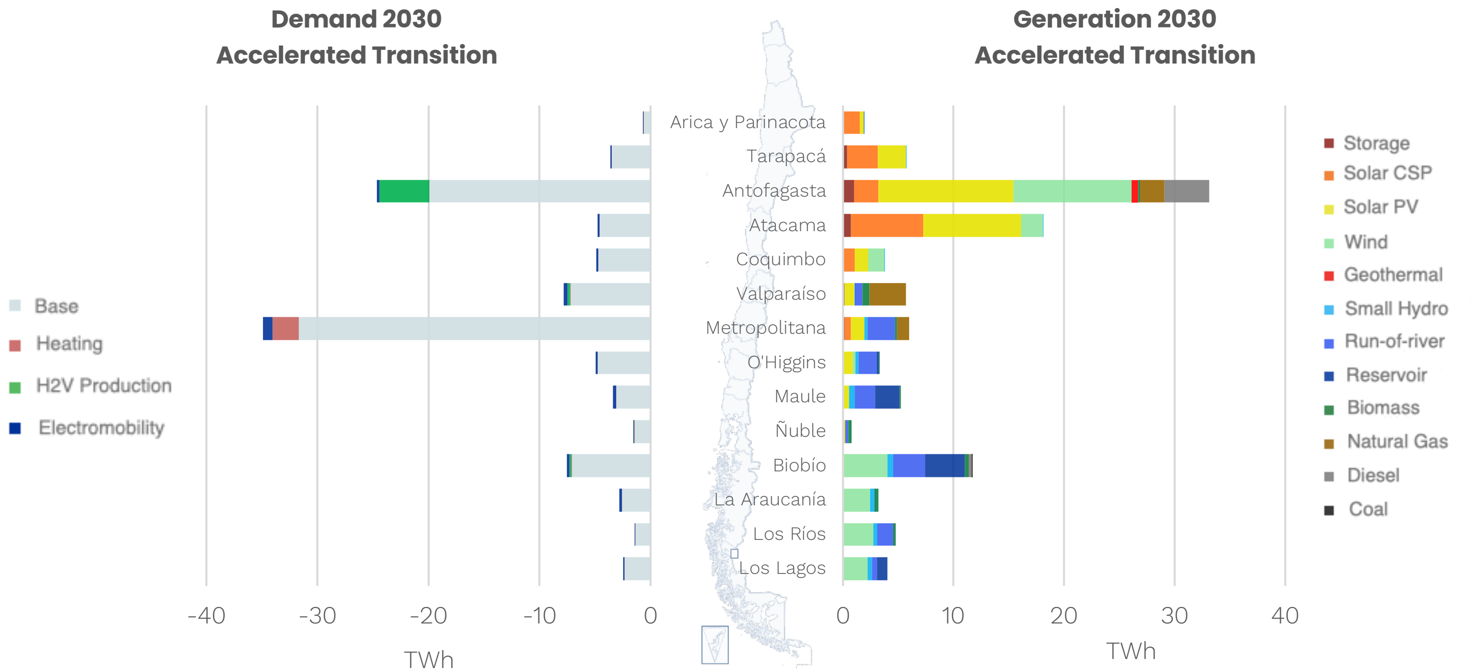


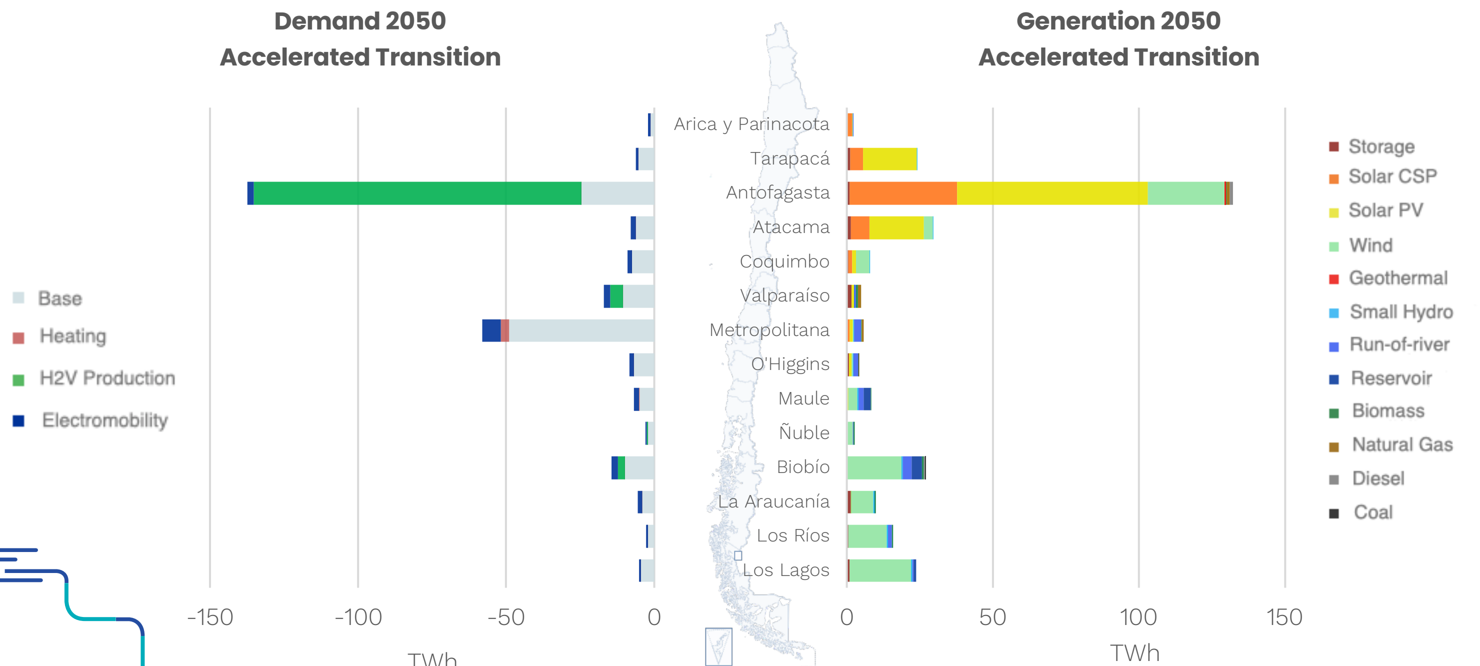


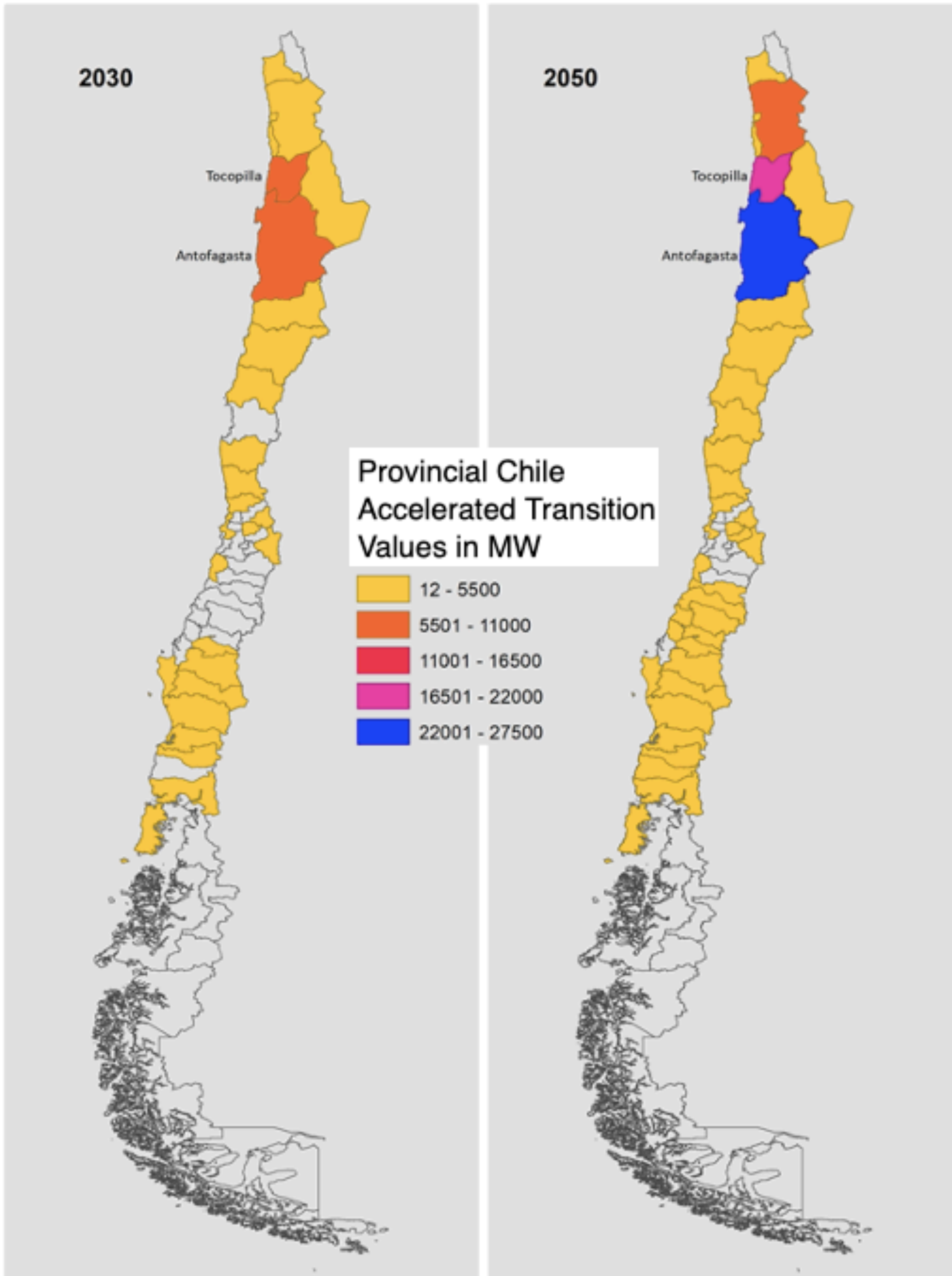


2030
2050
Tocopilla
Antofagasta
Tocopilla
Antofagasta
Provincial Chile Carbon Neutrality Values in MW
12 - 5000
5001 - 10000
10001 - 15000
15001 - 20000
20001 - 25000

6.3.3. Accelerated Transition Scenario



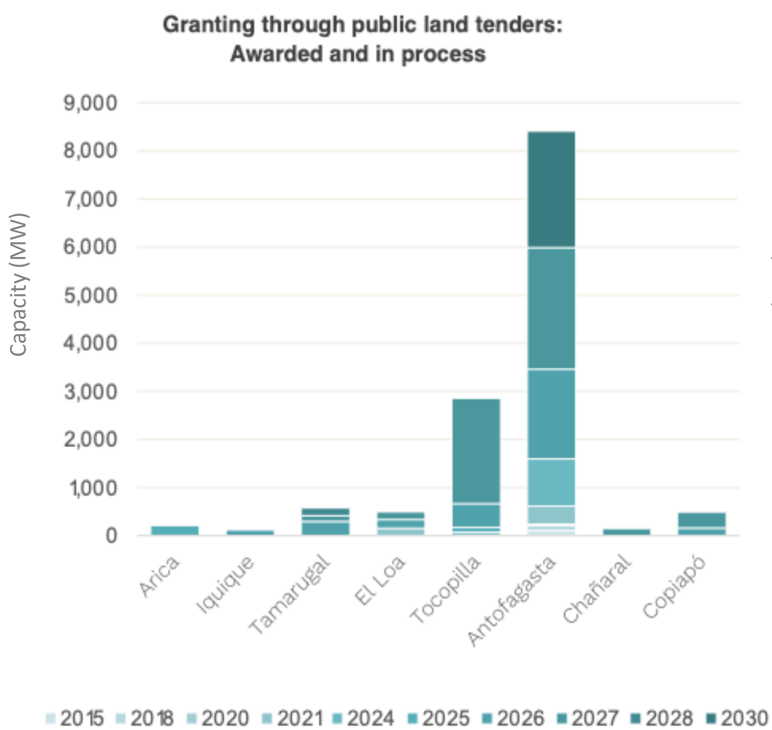


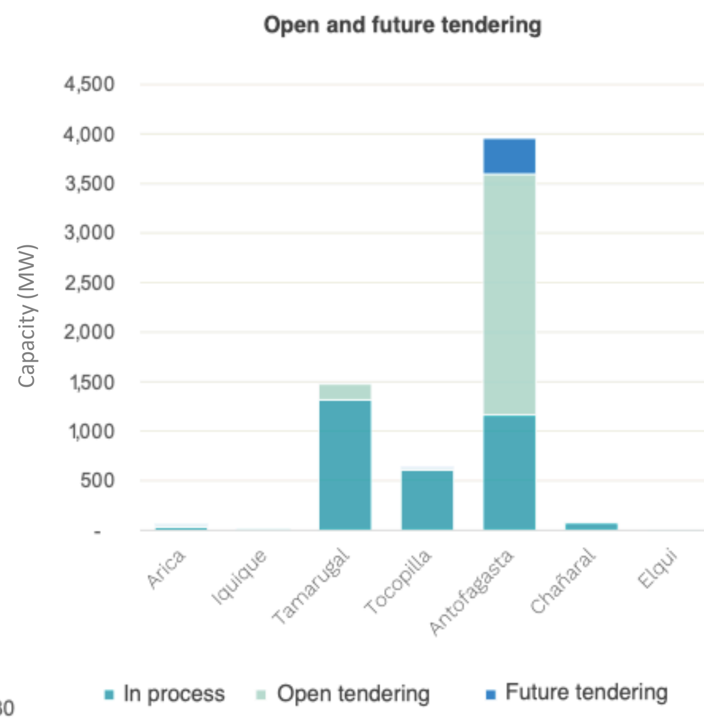

2030
Tocopilla
Antofagasta
2050
Tocopilla
Antofagasta
Provincial Chile
Accelerated Transition
Values in MW
12 - 5500
5501 - 11000
11001 - 16500
16501 - 22000
22001 - 27500

6.4. Investment trends

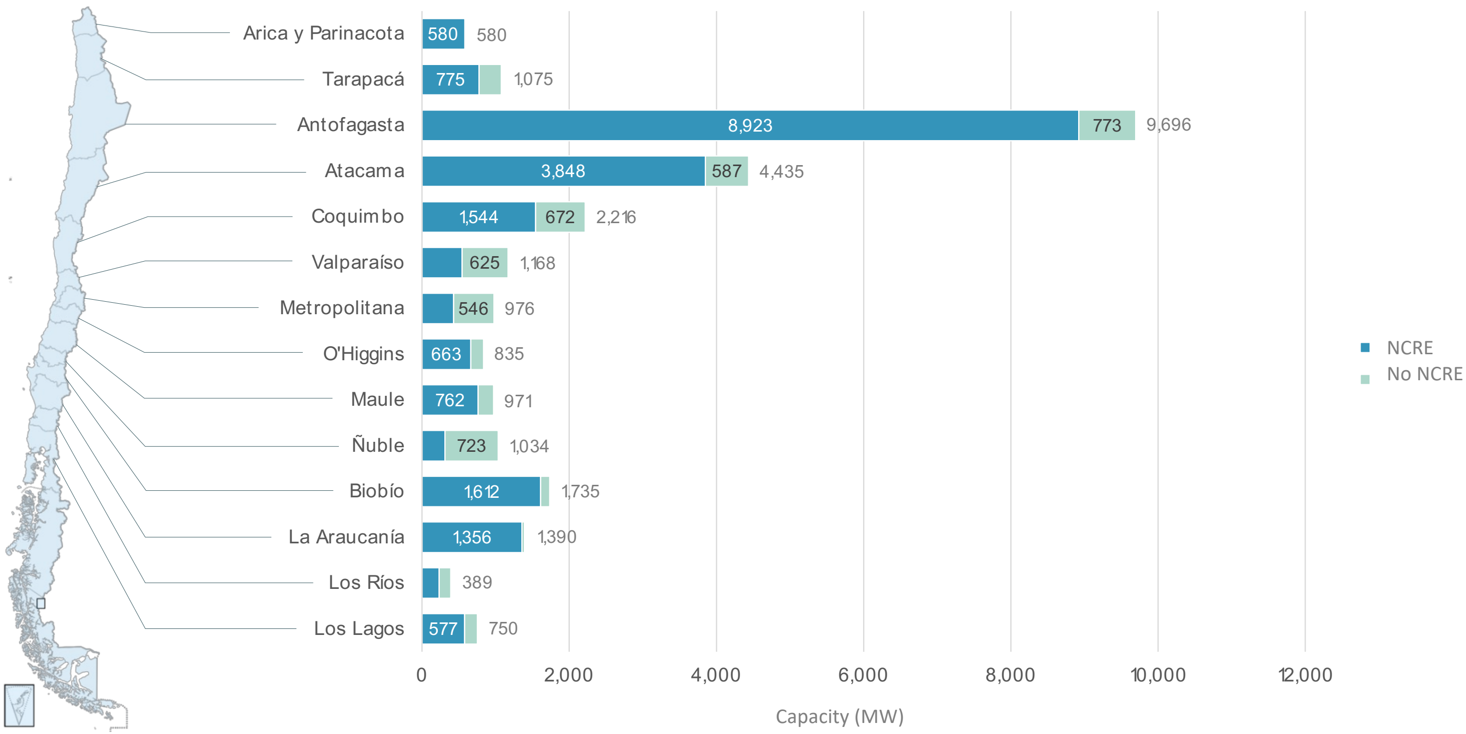
This section presents the investment trends provided by different sources: public land tendered by the Ministry of National Assets, projects in the Environmental Assessment Service with an approved Environmental Qualification Resolution, and projects that have requested a connection through the open access process of the National Electricity Coordinator.

6.4.1. Tenders of government land by the Ministry of National Assets

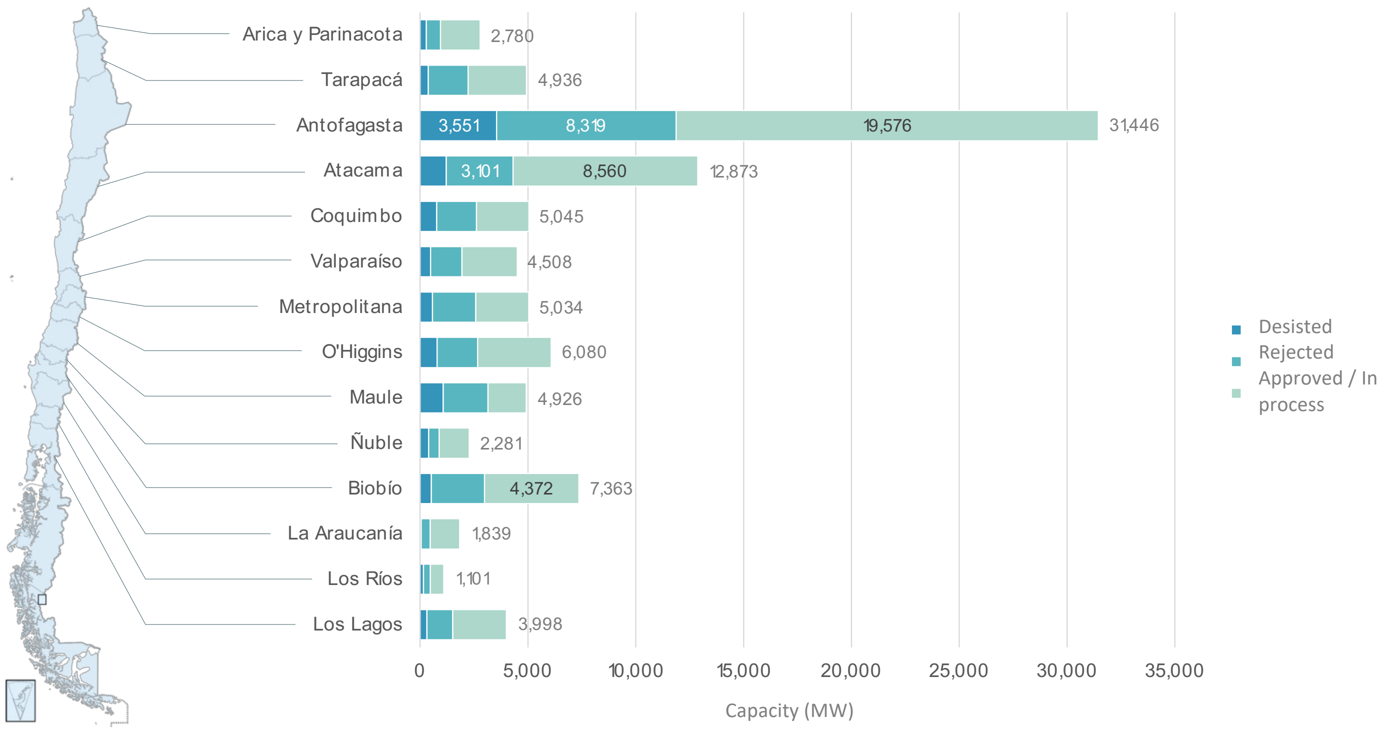




6.4.2. List of projects in SEA with approved RCA



Open access requests in the Electricity Coordinator



6.5. Temporality

Projections and investment trends present a high coincidence in the regions that will concentrate the greatest number of renewable projects in the future.

Using the concept of prioritization for this decade, this time the provinces of Antofagasta and Tocopilla, in the Antofagasta region, are defined as potential poles for the development of electricity generation, in accordance with the provisions of Article 85 of the General Law of Electric Services (GLES).

In turn, the same prioritization criteria allow us to foresee that the next PELP 2028-2032 process should identify development poles in provinces between the Biobío and Los Lagos regions, whose highest level of incorporation and connection of new renewable projects will develop between the decades of 2030 and 2050.

Regions	Provinces	Temporality	Main criteria
Antofagasta	Antofagasta Tocopilla	Immediate need Substations with high demand (Parinas, Kimal)	• High projection of additional electricity supply this decade, and is maintained until 2050. • High Open Access connection request. • High number of public land tenders. • Closure of coal-fired plants + Green H2 Hub • Kimal - Lo Aguirre HVDC location signal. • Reservation of sections / positions for poles.
Biobío Los Lagos	To be defined	Need early next decade	• High Open Access connection request • High projection of additional electricity supply for the next decade. • Location signal of Lines 2x500 kV between Ríos - Ciruelos and Ciruelos - Pichirropulli • Trace Study

PELP 2023 - 2027 | PELP 2028 - 2032

7. Energy modernization

Technologies at the service of society

An important part of long-term energy planning is the identification and characterization of technologies to be considered in the analysis, since these are the ones that allow sustaining the energy transition that is proposed in the different PELP scenarios.

The identification of the technologies to be considered in the PELP process, from energy supply to final use, come from four different but complementary aspects.

On the one hand, some technologies are already deployed on a large scale in the country and there is empirical information on their technical and economic characteristics. This group will be referred to as mature technologies. There is a second group, which are those for which there is robust evidence of their potential for technical-economic competitiveness in the medium and long term, which will be called emerging technologies and arise from technological surveillance processes that allow their identification and characterization. In a third group there are technologies that arise from specific challenges that the country will have to face in the future, which will be called enabling technologies, and that arise from needs and opportunities detected in different participatory processes led by the Ministry of Energy. Finally, there is a fourth group, known as disruptive technologies, and they are those that although they are modeled in the predictions of PELP scenarios, they are not yet reflected in the output of the process due to their high comparative cost.

For the first group, there are the well-known electrical technologies such as solar photovoltaic, onshore wind, thermal energy and hydropower. For example, from the end-use point of view, hydrocarbon-based transport and industrial thermal processes powered by natural gas can be noted.

The second group, known as emerging technologies, includes power generation, solar power concentration and geothermal energy, among others, as well as end-uses such as electromobility and green hydrogen for cargo transport.

For the third group, the enablers, it is necessary to first identify the challenges that need to be faced. Two examples of this is the decrease in local pollution resulting from combustion based on wet firewood for heating in the south of the country. The second challenge has to do with the maximum theoretical limits that the power system supports when incorporating variable renewable generation on a large scale. In the case of the first challenge, a range of technologies related to sustainable heating emerges, such as district energy solutions and heating electrification. For the second challenge, energy storage and efficient management technologies are generated through power electronics, such as synthetic inertia.

The fourth group includes the disruptive technologies, which, while there may be success cases in Chile or the world, have not yet reached, or are close to reaching, the maturity threshold with the costs required to be competitive. This is the case of ocean generation technologies, Carnot batteries, and carbon capture and storage systems.

Whatever the case of the group of technologies, and given the characteristics of the PELP process, it is necessary to identify them with constantly updated technical-economic parameters, and a socio-environmental balance in accordance with a sustainable energy transition. That is why, based on the current PELP, a multidisciplinary working group is being formed that will allow the variables of each technology to be identified and characterized in order to be considered in each annual update.

7.1. Towards a 100% clean electrical grid

7.1.1. Sustainable energy development

Chile is committed to achieving the goal of carbon neutrality before the year 2050. On its own, the energy sector contributes less than 80% of greenhouse gas emissions, but today it has the opportunity to be an environmental and climatic solution for society. Not only will it support the fight against climate change and intergenerational justice, but it will also help clean up the country's cities and communes, with a direct improvement in people's quality of life.

The country has an incredible potential for renewable energies, which are projected to begin to predominate in the country's electrical power systems in the next few years.

The measures and actions that will allow us to be carbon neutral as a country have been studied by the Ministry of Energy, and contemplate important advances in the use of renewable energies to supply the energy needs in the different sectors of society.

Electrification is one of the most efficient actions to bring renewable energies closer to consumption: distributed generation, direct electrification to electrical power systems and indirect electrification, through storage or energy vectors such as green hydrogen, to supply those consumptions that cannot be easily electrified. More than 80% of the actions are based on electrification.

Total energy demand is expected to grow by nearly 30% between 2021 and 2050, driven by strong and forceful energy efficiency measures. However, the electricity demand will grow to substantially higher levels due to the electrification measures that allow us to cleanse our energy matrix through the use of renewable energies.

Currently, about 25% of all energy uses are provided by electricity. The remaining 75% comes from fossil sources such as oil and its derivatives, biomass and firewood, natural gas and, to a lesser extent, biogas. Through electrification measures, it is expected that by 2050, between 50% and 75% of all energy uses will be provided by direct and indirect electricity.

Electrification for transport, heating, industrial and mining thermal uses, and green hydrogen production will significantly increase the demand for electricity. Together with the ongoing phase-out of coal-fired power plants, it presents a huge opportunity and demand for innovation and technological transformation in the electricity sector.

Given this, power electronics and digitalization of the electrical grid operation will be a fundamental enabler for achieving the goal of a 100% clean electrical grid.

7.1.2. Massive outbreak of renewable energies

The past decade has been a decade of renewable energy strengthening. They went from being a technological bet to the most efficient option. Chile has promoted an important renewable energy access in the country.

This decade has opened up a new challenge of operating an electrical grid that is strongly influenced by renewable energies. Chile can lead this great challenge. Simultaneously operating renewable sources in some hours of the day will go from less than 50% to almost 70% at the end of next year 2022, and before 2030, this percentage is expected to increase to more than 85% of simultaneous operations from variable renewable sources, such as wind and solar photovoltaic, in some hours of the day.

Different electrical grid operators in the world agree that a simultaneous operation of more than 75% of variable renewable energies is, until now, an unexplored path. In this context, Chile has the responsibility and the great challenge to proactively address this unexplored path, since it is projected that it will be one of the first countries to reach it, even more with the promotion of public policies and green investments that contribute to sustainable development by and for society.

The 4 pillars of the electrical grid of the future are:

1. **Renewable energies:** A greater incorporation of renewable energies while coal-fired power plants cease to operate.
2. **Infrastructure:** Electrical lines and substations that allow the connection of renewable projects and bring energy to the entire country to supply the energy needs of society.
3. **Modernization of the electrical power system:** Not only will classical infrastructure be required, but the promotion and commissioning of technological alternatives that are integrated into the electrical grid will also be required.
4. **Operation of the electrical grid:** It is necessary to plan the operation of the future electrical grid, which is strongly controlled by variable renewable energies, where digitization and automation will be the central axis of decentralized, efficient and safe operation. Classic technologies will be part of the transition, but decisions must be made in a way that is consistent with the grid of the future so that we can achieve and enable the goal of carbon neutrality.

7.1.3. New technologies for the electrical grid of the future

There is a large number of technologies that work together to help achieve a 100% clean electrical grid, such as:

1. Natural gas-fired power plants will play a fundamental role in the energy transition, but it should also be considered that an important part of gas-fired units (close to 2,000 MW, which is 50% of the total) has a current useful life of more than 20 years.
2. Thermoelectric reconversion of current coal and/or gas power plants to other alternatives such as: Carnot batteries, synchronous condensers, plants with blending through a conventional fuel co-firing with synthetic fuels.
3. Solar power concentration.
4. Energy storage (batteries, other options):
    a. As a source of energy arbitrage.
    b. As an alternative GridBooster that allows some electrical transmission corridors to operate with a capacity closer to the thermal limit, allowing safe operation beyond the N-1 transmission capacity criterion established in the Technical Standard for Safety and Quality of Service.
5. Flywheels and mechanisms for providing rotary inertia to the electrical power system.
6. Power electronics in electrical power systems and provision of digital security to the electrical grid:
    a. Inverters of solar photovoltaic power plants.
    b. Wind power plant inverters.
    c. Battery inverters.
    d. FACTS (Flexible AC Transmission System).

7.1.4. Power electronics as an enabling technology for a highly renewable and secure electrical power system

Indirectly, the electrical grid has been equipped with a large number of power electronics equipment. Solar photovoltaic and wind power plants are connected to the grid through semiconductor or transistor-based inverters that allow the connection of solar and wind energy to the electrical grid through digital control. BESS-type batteries are also connected to the grid through power electronics inverters.

These inverters are controlled by digital control algorithms that could make the renewable plants and/or batteries operate in the way that the operator requires, and can even emulate the behavior of conventional rotating machines, such as coal-fired power plants, gas-fired power plants or hydropower plants.

Technologies based on power electronics are not new in Chile, the mining sector already underwent a major technological transformation several decades ago, going from motors connected directly to the grid, through mechanical gears, to being now connected through rectifiers and inverters based on power electronics, which allows improving their operational efficiency, reducing maintenance and increasing their useful life.

In addition, the electrical power system has various equipment based on power electronics, mainly based on the need to control grid voltages.

At present, the electrical power system is controlled by synchronous generation, that is, in terms of safety conditions, conventional rotating power plants still dominate the daily operation. However, with the accelerated phase-out of coal and the massive use of renewable energies, inverter-controlled electrical power systems are expected to be operational by the middle of this decade.

A real opportunity opens up for innovation and positioning Chile as a leader in digital control-based technologies to allow greater access to renewable energies, which in turn contributes to grid security.

Generally speaking, technological transformation proposes two paths: try to face the future with proven technologies, or anticipate technological change and implement actions that the rest of the world has not yet taken. Both options have opportunities and risks. Given the dramatic change taking place in the energy sector and Chile's desire to lead and accelerate the energy transition, innovative solutions should be a fundamental pillar of electrical grid modernization.

The phase-out of coal-fired power plants and the introduction of renewable energies pose some challenges: more transmission infrastructure that must be planned in advance since its start-up requires several years, technologies that allow taking advantage of the existing transmission based on power electronics and digital control (short-term storage to operate on N-1 criteria, dynamic line capacity, etc.), operate a system with less inertia and less short-circuit level, adapt the short-term electricity market to the grid of the future, etc.

Technology enablement is key. It is expected that by 2026 the first operations with inertia levels below the conventional minimum will begin, which will require fast frequency control services and could enable options for power electronics to play a fundamental role. But that path must begin to be explored today.

7.1.5. R&D&i in power electronics

Chile has extensive and proven experience in fundamental and applied research in power electronics. Furthermore, electrical and electronic engineering is the strongest field of study in the country (80% higher than the world average) and has the highest participation rate of researchers in the world by 2%. The academy and research centers are considering the modernization of the electrical grid of the future as an important possibility to contribute to the country's energy innovation.

Today there is an electrical grid controlled by conventional generators with high inertia, security resources provided by large power plants, predominance of electromechanical phenomena associated with rotating machines, classical operation of the electrical power system and manual allocation of security resources and high level of short circuit.

The grid of the future will mainly be controlled by renewable photovoltaic and wind power plants, where frequency control will be based on fast control with low inertia and security provision distributed in many renewable power units, whose action must be centralized. Electromagnetic phenomena and switching of power electronic devices will predominate, and digitization requirements for automated, efficient and safe monitoring and operation of the electrical grid will be paramount. Moreover, there will be a lower level of short circuits in the grid, which must be maximized in those areas that need it, and in turn, a readjustment of the electrical protection systems in the country will be required, based mainly on digital protection relays.

Organizations such as the IEEE (Institute of Electrical and Electronics Engineers) are already promoting specific research for electrical grids highly controlled by power electronics, in which Chile is expected to be one of the first countries that will have to travel the paths that until now they have not passed, setting the standard in terms of technological innovation in energy, both from the specific development of the technology, as well as from the promotion, regulatory authorization and joint operation of the same.

7.1.6. The possibility of innovating within our reach

The future requires a clean electrical grid, in which power electronics inverters will predominate. From now on, a paradigm shift in the current operation of the electricity system must be driven.

Investors have a wide range of options to operate and provide security to the grid. It is important to establish and facilitate testing to demonstrate the technical feasibility of providing security in the National Electric System. Digitization will be key in this challenge.

Technology enablement is key. This decade is expected to be marked by the implementation of new technologies that address hitherto unexplored operational challenges. Chile can lead in this regard, for example, in the technological implementation and the relationship between the electrical power system that will be equipped with the new technologies.

7.2. Green hydrogen in mining transport

The challenge in transforming the country's mining industry into a green copper export industry is fundamentally improving its energy conditions. This transformation applies to the entire supply chain, right up to its final consumption, in order to move from a hydrocarbon-based to a renewable-based energy composition. In addition, however, it needs to make better use of energy, which is necessary to significantly increase its efficiency throughout the entire process.

The current PELP shows that mining energy demand will increase by 20% to 34% over the period from 2020 to 2050, depending on the PELP scenarios considered. To meet this demand, three main factors are modeled that will shape it: improvements in energy efficiency in its production processes, electrification of equipment and machinery, and massive incorporation of green hydrogen, mainly in its motor uses, which today are based on Diesel.

According to the 2019 National Energy Balance report, the total demand for diesel fuel by copper mining is 17,578 TCal, which is equivalent to 43% of the total energy consumption of copper mining. This consumption represents 1,920 million liters of diesel per year, with the main demand being energy use for transport in mining operations with CAEX trucks and LHD front-end loaders, which are the two largest consumers.

Amongst the alternatives to reduce the use of diesel in mining, in order to substantially mitigate CO2 eq emissions, there are mainly the following: improve combustion efficiencies (with the respective thermodynamic limits) and reduce displacement within the mines (which in practice is unfeasible given the aging conditions of the mining deposits). Another option is the large-scale deployment of battery and/or electric catenary-based e-mobility technologies. In both cases there are also technical restrictions to consider: the considerable increase in weight and the need for space in the case of incorporating battery-based vehicles; and the lower autonomy to reach the extraction sites in the case of electrical catenaries. There is also a third technological option, which is to incorporate green hydrogen into the energy supply chain for mining cargo transport.

Currently, there are at least two areas of R&D that could provide cost-effective solutions for the incorporation of hydrogen in mining trucks: dual hydrogen-diesel combustion, and the incorporation of fuel cells in CAEX trucks and LHD loaders.

The main advantage of dual hydrogen-diesel combustion is to take advantage of the same internal combustion engines that are used today, with modifications in the injection systems and in the physical space for fuel storage. This allows the use of the same engine manufacturing infrastructure that manufacturers currently have, as well as its associated logistics chain. Among the disadvantages, the main one is that there is little evidence of success in real working conditions. From experimental results under semi-controlled conditions, the main challenges to be faced with research and development emerge, such as: optimal hydrogen-diesel ratio for different engine loads, tendency to knock problems, NOx formation and low density of power output, among others.

The main advantage of mining equipment powered by hydrogen cells is that it replaces all diesel consumption and runs entirely on hydrogen, emitting water vapor into the environment. Amongst the disadvantages, the main one is related to the costs of the equipment powered by this technology, as well as the difficulties in the transition process, from diesel equipment to fuel cells, since, until today, it is not reconditioning of trucks that allows for the gradual technological change. Among the particular challenges that are in the process of research and development, there are actions related to vibration analysis given the high load and extreme working conditions of the hydrogen cells of CAEX trucks used in open pit mining and loaders LHD front-end loaders used in underground mining. Other challenges relate to the safety standards required for mining operations, as well as the conditioning and storage logistics of green hydrogen, and the quality of purity required to use it in hydrogen cells.

In the case of Chile, today there are two technological consortiums researching and developing solutions for the incorporation of hydrogen in mining cargo transport. One is led by Alset, which focuses on reconditioning large-tonnage CAEX trucks to operate in dual diesel-hydrogen mode, which is expected to exceed 60% diesel displacement. At the same time, a consortium led by the Universidad Técnica Federico Santa María is developing solutions to adapt LHD equipment from Diesel propulsion to one based on hydrogen cells. Both consortiums, co-financed with public resources, are in the middle of the prototype testing stage and close to carrying out pilot tests in real working conditions in mining operations.

PELP projections reinforce the relevance of incorporating green hydrogen into mining. The final energy use of green hydrogen, depending on the scenario considered, has a share between 7% and 24% in the national energy matrix by 2050, with motor uses in mining being one of the most important components of that demand representing a share between 24% and 33% of the final demand of hydrogen for national consumption, being only surpassed by cargo transport on the road, which would participate on average with 59% of the national consumption of hydrogen in the country.

7.3. Other technologies under analysis

- Offshore wind power.
- New technologies for run-of-the-river hydropower plants.
- Liquid Air Energy Storage (LAES).

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