Roadmap for an Accelerated Energy Transition

Vision of the National Electric Coordinator

June 2022

COORDINADOR
ELÉCTRICO NACIONAL

COORDINADOR
ELÉCTRICO NACIONAL

Welcome

Introduction

The Independent Coordinator of the National Power Grid in Chile (Coordinator), as a technical, independent and autonomous entity in charge of the secure and economic operation of the National Power Grid (NPG), has defined as a corporate vision, to be an institution recognized for its technical excellence, service and contribution to a sustainable power grid, which implies being facilitators of the transition to a 100% renewable energy matrix. In this context, the present document makes the Coordinator's vision available to the industry, along with a proposed roadmap, for a secure, efficient and consumer-focused energy transition.

A substantial change in the way the electricity grid is planned and operated, as well as in the way the Chilean electricity market is developed, is required in order to ensure an efficient, secure and reliable energy transition. The Coordinator has a fundamental role in contributing and promoting an important part of these changes, mainly oriented to preparing the electric grid to operate in a scenario based 100% on renewable energies.

The penetration of Variable Renewable Energy (VRE) is increasing rapidly, having reached in 2021 levels of approximately 22% share in terms of energy and 62% in instantaneous power share at the hour of maximum variable renewable energy penetration. This trend, with high levels of VRE insertion, is expected to continue and deepen in the coming years.

The studies and analyses carried out by the Coordinator, as well as the rapid evolution of new technologies, allow concluding that the decommission of fossil-fuel-based power plants is a challenging but possible scenario in order to reach a 100% share of renewable energies as of 2030. In order to make this accelerated energy transition scenario viable, it is necessary to meet the enabling conditions to prepare the electric grid to integrate new technologies, to execute the necessary investments in renewable generation to ensure the supply of demand 24 hours a day, the 365 days of the year, and to implement the necessary regulatory changes to achieve said objective.

Achieving the structural changes required in this transition will require the collaboration, effort and commitment of the entire industry, acting with a sense of urgency and seeking a broad consensus to design a system that allows this vision to be fulfilled in a timely and orderly manner, and with positive results for all electric energy users, who must be at the center of all decision-making.

This roadmap, which we propose to the market agents (Coordinators) and stakeholders, summarizes the Coordinator's vision for an accelerated energy transition, along with the minimum initiatives, proposals, and decisions necessary to prepare the power grid and enable a 100% renewable generation scenario, at any time of day, as of the year 2030.

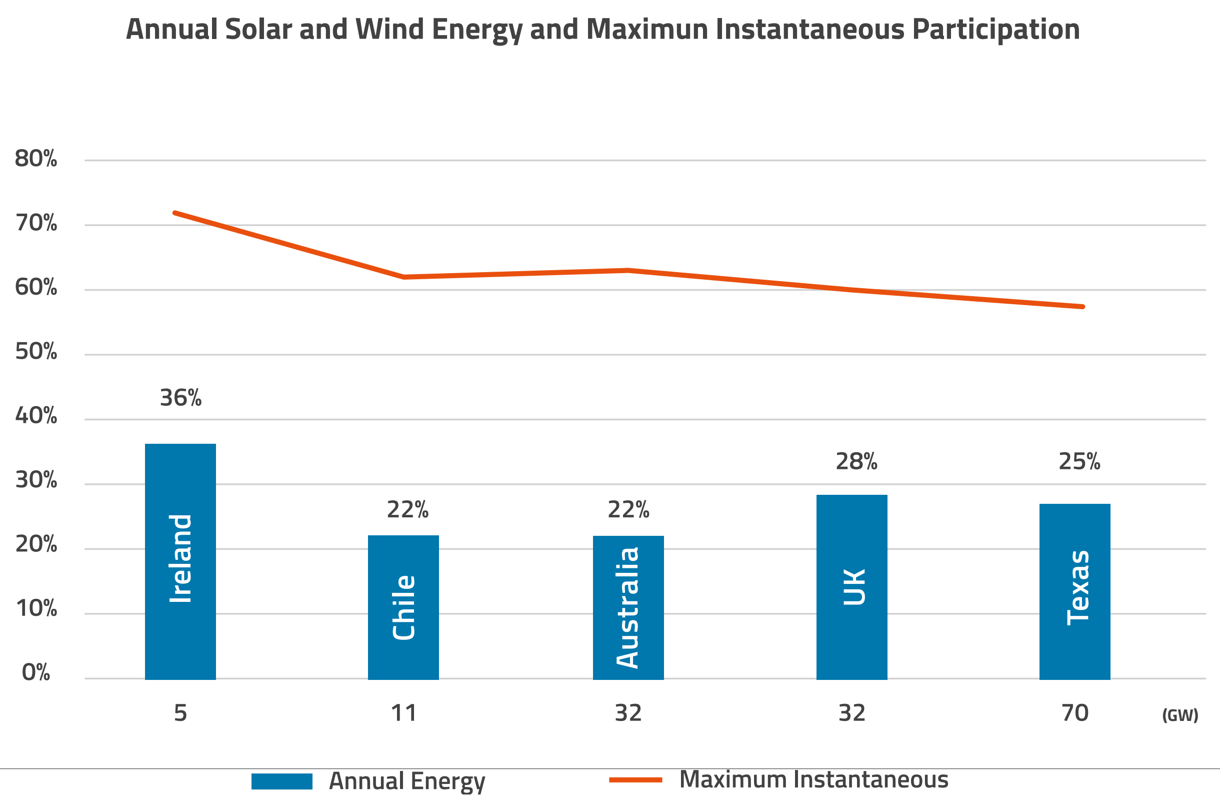
Objective

The purpose of this Roadmap is to:

- Contribute to the energy transition in our role as independent and autonomous operator of the national power grid.
- Promote an open and transparent discussion and collaboration with the industry and stakeholders on the actions required to plan, develop and operate a power grid and energy market under a 100% renewable generation scenario.
- Disseminate the conclusions, results, ideas and priorities identified by the Coordinator in the studies carried out to date on decarbonization and security of supply.
- Define the key strategic decisions required in the short and medium term to make a system 100% renewable, secure and reliable viable by the year 2030.
- Emphasize the need to work collaboratively and openly to identify and implement necessary changes, reduce gaps and remove non-economic barriers to achieve a fair energy transition.

Figure N°1

Participation of annual and maximum instantaneous VRE globally



Context

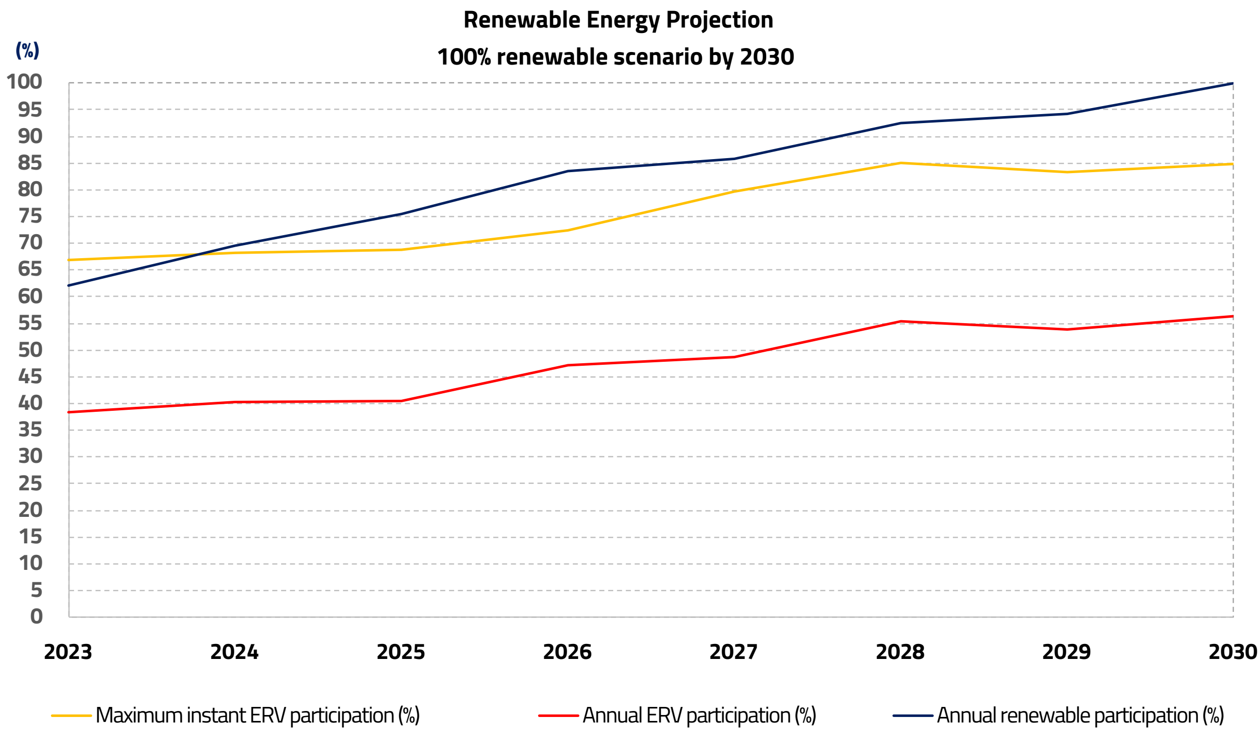
Accelerated Energy Transition

The NPG is undergoing a profound transformation, at an unprecedented scale and pace, and challenging operational conditions, that have not been experienced in the past in our country or in other power grids of comparable scale globally, are expected in the short term.

As a reference, Figure N° 1 shows the share of VRE in the energy matrix in countries with high levels of instantaneous VRE insertion. In the case of Chile, the annual variable renewable energy share reached 22% in 2021, mainly solar PV and wind, and the maximum instantaneous variable renewable energy share in the same year reached 62%. It is important to note that the indicated instantaneous values correspond to global values at system level, but these could reach 100% in some areas of the country, exceeding the levels identified as secure from the point of view of system stability (link ESIG, NERC). Figure N° 2, on the other hand, shows a projection to the year 2030 of the share in annual generation of the different renewable sources for an accelerated energy transition scenario. It highlights the fact that the maximum instantaneous share would be reached before the year 2030 for this scenario.

Figure No. 2

Projected Annual and Maximum Instantaneous VRE Share - Scenario 100% Renewable Energy by 2030



Designing the Power Grid of the Future

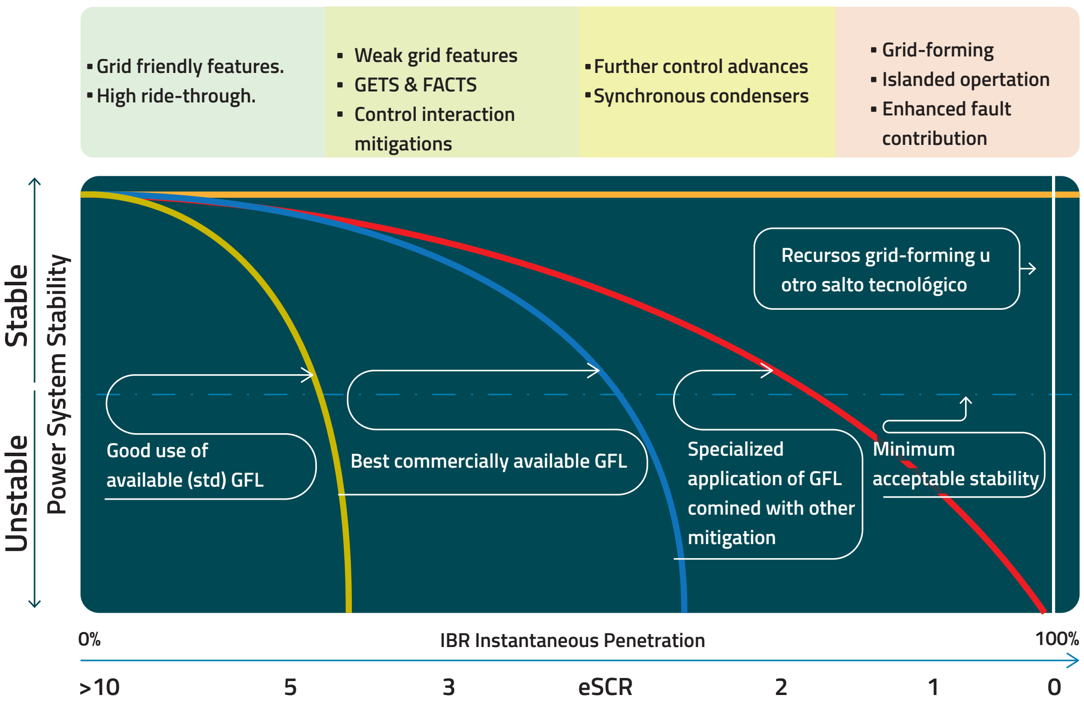
The transition to the operational conditions that would arise in the coming years will necessarily require that the design of the power grid considers a substantial leap in its level of security, strength and flexibility. This roadmap formulates the scale of transformation required and the horizon to achieve this objective.

The electric grid of the future will have to cope with increasingly complex dynamics in the transition from conventional synchronous resources to Inverter-based Resources (IBR), balancing increasing and uncertain volumes of VRE. It should also allow an increasingly decentralized operation, given by the growing integration of energy from Distributed Energy Resources (DER). In addition, this transformation is accompanied by a process of electrification of consumption in the industry, transportation and other end uses, which will imply doubling the demand for electric power by 2050. (link).

Figure N°3 shows the paradigm shift and technological evolution required to meet the challenges, from the point of view of power system stability, introduced by a high instantaneous VRE participation in weak systems (link ESIG) with low participation of synchronous generation, as is the case of the NPG.

the path to the electric power system of the future, with 100% participation of renewable energies, must be carefully designed to ensure a secure and economical operation at all times during the transition, but with the expected end goal in mind.

Figure N°3
Technology transition required for a 100% VRE system
Ref. source ESIG, 2022



As shown in Figure N°4, the current power grid was not designed for the disruptive transition that we are currently facing and that will be intensified in the coming years. While some traditional inherited approaches could be maintained in the short term, the inherent structural limitations should not limit the pace of the transition.

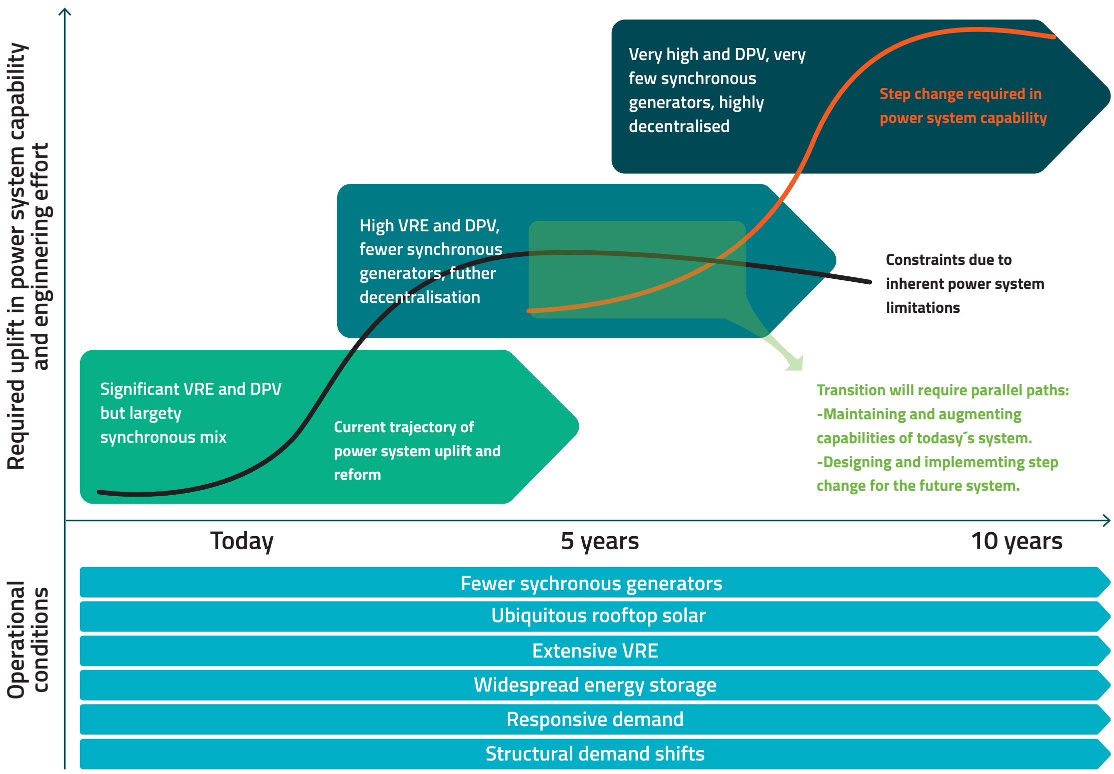
It is essential that the design of the power grid of the future, which shall have a radical change in its capacities and resources, be initiated as soon as possible, mainly due to:

- The magnitude of the challenge and scope of the work to be done in order to materialize the required changes and the need to coordinate actions in different areas, including, among others: planning, regulation, investment, engineering development and operation.

- The accelerated pace of the changes underway and the risk that a disorderly, restricted and inefficient transition would pose for consumers.

- The high risks for the operation of the system if action is not taken in time, due to the lack of adequate tools to securely, reliably and cost-effectively manage the new operational conditions that will arise in the electric power system.

Figure N°4
Increase in capacities required under new operational conditions
Ref. AEMO, 2021



To visualize the order of magnitude of the challenge, from the point of view of the investments required, to make an accelerated energy transition viable, Figure N°5 shows the capacity installed by renewable sources required for a 100% renewable scenario by 2030.

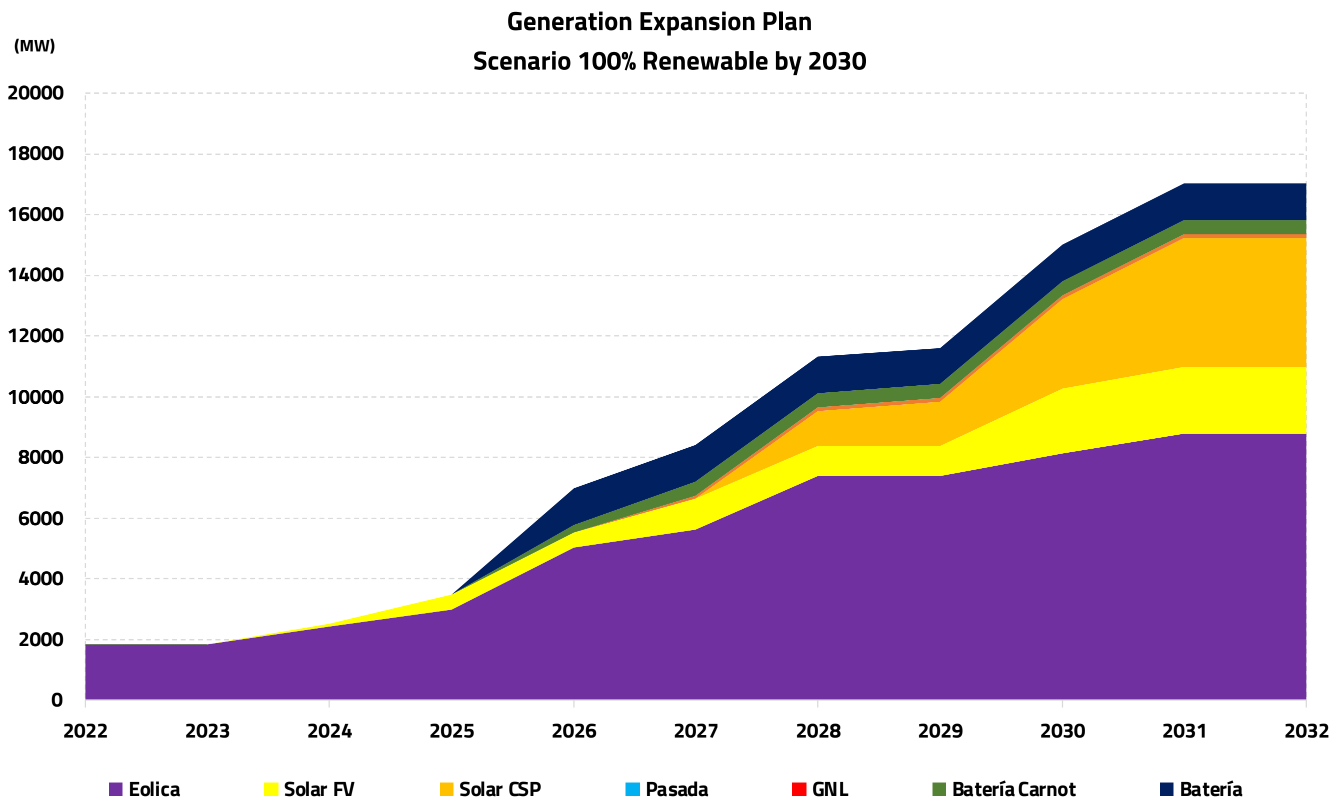


Figure N°5

Projected Installed Capacity – Scenario 100% Renewable Energy by 2030

Studies and Analyses Developed

The Coordinator has conducted a series of technical and economic studies in recent years, with the support of international experts, in order to identify the effects of the decarbonization process on the power grid and to identify the operational challenges, as well as the gaps that need to be addressed for an accelerated decarbonization.

The first study, conducted in 2019 (link), allowed determining the impact on system operation and marginal energy costs over a long-term horizon, as well as quantifying the necessary investments to be executed to enable a decarbonization process by 2040. The second study, carried out in 2021 (link), allowed identifying the operational conditions of the system and the necessary mitigation measures in scenarios with high levels of variable renewable energy for the year 2022 and the period 2025-2030. Additionally, during the bidding process for the HVDC Kimal - Lo Aguirre project, long-term planning studies and technical operational studies were conducted for scenarios with high insertion of renewable energy projected to the years 2030 and 2035, which allowed identifying the enabling conditions and the HVDC project specifications for a secure and reliable system operation.

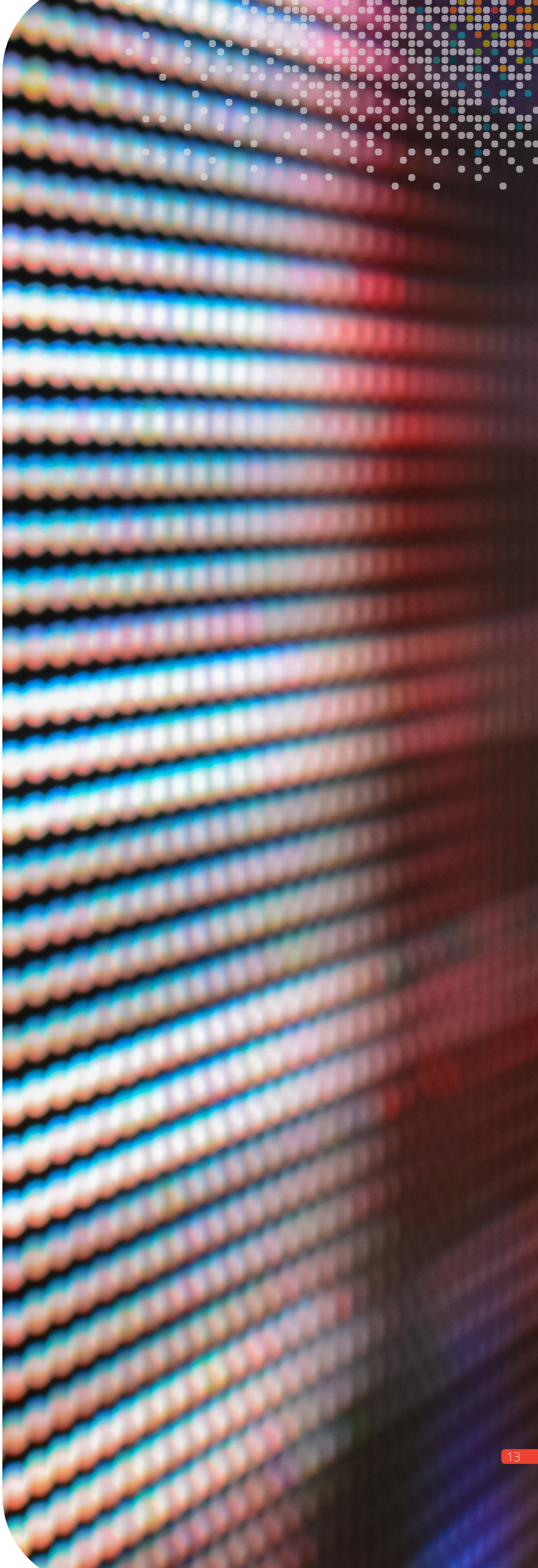
The Coordinator's planning and prospective areas have the function of permanently monitoring the new technologies available in the market in their different stages of maturity. Thus, in 2019 (link) a prospective study was conducted jointly with GIZ to assess the feasibility of converting fossil fuel-based thermal power plants to renewable power plants based on the Carnot battery or thermal battery technology.

The Coordinator's teams have collaborated in initiatives promoted by the Ministry of Energy in conjunction with GIZ, including a study carried out in 2021 (link), which analyzes different technological alternatives based on power electronics that provide security grid services, such as synthetic inertia, to the NPG, among which is the grid-forming technology.

Annually, since 2017, the Coordinator publishes a planning study that provides support for the Annual Proposal for Transmission Expansion (link,) which contains the vision for the development of generation and electricity demand growth scenarios for the next 20 years and allows promoting the necessary transmission works to be started in the following year. In 2021 and 2022, the demand projection for electromobility and the entry of distributed energy resources (DER) in the distribution systems have been incorporated in this study.

Innovation and collaboration

As part of the Coordinator's role of promoting innovation, research and development in the power grid, during the years 2021 and 2022 collaboration agreements were signed with leading international companies that are experts in the development of disruptive technologies, advanced software, and state-of-the-art real-time simulation equipment, including the U.S. company Google X, The Moonshot Factory (link press release) and the Canadian companies EMTP® and OPAL-RT (link press release). These strategic alliances will allow the development of advanced tools to support the planning and operation processes developed by the Coordinator to face the challenges that will be imposed by the power grid of the future with 100% renewable generation.



Diagnostic

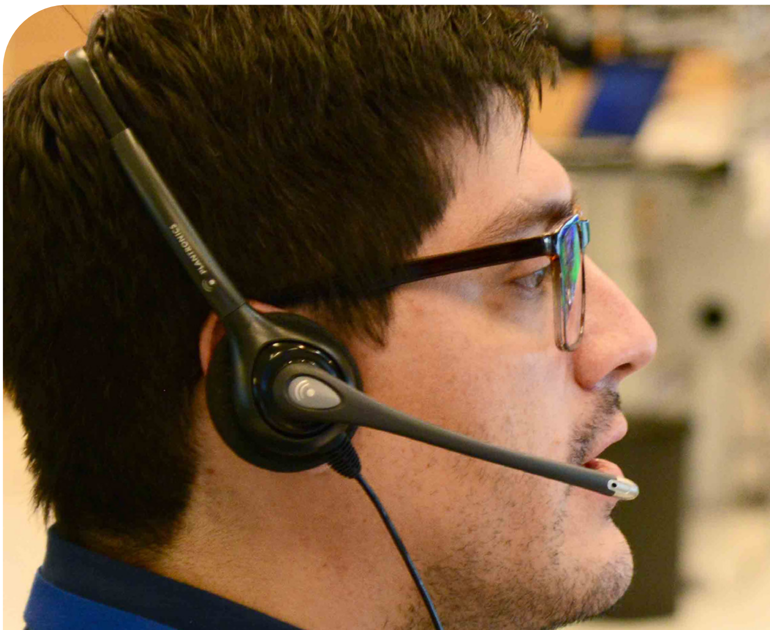
As a result of the analyses carried out by the Coordinator, the following gaps and decisions required to achieve a power grid with 100% renewable generation participation by 2030 were identified.

Fundamental Decisions

Urgent decisions need to be made regarding the future development of the NES, which was originally conceived and designed based on the use of large conventional synchronous generating machines that provide grid services and system strength. Within the framework of the energy transition, a radical change is taking place in the way we produce and consume electricity and in the type of technologies that will prevail in the NES. This will give rise to highly complex and unknown operational scenarios.

Profound regulatory reforms are required in the design and operation of the electricity market, in the way the grid is developed and planned, and in the specifications and technical requirements of the new technologies that will enable the energy transition. It is also necessary to review the short, medium and long-term incentives to attract investments and encourage physical modifications of existing facilities, in order to allow a secure, reliable and cost-effective integration of renewable energies.

It is also necessary to make decisions on the architecture, flexibility, robustness and resilience that the power system will require to guarantee a secure, efficient and cost-effective energy transition, under a risk approach and focused on end users. Risks include the slow implementation of regulatory reforms, investment signals and decisions, project delays, and the effects of climate change, such as extreme droughts and intense natural disasters, among others.



Call to Action

The NES is changing faster than ever, complexity, uncertainty and variability are constantly increasing, while technology and new innovative business models are outpacing system planning and regulatory reforms.

Decision makers must act with a sense of urgency in defining priorities, timing and approaches to align additional efforts that are key to the transition. Approaches to design, investment and construction decisions or asset retrofitting will need to be adapted promptly to keep up with the pace and speed of the energy transition. Parallel paths should be sought in order to maximize options and flexibility, while we navigate scenarios of high uncertainty during the transition.

Participation and Decentralization

It is expected that the participation of consumers and DER in a constantly evolving power grid will play a relevant role in the transition, for which we must be prepared. To this end, we must seek the commitment of the entire industry and society in the energy transition, a fundamental element in the development of decentralized markets, the development of new infrastructure projects and the necessary regulatory reforms.

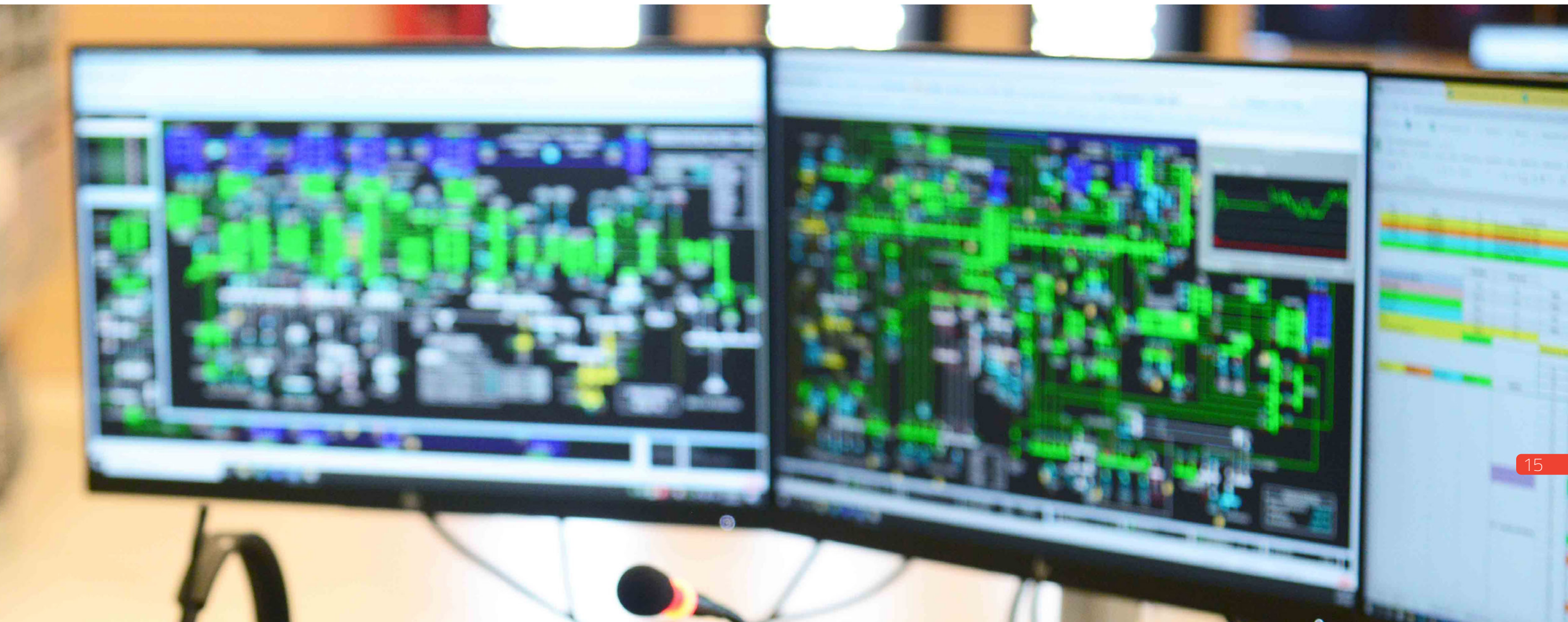
Preparation

There is an urgent need for trained and prepared professionals to carry out the energy transition and be able to face the challenges and complexities of the power grid of the future. It is necessary to develop a mysticism and a new culture for the transition in the industry, where new capabilities and concepts are integrated to broaden the vision towards solutions based on digitalization and new disruptive technologies, providing a different view and more innovative solutions.

Risk Management Approach

Risk management approaches used in system planning and operation processes must be flexible, dynamic and reflect the pace of changes we face.

A holistic and integral view of the processes and systems that support the operation of the electric grid is needed, as well as a more accurate modeling of the same, incorporating methodologies that allow testing the new technologies and operational conditions of the system in a controlled environment. The above, in order to mitigate risks during the implementation and operation phases of these new technologies.



Vision of the Coordinator

The Coordinator's vision for the accelerated energy transition scenario includes proposals for regulatory reforms, decisions and actions considered necessary to enable the transition to a 100% renewable generation scenario by the year 2030. The objective is to facilitate an orderly transition to a future renewable system, but at the same time, secure and efficient, with positive and cost-effective results for the consumer, who shall be at the core of all decision-making.

Regulatory Reforms

Wholesale Market Pricing

Marginal pricing based on declared costs shall evolve to a wholesale generation market scheme based on binding offers of energy, capacity and complementary services. The current wholesale marginal-pricing scheme will pose deficiencies and complexities in the new configuration the electric grid and the generation market are acquiring, with a high insertion of renewable energies, storage and distributed resources. This makes it necessary to adopt market schemes widely used at international level based on energy offers with binding dispatch and payment for sufficiency capacity.

Transmission and Location Signals

Urgent actions are required to implement new efficient and secure transmission projects, which will allow us to move towards a modern and resilient power grid that supports an accelerated energy transition. This is particularly relevant, since the construction deadlines for renewable generation plants necessarily depend on the completion of these transmission projects.

Currently, the regulation does not provide medium and long-term location signals to future generating plants, therefore they are often installed in areas with congested transmission capacity, limiting their contribution and forcing grid expansions. An efficient allocation of transmission costs among the players in the electricity market is essential, so that the cost of transmission development does not fall solely on consumers.

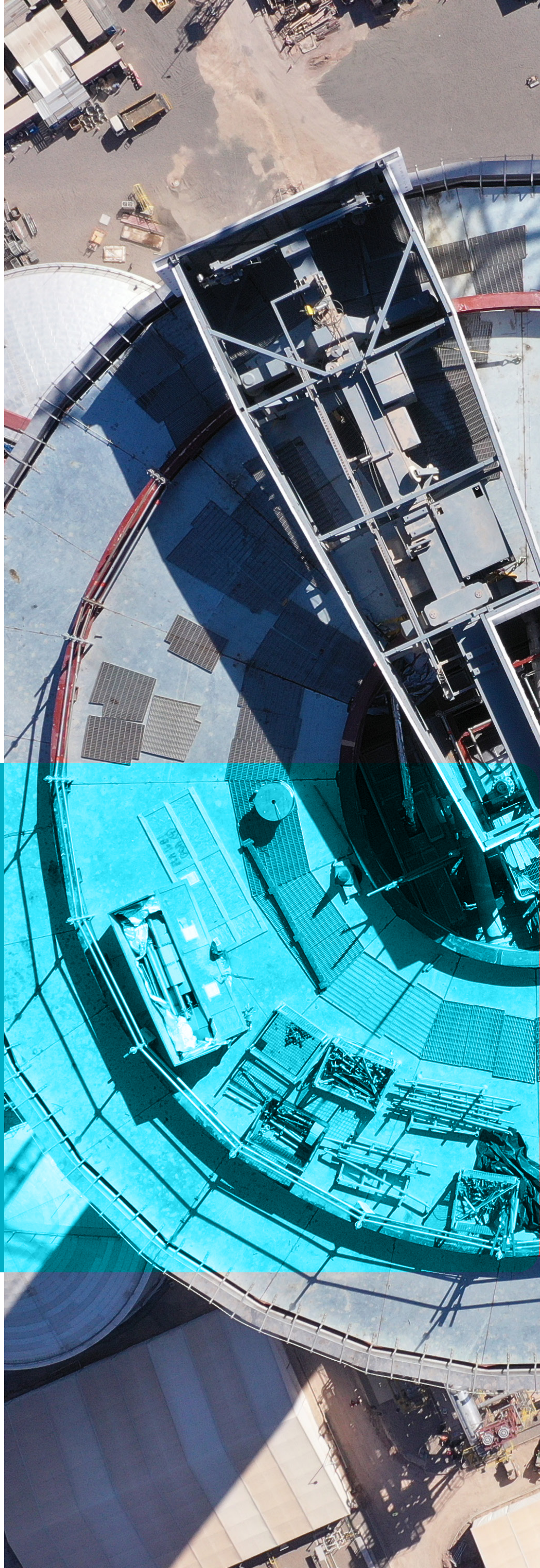
A modification of the current transmission payment allocation scheme is required, with the objective of delivering locational signals to new generation according to expected system usage, minimizing the risk of congestion and inefficient grid development.

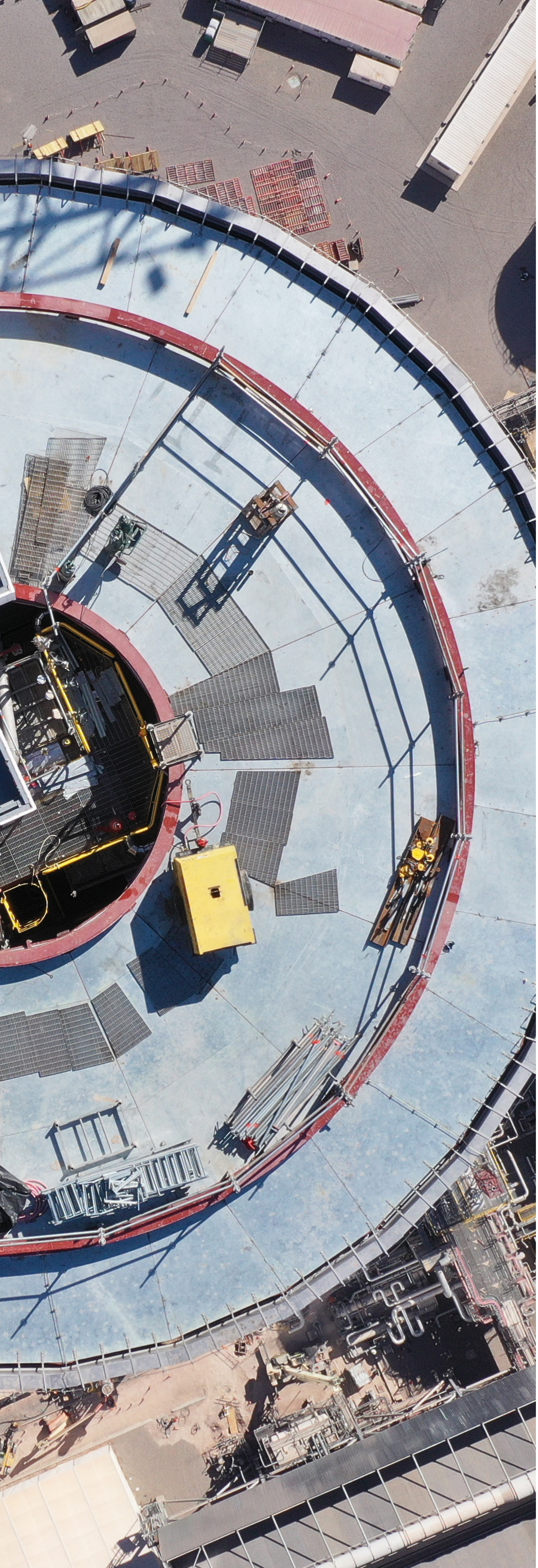
Reliability and Flexibility

Energy transition must be efficient and guarantee the reliability and security of supply to end consumers. In this sense, it is necessary to provide the right incentives to have carbon-free electricity 24/7, 365 days a year, as well as having the necessary attributes to ensure the quality of service. The grid of the future will be increasingly complex to plan and operate, as conventional synchronous generation technologies are replaced by new renewable technologies based on power electronics. The incorporation of storage systems and other grid-forming technologies will provide the security and flexibility attributes that the system needs, which also requires a review of current regulations to promote their incorporation into the power grid, as well as to define the minimum rules and requirements that the technical standards for these new technologies shall contain.

Tenders for Upgrade Works

The current scheme for the development of transmission upgrade works, based on EPC (engineering, procurement and construction) contracts, has been inefficient, resulting in higher costs of the works, generating serious breaches by the contractor companies due to abandonment of the works. On the other hand, significant delays have been observed in the execution of transmission system upgrade works due to non-compliance by EPC contract suppliers. In this sense, given the importance of the transmission systems and the opportunity of their development for an accelerated transition, it is necessary to modify the scheme of works for the upgrades of the transmission systems, so they are executed on time and at lower costs, with adequate supervision and monitoring mechanisms for the bidding process of the EPC contracts.





Energy Tenders for Regulated Consumers

The energy supply tenders for distribution companies require a new design, aligned with the objectives of decarbonization and energy transition towards a 100% renewable matrix. Until now, tenders have been awarded based on the criteria of energy supply at the lowest price. The decarbonization process requires that the new renewable generation to be incorporated not only replace the sources of energy generation that are being withdrawn, but also includes the attributes that the latter contribute to the system security and quality of service.

It is necessary to review the current energy bidding process and evaluate the incorporation of modifications to ensure the provision of all or part of these attributes. The proposal is to establish that the supply solutions awarded in the bids shall comply with the objective of providing carbon-free energy 24/7. Likewise, it should be evaluated whether the new technologies proposed in the bids should incorporate the attributes, or have the capabilities, to provide the necessary services to ensure the security and quality of service that the system requires or, at least, not deteriorate the current levels.

Together with the above, the particularities and restrictions that occur both globally and zonally should be identified, according to the location of renewable energies and the decommission of fossil fuel-based generation, evaluating the convenience or need to establish distinctions according to the reality of each zone of the NPG, unique in the world with a topology and extension only comparable to the Australian grid.

Distribution Segment and DER

It is necessary to modernize the current regulations for distribution systems in order to increase competition in the regulated segments above current levels, allowing the entry of new players, DER and new grid services.

The modernization of the regulations shall be accompanied by a substantial technological change that incorporates intelligence in the distribution networks and smart metering systems, increasing their digitalization and visibility and the access to information of the final consumers by the new actors. This, in turn, will allow for better coordination and management in the operation of the system as well as in the functioning of the energy, capacity and ancillary services markets, considering DER. The separation of the operation and maintenance of the networks from the coordination of the systems and DER should be evaluated, through the creation of an independent distribution system operator, which would guarantee a secure and low-cost operation of the networks and DER, integrated in turn with the generation and transmission system.

Technical Norms and Standards

It is essential to update the current grid code that establishes standards and technical requirements for renewable generation technologies, that are mainly based on power electronics. The vast majority of variable renewable projects installed in the system and those under construction use IBR, based on conventional inverter technology, known as grid-following, which have limitations to provide grid services typically delivered by conventional synchronous generation, that will be decommissioned over time.

It is necessary to define and incorporate new concepts to evaluate the robustness of the grid, to develop minimum standards and requirements for the renewable sources of the future, as well as to update the existing ones to modern standards, so that they incorporate requirements for grid-forming type of technology, which, it is expected, would allow providing the attributes delivered by synchronous generation.

It is necessary to make regulations more flexible in aspects related to network operation and services, in order to optimize the allocation of resources in a timely and more efficient manner.

Grid Modeling and Management

The grid of the future will contain a large amount of equipment based on power electronics, be it renewable generation, FACTS devices, HVDC systems, BESS or others, which makes it necessary to integrate more advanced and accurate simulation tools, and to have, in turn, more detailed models that can run in both off-line time-domain and real-time simulation environments.

Measures shall be taken to incorporate these tools, develop technical capabilities, and elaborate procedures that will allow for more detailed and accurate modeling by equipment manufacturers and owners of the power grid facilities.

In addition, cost-effective solutions shall be identified and studied to allow optimizing the use of the existing transmission assets, without jeopardizing the security and integrity of the system and the supply to end-consumers. These solutions shall be designed and tested in advanced simulation environments, taking into account the highest standards according to applicable international codes.

Decisions and Actions

System Performance Attributes

The existence and maintenance of technical requirements and attributes in terms of flexibility and security shall be ensured for an evolving power grid with changing and uncertain operational conditions. These requirements shall consider:

- **Security of supply at all times**
- **Frequency management and control**
- **Voltage control and grid strength**
- **Ability to operate in islands**
- **Post-fault black-start recovery**
- **Adequate coordination of protections**
- **Power system resilience**

Enabling technologies for the energy transition shall not only be able to operate securely and reliably in a more complex and uncertain environment where power electronics will be dominant, but also provide the attributes to allow maintaining the capabilities that the grid of the future requires. These attributes shall be defined collaboratively with the entire industry, including equipment manufacturers, in order to specify and test the control and protection architecture of these technologies as well as the effectiveness of the services that the system will require and that they will provide, in advanced simulation environments.

The need for the aforementioned attributes shall be identified in advance by the Coordinator, based on the permanent monitoring of operational conditions, and may be integrated through the provision of ancillary services, whether new or existing, the planning process for transmission systems, or regulatory requirements, as appropriate.

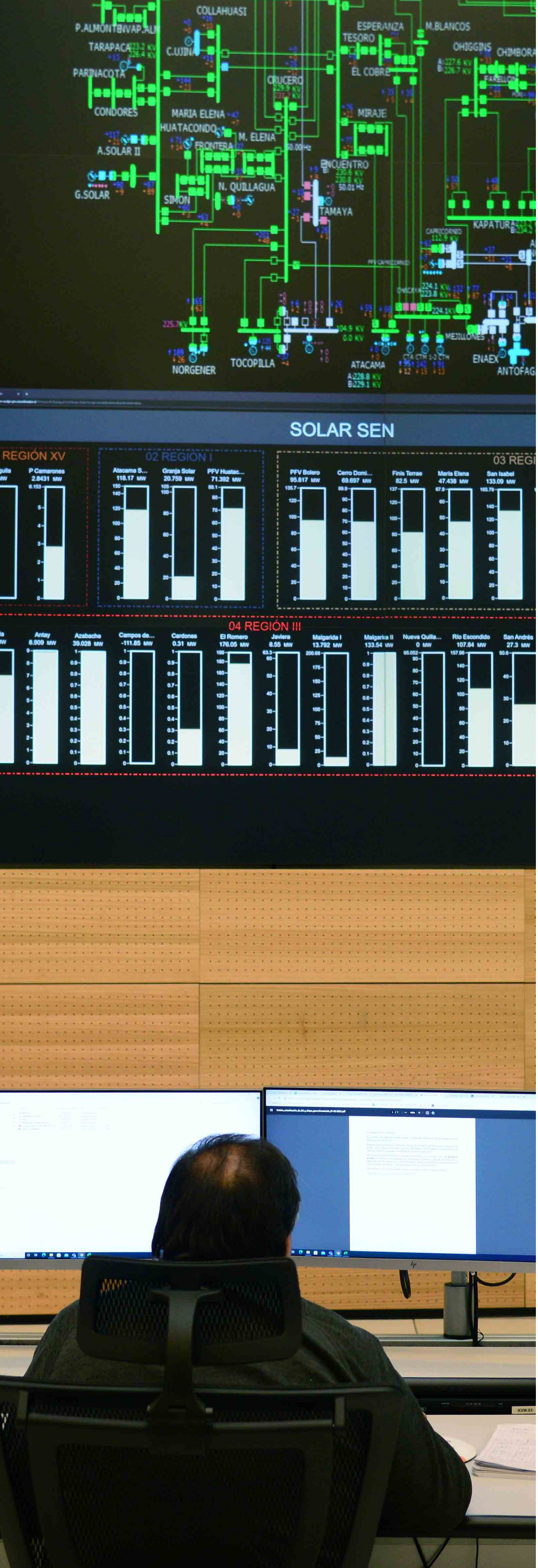
Security of Supply

It is necessary to accelerate the process of integrating new enabling technologies for the decarbonization that provide the attributes described in the previous point. Notwithstanding the above, and depending on the pace of such integration, it is necessary to precisely define the role that natural gas will play in this process, as a transition fuel in the short and medium term, given it low carbon footprint. Power supply reliability is particularly relevant in scenarios of low hydro contribution or other critical supply conditions, such as low inertia or grid strength levels when thermal generation is needed.

Likewise, regulatory signals are required to encourage the transformation of the hydroelectric park, currently designed for the provision of energy and power, into an enabler for the integration of variable renewable energies. Incentivizing its use for the provision of greater flexibility and operation aimed at the provision of ancillary services and the attributes that the network of the future will require (reduction of technical minimums, operation as synchronous condensers, increased load-taking speed, etc.).

System Operation

The Coordinator shall perform detailed analyses of the system more frequently and with greater granularity, for which will require operational tools and new practices to support an increasingly complex operation of the power grid. The new tools and capabilities to be incorporated shall allow analyzing multiple scenarios and contingencies in short periods of time,



with greater spatial and temporal granularity, managing and monitoring a large amount of data and information in real time, under high uncertainty in the availability of energy resources. It will be necessary to have new cutting-edge technologies and advanced artificial intelligence tools, machine learning and Big Data, making use, among others, of Cloud technology to support, accelerate and improve decision-making processes.

Integration of DER

A secure and efficient integration of new DER technologies, such as photovoltaic panels, batteries, and electric vehicles, among others, shall be encouraged, particularly with regard to location signals, and monitoring and control systems, which should coexist harmoniously with existing conventional technologies, taking into account the fossil fuel phase-out process, the current or future market model, and the proposed long-term objectives.

It is necessary to establish mechanisms and integrate technologies that allow the Coordinator to have a better visibility and understanding of the network, accurately identifying the entry of new distributed projects, their performance and behavior in real time, in order to guarantee the secure and reliable operation of the power system.

A key challenge of this integration is specifically related to the coordination of the operation of the transmission system with DER in the distribution systems, so as to ensure that they operate in a coordinated manner, supporting system security through grid services. To optimize these capabilities, the appropriate incentives shall be generated, and the technical specifications shall be defined to allow the participation of DER and other information and communication technologies inherent to a smart grid.

Transmission Planning

Transmission expansion planning is key to enabling the energy transition. Given the long development times of new transmission projects, it is necessary to have the best available information, and technical tools and capabilities to develop cost-effective expansion proposals. Furthermore, such tools and methodologies shall allow for a continuous review of expansion plans, in order to adapt and make the entry of new projects more flexible according to the requirements and capabilities of the future grid.

The Coordinator shall review, adapt and, if necessary, improve its planning methodology and tools according to the new reality with a grid with a predominance of technologies based on power electronics. It shall also review the models, tools and approaches for an integrated planning of transmission and distribution systems, considering DER and a high electrification of consumption.

Regional Interconnections

The advantages of building regional interconnections have been demonstrated internationally, not only to increase competition in electricity markets, but also for security reasons. Particularly in the case of Chile, integration with our neighboring countries would allow us not only to export part of the renewable potential that abounds in our country, but also to supply eventual deficits in the system during extreme conditions or periods of drought. Likewise, having synchronous interconnections at different points of the power grid would strengthen the system by providing inertia attributes and short-circuit levels, allowing a greater insertion of VRE.


MERLIN GERIN
BARRA PRINCIPAL


SAMSUNG
Galaxy S7
Es normal que sea resistente al agua

Research and Development

The energy transition requires solving a series of challenges along the entire value chain of the power sector, which involves significant efforts in research and development. This involves addressing aspects of design, tools and methodologies, as well as the development of new enabling technologies. Overcoming these challenges is urgent and of vital importance to accelerate the transition and shall necessarily involve all industry players, including the academia, coordinated companies, equipment manufacturers, the regulator and the Coordinator.

The main challenge is no longer just the cost of the renewable energies, but how to integrate this source of electricity production to replace fossil fuel-based energy, guaranteeing the security, reliability and stability of the future power grid. Working together and in a coordinated manner, it will be possible to identify, prioritize and address the challenges to be solved in order to guarantee the security and reliability of our power grid during the energy transition.

A research and development roadmap shall be designed for the energy transition, including technological, methodological and training aspects, involving manufacturers, academia and national and international research centers, to address issues related, among others, to the design of advanced inverters, storage systems, new control and protection systems, tools and methods to operate and analyze system stability in real time, digitization of transmission and distribution networks, development of smart grids, including DER and micro-grids, as well as advanced tools for scheduling and planning, etc.

The Coordinator shall continue making progress in signing new collaboration agreements at national and international levels, along with strengthening the work with universities and expanding participation in international organizations that are addressing the challenges of the energy transition at global scale. The above, in order to exchange experiences, best practices and train professionals responsible for carrying out and leading the energy transition process.

HVDC Kimal – Lo Aguirre Project

The HVDC Kimal-Lo Aguirre transmission system will be essential and key to make the decarbonization of the electricity generation matrix viable by 2030, as it will allow the transfer of 3,000 MW of renewable energy from the north to the center of the country. Therefore, it is required that all actors, being private or governmental entities, involved in the development of the project, from the granting of permits and authorizations for its execution, its construction to the commissioning, do so in a collaborative and expeditious manner.

Roadmap

The following table describes the roadmap elaborated by the Coordinator for the 2022-2030 horizon containing the decisions and actions required to achieve the accelerated energy transition scenario.

This roadmap has been prepared with a two-stage approach, Preparation and Adaptation, highlighting the risk factors that affect its implementation and the timeframe for the transition to a generation matrix with 100% renewable energy by 2030.

Horizon	Preparation 2022-2025		
System Attributes	Maintain the essential capabilities that the power system requires as synchronous generation is retired **Risk: Very early retirement of all synchronous generation**		
	Planning efficient installation / reconversion of synchronous condensers	Develop mechanisms to allow for flexibility in the delivery of essential services for the power grid	Test, enable and encourage the installation of advanced or grid-forming inverters.
System Operation	Improve the system's modeling, simulation, and short-term analysis capabilities **Risk: Lack of tools and detailed models of different technologies**		
	Improve data access and governance, and management of simulation models	Improve modeling capabilities and resources to avoid congestions and optimal curtailment	Define decision criteria to balance modeling capability vs. performance
DER Integration	Manage periods with high DER penetration **Risk: Insufficient visibility and predictability for grid planning and operation**		
	Apply advanced DER monitoring	Develop, adapt and monitor equipment performance and capability	Look for incentives for DER grid services contribution

Adaptation 2026-2030

Horizon

System Attributes

Manage the variability and uncertainty of variable renewable generation

Risk: Insufficient flexibility to balance VRE variability

Improve generation and demand forecasting tools and models	Develop infrastructure and data models for monitoring critical variables (climate, etc.).	Optimal dispatching with sufficient flexibility and in different time scales

System Operation

Maintain a secure, operable and resilient power grid

Risk: Complex operational conditions ahead of schedule

Develop operational tools for situational awareness and proactive decision making in real time	Monitoring system to improve grid visibility and controllability	Establish plans, operating policies and processes for complex scenarios under new operating conditions

DER Integration

Integration of new technologies

Risk: Reduced security and reliability due to poor management of data, resources and network constraints

Define roles and responsibilities for security and operation coordination in an integrated system	Build a scalable and secure architecture and infrastructure for massive data exchange	Integrating DER into energy, capacity and ancillary service markets

Horizon	Preparation 2022-2025

Transmission Planning

Improve the system's long-term modeling, simulation and analysis capabilities

Risk: Lack of information, scenarios and modeling capabilities with greater granularity

Improve data access and scenario manage-ment	Improving modeling capabilities by adding greater temporal and spatial granularity	Decision criteria to de-fine future scenarios

Regulation

Proposed changes to current regulations

Risk: Lack of reforms or delays in their enactment and implementation

Improve the grid code to update and incorporate technical requirements for new technologies (Grid-forming IBR, or others)	Implement procedure for homologation and validation of EMT type models	Seek incentives for long-term storage systems with attributes of security and flexibility	IIncorporate location signals based on te-chnical and economic criteria

Research and Development

Development of new capabilities, tools and methodologies

Risk: Slow pace in the development of new tools and methodologies

Development of capabilities and attributes in inverter-based resources (IBR) to ensure system reliability	Development of new operation and planning tools and methods to ensure security and stability in systems with high IBR penetration	Development of new technologies and approaches to improve real-time visibi-lity and analysis in system operator control rooms

Adaptation 2026-2030

Horizon

Transmission Planning

Planning a robust and efficient power grid

Risk: Uncertainty of functionality of new technologies

IDevelop tools to improve decision making under high uncertainty scenarios	Add new applications based on AI/ML and Big Data	Establish plans and processes to anticipate complex scenarios given by the effect of climate change and other extreme events, considering regional interconnections

Regulacion

Structural regulatory reforms

Risk: Lack of reforms or delays in their enactment and implementation

Modernization of Distribution	Revise energy tenders incorporating technical attributes in 24/7 carbon-free generation	Transition to a bidding market for energy, capacity and ancillary services

Research and Development

Development of new architecture for the grid of the future

Risk: Slow pace of development of new enabling technologies

Develop technologies and architectures for future electricity markets and power grids to operate an integrated and highly distributed system	Develop information and communication technologies to overcome the challenges that limit the creation of a competitive market	Investigate the behavior of a grid with high DER penetration to ensure the security and stability of the system

Next Steps

The Coordinator will initiate and reinforce a set of activities within its areas of responsibility to address the future challenges in order to achieve a secure and reliable energy transition by 2030, and thus reach a 100% share of renewable energy by that year. These initiatives include:

1. Continue with the virtualization project work under the agreement signed with Google X for the development of advanced tools for grid planning and operation.

2. Continue working on the development of a digital twin of the power grid in off-line and real-time EMT simulation environments.

3. Conduct a study in the time domain (EMT environment) for the years 2025 and 2030 to model and analyze the feasibility of scenarios with instantaneous 75% and 100% VRE participation respectively, incorporating new technologies such as grid-forming.

4. Move forward with the development of a pilot project to model, simulate and test grid-forming technology in the Coordinator's real-time simulation lab.

5. Move forward with the responsive demand tender process as part of the ancillary services.

6. Prepare bidding terms for grid inertia and strength service, based on the studies carried out in 2021, which concluded on the need to incorporate synchronous condensers and grid-forming technology in the short and medium term.

7

Implementing the model homologation and verification procedure, which contemplates the delivery of detailed EMT type models by the coordinated companies to be incorporated into the NPG digital twin currently under development.

8

Move forward in the development of tools for real-time monitoring of variables that measure the robustness and strength of the grid, such as inertia and short-circuit level (ESCR).

9

Work on proposals for changes to the grid code (NTSyCS, for its acronym in Spanish) that include requirements and specifications for new technologies based on power electronics, and updating of some existing requirements.

10

Complete implementation of intra-day scheduling and model enhancements for the daily operation scheduling.

11

Implement improvements to generation (wind and solar) and demand forecasting models.

12

Sign collaboration agreements with international entities for the exchange of experiences energy transition processes.

13

Integrate the necessary resources and train Coordinator's professionals with the necessary skills to plan and operate a power grid with 100% participation of renewable energies.

14

Work on a proposal for a I2D road map for energy transition.


50.01
GENERACIÓN SISTEMA ELÉCTRICO NACIONAL 24H
HIDRÁULICAS SEN
COTAS EMBALSES


SOLAR SEN
EÓLICAS SEN

www.coordinador.cl

COORDINADOR
ELÉCTRICO NACIONAL