MINISTÉRIO DE MINAS E ENERGIA
SECRETARIA DE PLANEJAMENTO E DESENVOLVIMENTO ENERGÉTICO

2031
TEN-YEAR ENERGY EXPANSION PLAN

epe
Empresa de Pesquisa Energética

Ministério de
Minas e Energia

4. Power Transmission

The objective of this chapter is to debate topics that are currently under greater discussion in the scope of planning the expansion of electric energy transmission and that permeate the recommendations of this PDE.

In addition, it seeks to describe and detail the evolution of the transmission capacity of regional electrical interconnections within the timeframe of the Ten-Year Plan, which is a fundamental input for carrying out the energy analyzes of Chapter 3.

Finally, as an economic signal for the sector, general aspects related to the expansion of the National Interconnected System (NIS) are addressed, such as the planned investments and the associated physical evolution, the potential investments in the replacement or refurbishment of transmission assets at the end of regulatory service life, and the estimate of the evolution of the Tariffs for Use of the Transmission System.

For the preparation of this Plan, the information regarding the transmission area available in August 2021 was considered. Thus:

- Only the planning studies issued up to the aforementioned date were considered (studies involving the expansion of the North/Northeast system and its regional interconnections, resulting from greater renewable expansion and Law No. 14,182/2021, were not addressed).
- The operation start date of the transmission assets not yet granted were estimated according to the expansion scenarios described in section 4.4.1.
- The operation start date of the transmission assets already awarded were updated based on a query made to the SIGET system (ANEEL) on the aforementioned date.
- The results of the Transmission Auction No. 002/2021, held at a later date than the one considered as a reference for this Plan, were not considered in the characterization of the projects as granted or not yet granted.

The main documents cited throughout this chapter can be accessed in the transmission planning area on EPE website, through the following link.

4.1 Transmission Expansion Planning

Activities related to transmission expansion planning are coordinated by EPE and count on the collaboration of transmission and distribution concessionaires within the scope of the Regional Transmission Study Groups (GET), in accordance with MME Ordinance No. 215 (05/11/2020), and EPE/DEE Ordinance No. 1 (01/12/2021).

The planning studies are carried out, within PDE timeframe, based on the electrical load forecasts, on the generation reference expansion plan, and on the expected evolution of the power grid topology.

The initial diagnosis of the transmission system is made from electrical performance studies at different load levels and generation dispatch scenarios, through simulations of power flows in normal conditions and in non-simultaneous contingency of the grid elements (criterion N-1).

Then, the diagnosis of the electric grid results in the realization of a set of transmission studies, which make up the R1 - Technical-Economic Feasibility and Preliminary Socio-environmental Analysis reports, in which new transmission projects are planned and recommended to solve the problems previously identified, feeding back the power grid topology in the planning process.

In the case of projects of a bidding nature, additional studies are necessary to dimension and specify the works to be included in the next transmission auctions. These studies make up the R2 to R5 reports, which are usually carried out by players at the request of the MME: (i) R2 – Details of the Reference Alternative; (ii) R3 – Definition of the Tracing Guideline and Socio-environmental Characterization; (iii) R4 - Characterization of the Existing grid; and (iv) R5 – Land Costs.

The following is an overview of the main documents adopted in carrying out the planning studies, as well as in the preparation of the aforementioned reports.

CRITERIA AND PROCEDURES

The studies that make up the transmission expansion planning process are carried out based on the electrical performance criteria recommended in the document "Criteria and Procedures for Planning the Expansion of Transmission Systems", prepared by the Coordinating Committee for Planning the Expansion of Electrical Systems (CCPE) in 2002.

In 2018, EPE started work with the objective of updating this document taking in consideration the current scenario and the forecast for the future with a strong presence of renewable sources in Brazilian energy matrix, which requires the application of specific procedures and criteria for analysis of the transmission grid.

In general, this work covers the review of the methodology currently considered for carrying out electrical studies, aiming at the dimensioning of new projects, and an economic analysis for the selection and technical-economic recommendation of transmission alternatives.

It is worth noting that the activities associated with this work have been developed with the technical support of an external consultancy, with public hearings being planned for the collection of contributions from interested parties, in addition to workshops for presentations and discussions on the intermediate results.

It is also noted that, in parallel with these activities, EPE and ONS have been holding discussions on differentiated reliability criteria for serving locations connected by radial systems, particularly in the case of federation units geographically distant from other urban centers, a complicating factor for the adoption of emergency measures during the occurrence of critical contingencies. The results of this activity will be incorporated into the update of the general criteria document.

It is estimated that the elaboration of the new document of criteria and procedures for planning the expansion of transmission will be completed in the first half of 2023.

GUIDELINES FOR R REPORTS

The reports developed during the transmission planning process follow the structure and guidelines contained in the document "Guidelines for the Preparation of Technical Reports for the Bidding of New Works on the Main grid", originally prepared in 2005 and last updated in 2020.

It is important to note that this document is constantly being improved. In this sense, throughout 2021, the MME promoted a specific Public Consultation to obtain subsidies from players with a view to publishing a new edition of the guidelines document.

Currently, EPE is analyzing the contributions sent by players to the MME, and should propose a new update of the document in the first half of 2022.

4.2 Important Topics under Discussion

4.2.1 ADEQUACY OF PROACTIVE TRANSMISSION STUDIES

As highlighted in Chapter 3, wind and solar sources should reach an installed capacity of approximately 40 GW at the end of the ten-year timeframe. This increase in the insertion of renewables in the energy matrix brings new challenges for the planning of the transmission system. One of the main challenges is related to the indicative nature of the expansion of generation and the difference in deadlines between the construction of smaller renewable plants (up to 3 years) and transmission lines (about 5 years), which makes adequate coordinating expansion of generation and transmission systems difficult.

To mitigate this effect, EPE has been developing, since 2013, the so-called "Proactive Transmission Studies", which aim to anticipate the planning, dimensioning and recommendation of large trunks for the flow of the previously prospected generation.

Until the end of the last decade, this prospective planning has been facilitated by the fact that energy contracting has occurred mainly from auctions in the Regulated Contracting Environment - ACR, with amounts defined predominantly from the demand of distributors and with registration and monitoring of the candidates for the expansion of generation carried out by EPE itself, through the Monitoring System for Electric Energy Generating Enterprises - AEGE.

However, more recently, with the reduction of investment values for wind and photovoltaic projects and the consequent greater competitiveness and protagonism of these sources in the expansion of the generation supply in the Free Contracting Environment - ACL, new challenges were launched to transmission planning, which began to have greater difficulty in managing information related to prospecting the generation supply, reducing the predictability of amounts and their location.

Furthermore, it is worth noting that this new dynamic of expansion of renewable supply surpasses the very need to meet the demand growth from the NIS, as historically indicated in PDEs, encompassing market interests that result from the greater competitiveness of new technologies, and may even result in the replacement of existing energy supply contracts rather than setting up new expansions.

This issue is evidenced by the numbers of projects in the access queue within the ONS (SGAcesso system), which total almost 180 GW of projects, mainly due to Law No. 14,120/2021, which lays down a closure date for discounts in transmission tariffs of generation players, and, according to Chapter 3, the expectation of additional contracting by the end of the decade, considering all sources, is 40 GW. Thus, planning a transmission system for the integration of all projects in the access queue would lead to an expansion capable of transporting 4.5 times Brazil's energy demand in the ten-year timeframe, generating excessive and unnecessary costs for the payers of the electricity transmission systems through transport tariffs.

Considering the above, and seeking to meet the expansion needs, overcoming the challenges imposed on planning, especially with regard to information management, EPE began to improve the system previously applied in proactive transmission studies.

Within this context, in 2021, innovative strategies were adopted to define the potential of renewable energy to be considered in the proactive transmission studies currently underway in the North and Northeast Regions (item 4.3.2), as detailed in EPE-DEE report -NT-072/2021 – "Expansion of Regional Interconnections – Initial Diagnosis", July 2021.

In general, the forecast of the total amount of installed capacity for these sources in the last year of the studies was based on the annual increments of indicative generation signaled in PDE approved at the time, resulting in a total power of 57 GW and 72 GW, depending on of the evolution scenario of PDE.

Then, a careful process began to investigate the locational aspects of these amounts.

With this objective, we sought to analyze the information available not only in the AEGE (EPE) system, but also in the SIGEL (ANEEL) and SGAcesso (ONS) systems, which made it possible to evaluate a large sample of data and make its categorization, at different levels of trust, from the separation between projects in the DRO phase, Preliminary Access Report (Informação de Acesso), Grid Access Report (Parecer de Acesso), and signature of transmission contracts (CUST/CUSD).

From the largest sample evaluated, it was possible to identify the grid points with the greatest interest in the market for connecting new projects, respecting the growth in demand from PDE, and, based on this, a methodology was formulated for aggregation and representation of the generation prospective study in the transmission planning studies referred to above.

With this methodological advance, it is expected to reduce uncertainty regarding the locational aspect of transmission expansion. Likewise, the representation of prospective generation data with a higher level of confidence, associated with short and medium-term projects with Grid Access Report and CUST/CUSD signed, minimize the risks of regret regarding the amounts of transmission expansion to be carried out.

Finally, it is understood that the improvements in the process must be permanent and must always provide greater synergy between the expansion of the generation supply and the expansion of the transmission grid, in order to avoid the mismatch of schedules, as they make the proactive expansion of the transmission system, with minimal regret costs involved.

4.2.2 FLEXIBLE PLANNING OF ELECTRICAL SYSTEMS

The electrical energy sector has been undergoing major transformations, being strongly driven by the worldwide penetration of non-dispatchable renewable energy sources, such as wind and photovoltaic, allied to the emergence of a new energy market where the consumer gradually tends to play a less passive role, turning into an active energy producer or managing its demand based on economic stimuli and in a decentralized manner.

In the specific case of Brazil, there is also a relative reduction in the energy storage capacity in hydroelectric power plant reservoirs in relation to the load, whose maximum capacity in terms of MWmonth was 7 times the load at the beginning of the century and will become around 3 times the load in 2031, bringing new challenges to the planning and operation of the electrical system, and demanding new services to be provided by the power grid. In addition, these challenges lead to the need for detailed modeling of the hourly variation of wind and solar production, and operational aspects that previously only made sense to be addressed in short-term studies.

In this new environment, it is imperative that the electrical system planning is capable not only of considering the temporal and locational dynamics associated with the expansion of renewable generation, as has been done in proactive transmission studies, but also of using expansion strategies that result in a system that is optimal and flexible enough to accommodate the different load and generation availability scenarios in the different subsystems.

Indeed, there is global recognition that flexibility is an essential component to guarantee the reliability, stability, and energy security of the NIS as the proportion of renewables increases and the new energy market consolidates.

It should be noted that EPE is very sensitive to this issue and has been seeking to guide the studies on the expansion of the transmission grid, notably of regional interconnections, in order to increasingly enable the efficient management of the global resources available in the system, such as inertia and operating power reserve, providing greater resilience to the system in the face of variations in load, generation or even the contingency of large transmission blocks.

In order to add flexibility to the interconnected system, expansion can take place considering different technologies applied to the grid, such as FACTS devices (Flexible AC Transmission System) and energy storage, which can contribute to controllability and increase in energy transmission capacity, optimizing the expansion of the power grid. From another perspective, flexibility can be added to the NIS through the provision of ancillary services.

FACTS DEVICES

FACTS devices are technologies based on power electronics developed with the objective of improving the control and stability of the system, making it possible to increase the energy transfer capacity between certain points in the grid.

Among the diversity of FACTS devices available on the market, the ones that have been most considered by EPE in the scope of the NIS planning are the static compensators (SVC). Other devices based on power electronics are the High Voltage Direct Current links (HVDC) which, in turn, have been showing increasing application in Brazilian system, being the object of EPE analyzes in the proactive transmission studies currently underway in the North and Northeast regions (item 4.3.2).

Considering that the expansion of supply follows the trend of greater spatial distribution, mainly due to the contracting of renewable sources, the alternative of multiterminal HVDC systems becomes a potential application in Brazilian transmission system, since the possibility of installing three or more converters would allow, for example, to collect the generation from, at least, two different points of the grid and drain this energy to a point of high load concentration.

In addition, recent technological advances associated with the DC/AC conversion process, through VSC (Voltage Source Converter) solutions, constitute a potential solution for problems of integrating DC links to weak grids, as well as for the reduction of multi-infeed interactions. In this sense, the reduction of technological gaps, which constituted barriers to the application of this technology in the transmission of power over long distances, as in Brazilian case, has been provided through the use of new converter arrangements, such as the Full-bridge MMC (Modular Multilevel Converter).

In addition, there is also the possibility of implementing hybrid HVDC systems, with rectification based on LCC (Line Commutated Converter) technology and inversion based on VSC (Voltage Source Converter) technology, which can result in an attractive cost-benefit ratio, adding reliability gains combined with reduced project costs compared to the complete VSC solution.

It should be noted that EPE has followed studies in progress on the application of these new technologies and has interacted with manufacturers of direct current equipment, aiming to assess the feasibility of applying them in the NIS, in the medium- or long-term timeframe, considering the technical constraints of design and operating performance requirements usually required.

Within this context, a survey to identify potential suppliers of new technological solutions is also being carried out by EPE, with the objective of verifying if there are sufficient competition conditions to guarantee the good results of future transmission auctions and, also, balanced modular maintenance prices and replacement of equipment throughout the life cycle of transmission assets.

ENERGY STORAGE SYSTEMS

Energy storage technologies, such as electrochemical batteries, electrochemical capacitors, among others, can provide several services in the transmission sector.

Such technologies provide multiple applications, among which are: load balancing, frequency control, voltage control, grid stabilization, among others.

Storage systems are particularly interesting alternatives to eliminate systemic problems in places where the expansion of the transmission system is complex, such as areas with dense urban occupation and/or with environmental restrictions.

In addition, energy storage systems can be installed in the NIS with the objective of postponing system expansions and/or reinforcements in facilities already in operation, avoiding the anticipation of replacements or refurbishments that would only occur at the end of their physical service life.

Another benefit about storage systems is related to their fast implementation speed (average of 6 months for contracting and commissioning) in relation to the construction of substations or construction/repowering of transmission lines. Thus, storage devices can eliminate systemic problems in the short term, providing time for the operation start date of conventional solutions.

Regarding this issue, attention is drawn to the innovative recommendation made by EPE and ONS in EPE-DEE-NT-085/2020 / ONS NT 0129/2020, also approved by the MME, involving the installation of battery banks with an installed capacity of 30 MW and at least 2 hours of discharge time (60 MWh) at SE 138 kV Registro, located on the coast of the State of São Paulo, with the objective of mitigating short-term electrical problems caused by the delay in the implementation of the structural solution originally planned, constituted mainly by the new SE 230/138/88 kV Manoel da Nóbrega.

In addition, the mobility potential associated with this technology is also highlighted. Container energy storage system solutions, for example, are relatively compact and, therefore, have greater feasibility of insertion into existing substations. They can also provide services at multiple points in the system throughout its lifespan if it is possible to overcome the challenges associated to transport and relocation logistics.

In summary, EPE understands that energy storage on a scale compatible with Main Grid installations should be seen as an alternative or complement to the conventional expansion of the transmission system and, when incorporated into the market as a system resource, it can considerably increase the consumer welfare at a certain cost and reliability.

ANCILLARY SERVICES

In addition to the expansion of interconnections between the subsystems and the implementation of equipment with greater controllability, there are other ways to add flexibility to the interconnected system, one of which is based on the provision of ancillary services, which are currently predominantly supplied by centralized generation plants.

Taking into consideration the different paradigm shifts in the composition of the energy matrix and in the operation of the electrical system, which have been occurring in recent years, ANEEL established, in 2019, a Public Consultation to foster discussions on the subject, dealing not only with the possibility of creation of new ancillary services, in addition to those that until then are regulated by Normative Resolution no. 697/2015, as well as on different market views and regulatory treatment.

Since then, EPE has been engaged in the analysis of the topic, having published, in October 2021, the study EPE-DEE-NT-090/2021-r0 – "Ancillary Services from the perspective of Expansion Planning", in which are presented initial proposals for the creation of new ancillary services, as well as proposals for differentiated treatment from those already regulated, aiming, through the establishment of a set of attributes for potential providers, to allow technological neutrality and a competitive environment for the supply of services.

In that study, the ancillary services with the greatest impact on the long-term planning environment were addressed with greater emphasis, namely: (i) frequency control in its different time scales (primary, secondary and complementary dispatch); and (ii) the reactive power support.

Specifically with regard to frequency control, new possibilities for ancillary services were categorized, such as the provision of rapid frequency control and demand response.

In addition, the possibility was raised for Distributed Energy Resources (DER), such as storage itself and demand-side response, to participate in the provision of frequency control and reactive support services, in addition to conventional generation and transmission solutions, competing with centralized resources. Such participation could be done individually, requiring greater operational complexity, or through "aggregators", which form better manageable virtual plants.

Finally, recognizing the importance of deepening and advancing the topics addressed, EPE proposed, in the aforementioned study, a roadmap with the chronology of the next steps and planned activities, which include carrying out specific studies to identify new requirements or resources for Brazilian electrical system in the medium and long term, aiming at the basis of more advanced discussions, from the perspective of planning.

4.2.3 INTEGRATION OF THERMAL PLANTS OF LAW NO. 14,182/2021

Law No. 14,182/2021, enacted on 07/12/2021, provides for the privatization process of Eletrobras and for the contracting of a total amount of 8,000 MW of natural gas-fired thermoelectric generation in the North, Northeast, Mid-West regions and Southeast, considering different milestones between the years 2026 to 2030, according to **Figure 4 -** 1.

From the perspective of transmission expansion planning, the integration of generation potential of this order represents a major challenge for the effective coordination of the expansion of generation and transmission assets. Although the regions where this generation expansion will take place have been established, some more specific information, such as the connection point and the individual installed capacity of the projects, will only be known when the contract is actually firmed. These data are decisive and need to be known in advance to make possible not only the analysis of the electrical performance of the NIS with the new generation, but also the realization of specific transmission planning studies, in case reinforcements are required to ensure the integration of those projects.

It should be noted that the singularities associated with those contracts make it difficult to adopt pre-emptive planning strategies such as those that have been adopted in proactive transmission studies, oriented towards the integration of renewable sources, where it is possible to estimate the dynamics of potential realization from consolidated databases, as described in item 4.2.1. In the case of these thermal plants, there is little information about potential candidates for generation expansion. In addition, the very dynamics of contracting can result, within the same region, in the establishment of large plants that can be implemented both adjacent to each other or in completely different areas, which totally changes the approach to transmission expansion planning studies.

Thus, in the case of thermoelectric plants under Law 14,182/2021, the understanding is that planning the expansion of transmission after the energy auctions is the best strategy to be adopted. On the other hand, the challenge for coordinating the expansion of generation and transmission assets becomes even greater, especially considering the contracts involving integration by 2026 and 2027, which may eventually require expansion of the main power grid.

It is expected that the recommendations of the proactive transmission planning studies that are currently being carried out by EPE with the objective of expanding the transmission capacity from the North/Northeast regions to the Southeast/Center-West regions (item 4.3.2) may also contribute positively to mitigating any restrictions on the existing interconnections. However, depending on the location of the thermal plants that are going to be effectively contracted, new transmission expansion studies may be required.

Regarding this issue, it is noted that the processes of planning, bidding and construction of transmission projects currently require about 7 years to complete. This process begins with the recommendation in the R1 Reports, goes through the preparation of complementary reports (R2 to R5 prepared by the transmission agents by request of the MME), by the inclusion of the projects in the Power Transmission Concession Plan - POTEE prepared by the MME, by conducting the bidding process for the new assets (ANEEL), for the external control carried out by the Federal Court of Accounts (TCU), for the signing of concession contracts, for obtaining environmental licenses, until the implementation of the project by the transmission agents.

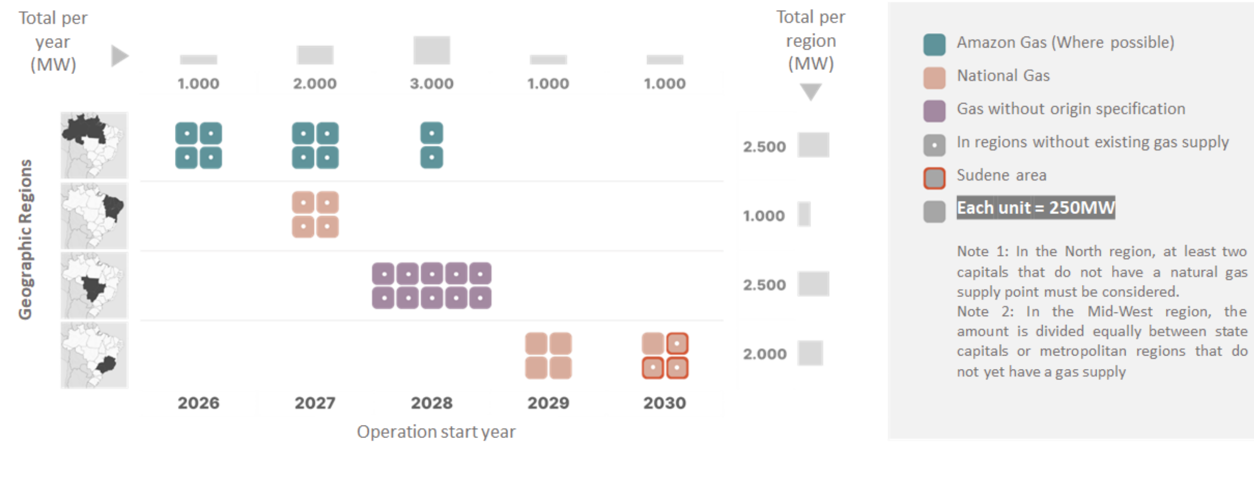
It should be noted that the processes related to transmission granting process had important regulatory updates with the issuance of the IN-TCU Normative Instruction No. 81/2018, which considers the inspection of privatization processes by the TCU and which revoked the Normative Instructions No. 27/1998, 46/2004 and 52/2007. With this new Normative Instruction, the deadlines for sending the necessary documents for the TCU examination were standardized, changing to 90 days before the publication of the public notice. This way, parallel activities to the TCU examination are no longer allowed. In addition to the other deadlines for the instruction of the bidding process, approximately 11 months are required for the execution of the entire bidding process.

In practice, this chain of deadlines only allows the execution of a maximum of 2 transmission auctions per year. Therefore, any unforeseen events that delay the publishing of the planning reports (R1 to R5) or in the inclusion of projects in the POTEE, even if they are small delays, can directly reflect on the feasibility of including a particular project in a bidding process. When the window of opportunity for an inclusion is lost, the next possibility usually appears approximately 6 months later, which delays the beginning of the other stages, especially the implementation of the projects.

It is noted that the improvement of this process, with the discussion on the review of the established deadlines and the parallel execution of some of the phases that involve the instruction, inspection and publication of the bidding process can contribute positively to the reduction of the total deadlines involved in the bidding for transmission projects and also for the adequate coordination of the expansion of generation and transmission assets, which is particularly important considering the challenges for the integration of thermoelectric plants provided for in Law 14,182/2021.

Consequently, it is important that the sector agents discuss the convenience of reducing and/or simplifying the steps related to the bidding process for transmission assets to speed up the implementation of the planned expansions and reduce possible mismatches between the operation start dates of the generation projects and the transmission assets.

Figure 4 - 1: Summary of Law No. 14,182/2021 determinations



Source: EPE

4.2.4 DEALINGS WITH EXISTING INTERNATIONAL INTERCONNECTIONS

In addition to the binational Itaipu project, involving Brazil and Paraguay, Brazil also has electrical interconnections with Argentina, Uruguay, and Venezuela.

The possibility of modernizing or expanding these interconnections, and even deactivating some of the current interconnection points, has been the object of joint analysis by EPE and the ONS in recent years in response to requests from the MME.

The following items present an overview of the negotiations that have already been or are being carried out in relation to the aforementioned interconnections.

PARAGUAY (UTE ITAIPU)

The transmission system responsible for the flow of energy from HPP Itaipu is composed of three transmission lines of alternating current at 765 kV, one line of alternating current at 525 kV, and by two high voltage direct current bipoles (HVDC), in ± 600 kV.

It should be noted that bipoles 1 and 2 of Itaipu, an innovative project at the time, in terms of technology and voltage class, began operating in 1984 and 1987, respectively, reaching around 37 years (bipole 1) and 34 years (bipole 2) of operation. Such values are higher than the international experience regarding the average service life of important elements that make up similar technology and size HVDC bipole installations (Guidelines For Life Extension of Existing HVDC Systems, WG B4.54, Cigre, February 2016), which motivated Furnas, responsible for these two bipoles, to present to the MME a proposal for their modernization (Revitalization of Direct Current Converter Stations, Technical Note, Furnas, 2017).

Thus, in December 2018, the MME then started the evaluation, with the support of EPE, ONS, and ANEEL, of the technical, economic, regulatory and commercial conditions for the modernization of the direct current transmission system associated with the HPP Itaipu, focusing on the converting substations of the Foz do Iguaçu substation and the Ibiúna substation, based on the proposal initially presented by Furnas.

As part of this activity, EPE and ONS issued, in June 2020, the Technical Note EPE-DEE-NT-099/2019 / ONS-NT-0118/2019, dealing with the electrical energy and technical aspects associated with the modernization of the converters in question.

In general, the electro-energetic studies carried out indicated that the primary factor that justifies the modernization of the CCAT system is the contribution that this link can provide, at a competitive cost, to meet the growing need for peak capacity in the SIN, from the generation of the Itaipu HPP.

The studies also indicated that the initial modernization of the converters of only one of the two bipoles, with the same characteristics as the current ones, is the most appropriate strategy from a technical point of view, with the decision regarding a subsequent modernization of the second bipole conditioned to a more detailed investigation on the forecast of Paraguay's load and on the coincidence of the maximum demands of Brazil and Paraguay, variables that determine the surplus energy available to Brazilian system.

It should be noted that the replacements of the facilities referred to in the previous paragraph were incorporated by the MME into the POTEE 2020 - 1st Issue (tab DIT Itaipu), currently being implemented by Furnas/Itaipu, based on an agreement proposed by these players to the Granting Authority , without involving the transfer of costs to the SIN.

ARGENTINA

Brazil has two electrical interconnections with Argentina, both made using 50/60 Hz back-to-back frequency converters.

The first converter, Uruguaiana, of smaller size (50 MW of nominal power), went into operation in 1994, connecting to the Argentine system through a 132 kV transmission line between the Uruguaiana substation, in Brazil, and the substation of Paso de Los Libres, Argentina.

The second converter, Garabi, is composed of two units of 1,100 MW each, which came into operation in 2000 and 2002, respectively. This converter is connected on the Argentine side via a 500 kV transmission line between Garabi and Rincón and, on Brazilian side, by 525 kV lines between Garabi and the Santo Ângelo and Itá substations.

At the beginning of the 2010s, these facilities were considered as having the same characteristics of assets that belong to public electricity transmission service concessionaires. Also, their authorization validity periods will end by 2020 and 2022.

Thanks to the proximity of these milestones, and because of the formal request of MME in March 2020, EPE and ONS carried out joint analyzes in order to indicate the destination to be given to the assets, which would involve the maintenance of their operation, their decommissioning, or even the modernization of these facilities.

Regarding Uruguaiana, it was recommended, based on the Technical Note EPE-DEE-NT-036/2020 / ONS DPL-REL-0160/2020, the decommissioning of the converter by July 2021. This recommendation, which is still under analysis by the MME, was based on the evolution of the NIS, on the constructive characteristics and on the history of use of the Uruguaiana converter, as well as the results of the studies carried out by EPE and ONS so far.

In relation to Garabi, after the decision of the MME to demand from ANEEL the tender for the operation and maintenance of the facilities for a period compatible with the end of the physical service life of most of the assets of these facilities, estimated at around 10 years (year 2032), EPE and ONS issued the Technical Note EPE-DEE-RE-051/2021 / ONS DPL 0062/2021, with the analysis of the modernization of the assets necessary for the continuity of the operation of the facilities of the Garabi I and II converters in a compatible timeframe with the intended bidding period, based on: (i) information previously made available by the concessionaire Enel CIEN, currently responsible for these assets; (ii) international references on the subject; and (iii) contacts and interactions with the main manufacturers of HVDC converters, given the particularities of the technology involved (CCC type), with only three installations of this type in operation in the world.

Still on Garabi, it should be noted that MME, EPE, ONS, and ANEEL are working on specific documentation to serve as a basis for the transmission auction in which the operation and maintenance of the facilities will be tendered. The total investment associated with the modernization of these assets is still being evaluated.

URUGUAY

The first electrical interconnection between Brazil and Uruguay was established in 2001, from a 50/60 Hz, back-to-back frequency converter, with a power of 70 MW, located in Rivera (Uruguay), and connected to Brazilian side a 230 kV transmission line to the Santana do Livramento substation.

Subsequently, in 2016, the interconnection between the countries was increased through a 50/60 Hz, back-to-back frequency converter, with a power of 500 MW, located in Melo (Uruguay), with integration to Brazil from a line transmission line at 525 kV to the Candiota substation, which has a 525/230kV transformation and is connected to the NIS through a 230 kV transmission line to the Presidente Médici substation. This system will be reinforced, in 2022, through the implementation of two 525 kV transmission lines between the Candiota Region and the Porto Alegre Metropolitan Region.

Regarding the Rivera interconnection, it should be noted that the granting of associated facilities expired in early 2021, and ANEEL Resolution No. 043/2001 established that, at that time, the assets and facilities that make up this transmission system should be incorporated, free of charge, to the Federal Government's assets, if they were recognized as useful for the electric energy service or for the continuity of energy integration between Brazil and Uruguay.

Thus, in response to a recent MME request, made in November 2021, EPE and ONS are evaluating the opportunity and convenience of maintaining the operation, decommissioning, or modernization of these facilities.

VENEZUELA

In 2001, Brazil-Venezuela interconnection came into operation, using a transmission system at 230 kV, with approximately 780 km, connecting the substation of Boa Vista, in Brazil, with the substation of Macagua, in Venezuela.

Although the capacity of this system is 200 MW, it is not possible to establish imports above 150 MW by Brazil, due to the deficit of reactive power on the Venezuelan side. It is important to mention that even with the start of operation of a static VAR compensator in the 230 kV sector of SE Boa Vista it was not possible to increase the power transfer between the countries.

In 2010 the supply of energy from Venezuela began to suffer frequent interruptions, which imposed the need to hold a specific auction for contracting thermal generation in Roraima on an emergency basis. Since March 2019, this interconnection has been out of operation, with no resuming forecast.

It is noted that the contract signed between Brazil and Venezuela ends in 2021 and now the MME is studying the maintenance or deactivation of the Boa Vista – Santa Elena transmission line and the maintenance of the Boa Vista substation.

4.2.5 IMPROVEMENT OF THE LOCATIONAL SIGNAL FOR GENERATORS

The Tariffs for Use of the Transmission System – TUST are established based on the Nodal Methodology. The application of this methodology requires the definition of previous conditions that have a significant impact on the calculations that define the locational and stamp portions that make up the tariffs, which may lead to inadequate signaling for the efficient use of the transmission grid.

Among these constraints, the consideration of the proportional dispatch of generation by submarket stands out, which is equivalent to considering a single energy scenario where the flow in the interconnections between the subsystems is quite reduced, with a very low probability of occurrence. This condition makes it difficult for the Nodal Methodology to adequately capture the use of the power grid, especially regional interconnections, by the generation players.

As a result, there is a predominance of the contribution from the stamp portion of TUST (approx. 100%), which "socializes" the remuneration of the system around average values, conflicting, therefore, with the general guidelines of Law no. 9427/1996, which determines the allocation of higher costs to the agents that make the most use of the transmission system. The graphs below, extracted from Technical Note EPE-DEE-NT-014/2021 - "Calculation of TUST – Sensitivity Analysis", illustrate this issue.

Chart 4 - 1: **TUST-generation portions**

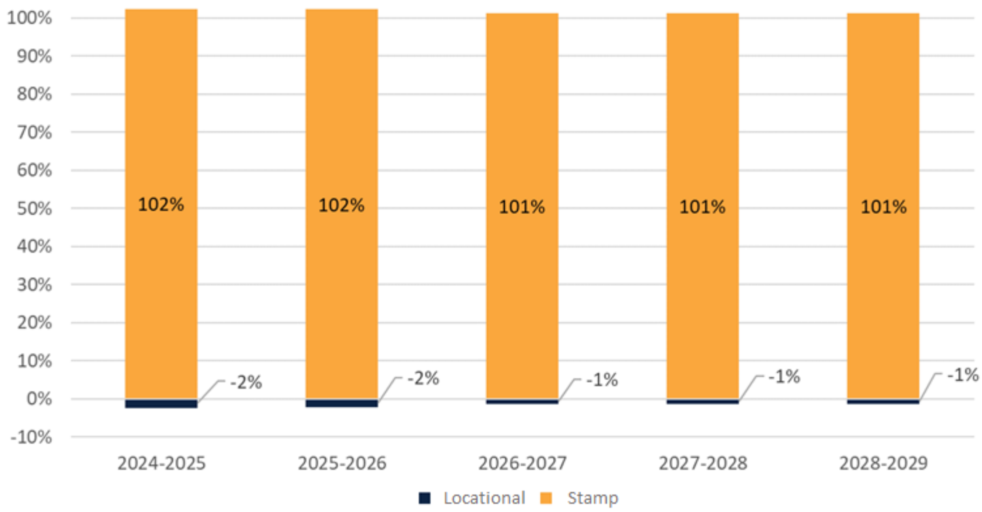
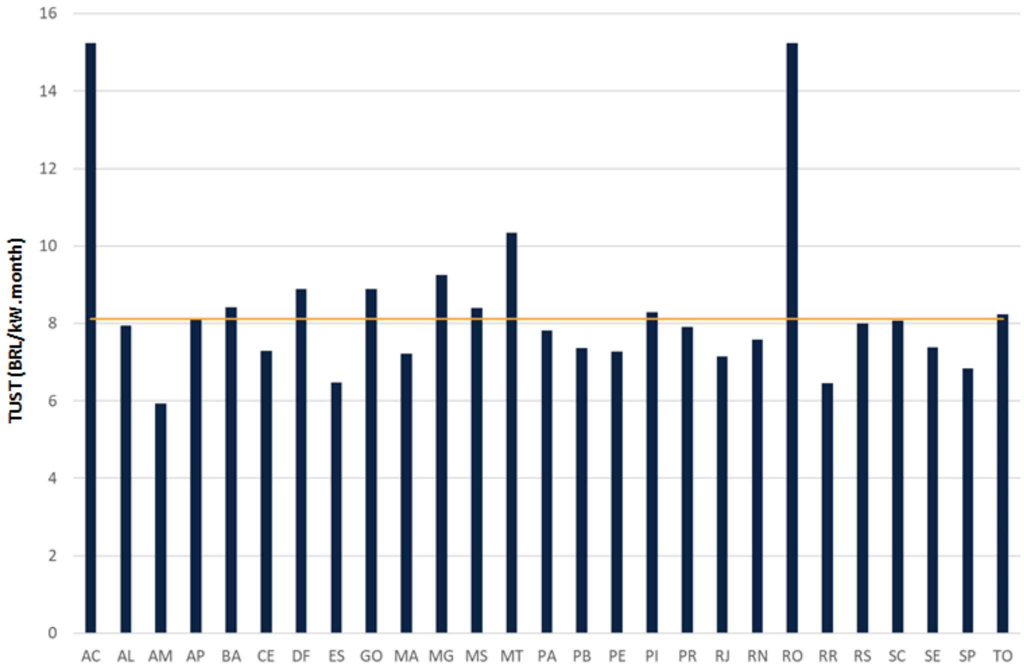


Chart 4 - 2: TUST-average generation per federation unit, 2028-2029 cycle



It is worth noting that the "socialization" of the grid's remuneration artificially contributes to the greater attractiveness of generation projects located outside the large load centers and that export energy to these centers, since TUST is unable to capture the greater use and investments necessary for the expansion of electrical interconnections with these areas. As an example, it is worth mentioning that despite demanding significant investments for the expansion of the interconnection between the North/Northeast and Southeast/Center-West regions, the projects located in the Northeast region have an average TUST very close to the tariffs of the Southeast region.

In addition, it is worth noting that due to the volume of potential generators in the Northeast Region, the access of plants to the transmission system is often conditioned to the entry into operation of new transmission lines, which may affect the expansion of energy supply and, ultimately, the NIS' own energy security.

Therefore, it is understood that the improvement of TUST's locational signal is essential to ensure a more rational use of the transmission system, including the potential to facilitate/accelerate the integration of new generators into the transmission system, by adding competitiveness to projects closer to large load centers, notably less dependent on significant grid expansions.

In fact, the importance of this improvement goes beyond the correct and "fair" allocation of costs associated with transmission systems, also interfering in the generation planning expansion. On this issue, the studies carried out within the scope of the Technical Note EPE-DEE-NT-014/2021 indicate, in a macro way, that the improvement of the TUST locational signal can result in different spatial distributions for the indicative generation in the ten-year timeframe, eventually representing relief in the transmission grid.

EPE can contribute a lot to the discussions on this topic. Within this context, as indicated in the Technical Note EPE-DEE-NT-014/2021, it is understood that it is appropriate for the TUST to be calculated based not only on a single generation dispatch scenario, but on associated more likely scenarios/weighted with their probabilities of occurrence derived from energy studies, respecting known electrical restrictions in the system.

4.3 Regional Electrical Interconnections

The electrical interconnection between regions enables the optimal use of the energy resources available in the system, providing the management of seasonal complementarity between hydrographic basins and intraday between renewable sources, such as wind and solar, as well as taking advantage of portfolio effects.

In addition to bringing benefits to the electrical security of supply, the expansion of interconnections also causes positive impacts on price formation, allowing the export of surplus energy generated by sources with lower operating costs to meet the demand of subsystems whose marginal cost of operation is higher.

The following sections deal with the prospects for the expansion of regional electrical interconnections within the timeframe of PDE 2031.

4.3.1 PLANNED EVOLUTION OF INTERCONNECTION BOUNDARIES

The graphs throughout this section present an overview of the evolution of interconnection capacity limits, up to December 2031, based on the assumptions indicated at the beginning of this chapter.

Within this context, three distinct NIS configurations are considered in this comparative analysis: (i) existing system in January 2021; (ii) planned system until December 2026, considering only transmission assets already tendered; and (iii) system planned until December 2031, also considering transmission assets not yet tendered. **Table 4 - 1** and **Table 4 - 2** present the main expansions considered in configurations (ii) and (iii), respectively.

It is worth noting the expressive evolution of the total export and import capacity of the Northeast Region, at 150% and 60% of the initial year's capacity, respectively, until December 2026. This expansion increases the reliability of meeting the subsystem's demand, reducing the possibility of islanding, as well as bringing systemic benefits to the NIS. It also provides the export of lower-cost energy from the abundant renewable supply subsystems to the others.

Regarding the evolution of the simultaneous export capacity of the North and Northeast subsystems, it is observed that the consideration of the direct current system at 800 kV DC Graça Aranha – Silvânia, originally documented in the report EPE–DEE-RE-020/2016 and currently in the reassessment phase (more details in section 4.3.2), can add approximate gains of 4 GW by the year 2031, in addition to the gain of approximately 6 GW expected with the implementation, by the year 2026, of projects already planned and tendered. This evolution of limits signals the possibility of reducing the restrictions on the flow of hydraulic and/or renewable surpluses that occur mainly in the transition between the wet and dry periods of the North Region, when there is a possibility of high availability of water resources, concomitant with high-capacity factors of renewables in the Northeast Region.

It is important to point out that, in addition to promoting the optimization in the use of energy resources, the strengthening of the interconnections between the North/Northeast and Southeast/Mid-West systems also makes the electrical system more robust and resilient to the occurrence of contingencies, bringing greater operational flexibility in different scenarios of generation and load availability in the NIS.

Finally, attention is drawn to the gains in energy transfer capacities from the Southeast Region and the South Region, around 30% by December 2031, from the start of operations of important planned transmission lines. It should be noted that the planned reinforcements for this interconnection, bid on in the Transmission Auction 002/2021, were included in the third configuration of the system, with operation start date scheduled for the year 2027.

Table 4 - 1: Planned and tendered projects with an impact on the evolution of interconnection capacity, until December 2026

Interconnection	Planned and tendered works, with entry into operation by December 2026
North ↔ Southeast/Mid-West	TL 500kV Xingu - Serra Pelada - Miracema C1/C2 TL 500kV Serra Pelada - Itacaiúnas C1
North ↔ Northeast	TL 500kV Miracema - Gilbués II C3 TL 500kV Gilbués II - Barreiras II C2 TL 230kV Dianópolis - Barreiras II C1
Northeast ↔ Southeast	SE 500 kV Janaúba 3 - Synchronous Compensators - 2 x (-90/+150) Mvar LTs 500kV Pirapora 2 – President Juscelino C1/C2 TL 500kV Presidente Juscelino – Itabira 5 C1/C2 SE 500 kV Padre Paraíso 2 - Static Compensator 500 kV (-150/+300) Mvar TL 500kV Poções III - Padre Paraíso 2 - Governador Valadares 6 C2 TL 500 kV Governador Valadares 6 - Mutum C2 TLs 500kV Buritirama - Queimada Nova II - Curral Novo do Piauí II C1 TL 500kV Gilbués II - Barriers II C2 TL 500 kV Porto Sergipe – Olindina – Sapeaçu C1 TL 500kV Sapeaçu – Camaçari IV C1 TL 500kV Morro do Chapéu - Poções III – Medeiros Neto II – João Neiva 2 C1
South ↔ Southeast/Mid-West	TL 525kV Ivaiporã – Ponta Grossa – Bateias C1/C2 TL 525 kV Foz do Iguaçu – Guaíra -Sarandi -Londrina C1/C2 TL 525 kV Areia - Joinville Sul - Itajaí 2 - Biguaçu C1 New SS 525/230kV Gaspar 2 and other works associated with the electrical service of the State of Santa Catarina: North and Itajaí Valley Regions

Table 4 - 2: Planned projects with an impact on the evolution of interconnection capacity, not yet tendered and/or with entry into operation as of the year 2027

Interconnection	Works not yet tendered or expected to start operating in 2027
North ↔ Southeast/Mid-West	TL ±800kV CC Graça Aranha - Silvânia
South ↔ Southeast/Mid-West	TL 525kV Bateias – Curitiba Leste C1/C2 TL 525kV Assis – Ponta Grossa C1/C2

Chart 4 - 3: Progress of the average total export/import capacity of the Northeast Region

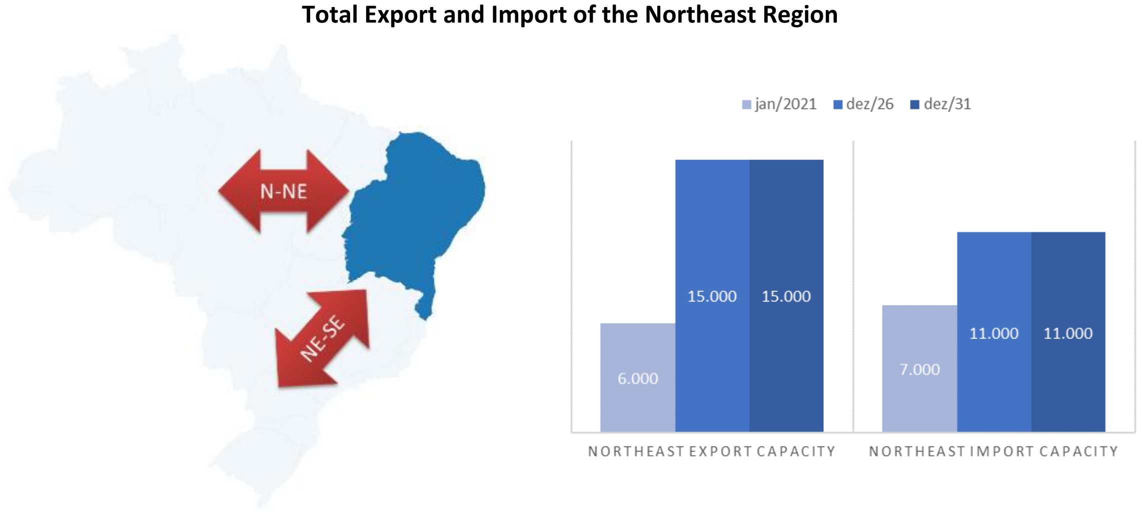


Chart 4 - 4: Progress of the average total export capacity of the North/Northeast

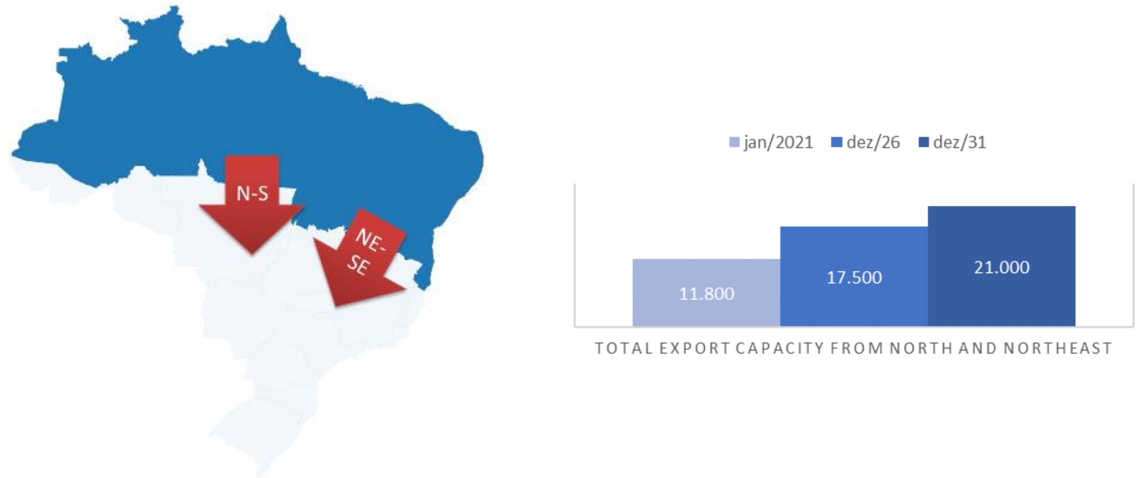
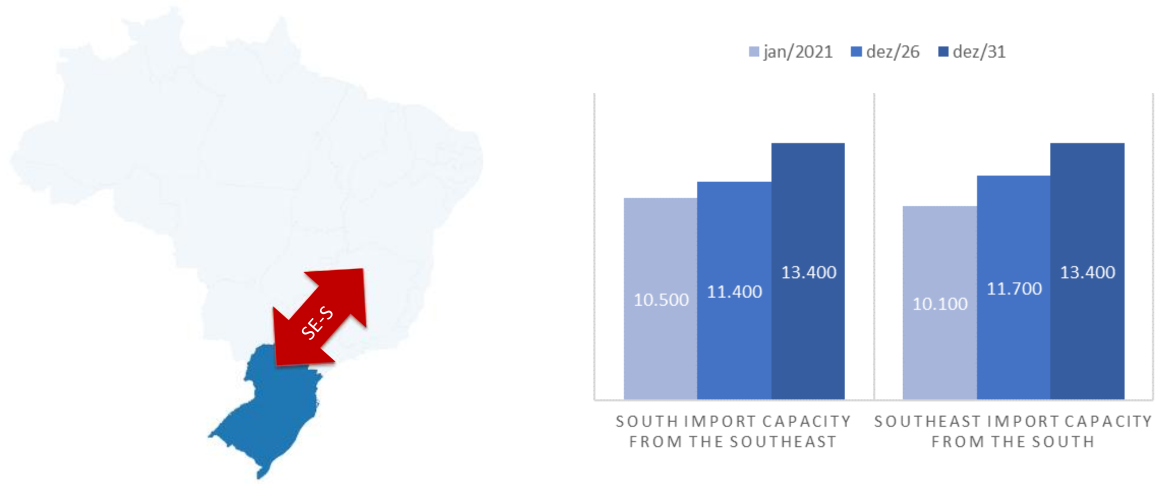


Chart 4 - 5: Progress of the average capacity of imports from the South through the Southeast and imports from the Southeast through the South



4.3.2 EXPANSIONS OF INTERCONNECTIONS UNDER STUDY

PDE 2031 reference generation plan signals a strong trend towards expanding the supply of renewable generation in the North/Northeast regions. It is expected that this expansion will take place not only through energy auctions, but also through contracts directly carried out in the Free Contracting Environment - ACL, as previously contextualized in item 4.2.1.

Considering the order of magnitude of the amounts of generation, and considering the electrical performance criteria usually applied in the scope of the planning and operation of the power grid, it appears that the expansion of the transmission system will continue to be required in the coming years.

In fact, even though the expansion of generation occurs in a different way, according to the sensitivity scenarios analyzed within the scope of PDE, the reinforcements in the transmission grid are shown to be the least regret solution, since they allow greater energy integration between the subsystems, allowing the flow of regional generation surpluses, regardless of the energy source of origin, making the interconnected system also less susceptible to prolonged droughts and safer with regard to electrical energy supply.

STUDIES IN PROGRESS

After the elaboration of PDE 2030, which also indicated a significant expansion of the prospective generation supply in the North/Northeast regions, EPE prepared the Technical Note EPE-DEE-NT-072/2021 - "Expansion of Regional Interconnections - Initial Diagnosis", of July 2021, in which the need to expand the total export capacity of the Northeast Region by approximately 15 GW by the year 2031 is signaled.

It is important to mention that this expansion is additional to the total increase of 9 GW indicated in **Chart 4 - 3**, already foreseen for the period 2021-2031, considering the operation start date of the transmission projects already planned and tendered. In other words, it is required that at the end of PDE timeframe, the total export capacity of the Northeast Region reaches about 30 GW.

This expansion is necessary so that the North/Northeast Region can reach approximately 57 GW in installed capacity in renewables, considering the criteria and assumptions adopted in the calculation of the available transmission system capacities necessary for the access of new generation projects to the power grid, as well as electrical system performance criteria recommended in the planning and operation of NIS.

In order to identify the minimum global cost solution for the expansion of the system, EPE programmed the simultaneous execution of a set of proactive transmission studies aiming two macro-objectives: (i) provide greater capillarity of the Main grid, thus enabling greater capacity to integrate generation resources and load growth; and (ii) guarantee the full flow of regional generation surpluses without power restrictions.

To meet the first macro-objective, regional studies are being developed whose recommendations should guarantee an increase in the transmission system capacities for the connection of new generations projects to the NIS, benefiting not only the new generation projects, but also large consumers, who demand a robust infrastructure for its connection.

The transmission assets to be recommended from the regional studies also configure complementary infrastructure to the interconnections, supporting contingency situations of transmission elements and adding additional gains to the power transfer capacity between subsystems.

It is noteworthy that these regional studies should recommend transmission assets that will complement recently planned transmission corridors for the Northern Area of Minas Gerais (study EPE-DEE-RE-064/2020), providing partial gains so that the total export capacity of the Northeast Region reach around 30 GW.

To meet the second macro-objective, the study entitled "Expansion of Regional Interconnections - Analysis of Alternatives" is in progress, where transmission solutions that allow a high transfer capacity increase are being assessed. In this study, “express transmission corridors” that provide the direct flow of regional power surpluses to the largest load centers in Brazil are being assessed.

As an integral part of the solution, the Graça Aranha – Silvânia +800kV DC system can be highlighted, originally documented in EPE–DEE-RE-020/2016 report, which is being reassessed within the scope of the current study and should be complemented by other grid expansions that provide the necessary interconnection capacity gains.

Finally, it is worth noting that, while the North/Northeast Region acquires a predominantly exporting profile in the timeframe of PDE 2031, the South Region follows a trend of preponderance in import energy scenarios. In the analyzes of Chapter 3, it is possible to see the need to expand the interconnection capacity of this subsystem by 1 GW in addition to complementing the supply of local generation.

Given this scenario, within the scope of the study of the "Expansion of Regional Interconnections - Analysis of Alternatives", synergistic solutions are being evaluated that allow the direct flow of energy surpluses from naturally exporting regions to naturally importing regions that lack additional supply to meet the local demand.

4.4 Economic Signaling for the Sector

4.4.1 EXPECTED INVESTMENTS AND PHYSICAL EVOLUTION OF SIN

The planning studies completed by August 2021 originally recommended a total investment of BRL 126.4 billion in the 2022-2031 period. Of this total, BRL 51.8 billion are associated with projects with concession (CO), while BRL 74.6 billion refer to projects not yet granted (SO).

Considering the uncertainties inherent to the planning process, this edition of PDE sought to evaluate the temporal dynamics of carrying out these investments from different expansion scenarios, each one based on specific hypotheses for the implementation of SO projects, maintaining the execution schedule of CO projects, whose investments have already been made.

The scenarios considered in the analyses can be characterized as follows:

- Optimistic scenario: implementation of all SO projects considering the original dates foreseen in the planning studies and the estimated trend date based on the average deadlines of the granting process.
- Reference scenario: base scenario of this PDE; variation of the optimistic scenario, considering the reassessment of the need date of the SO projects within the time frame of 2031, reflecting the results presented in the document "Regional System Performance Analysis of the power grid - PDE 2030", published on EPE'S website and more recent complementary assessments carried out on the performance of SIN.
- Pessimistic scenario: without the implementation of the SO projects. Therefore, only the CO projects were taken into account.

It should be noted that the optimistic and pessimistic scenarios represent more extreme hypotheses of expansion and are therefore less likely to occur. The reference scenario, on the other hand, consists of a more realistic scenario, prepared with more up-to-date information about the system, which justifies its establishment as the base scenario of this PDE.

Chart 4 - 6 illustrates the results of system expansions in each scenario. As can be seen, the optimistic scenario preserves the information from the original planning, including a total investment of BRL 126.4 billion up to 2031. In turn, the reference and pessimistic scenarios involve lower investments, around BRL 100.7 billion and BRL 51.8 billion (this number represents the total assets that have already been granted in the other scenarios).

Additional information about the expansion of the transmission system considering the evaluated scenarios can be accessed from the electronic spreadsheet made available with the PDE, where the projects planned for each federative unit until December 2031 and the expected implementation dates in each case are indicated.

In the following items, the results obtained for the reference scenario, which was taken as a basis for this PDE, are detailed.

REFERENCE SCENARIO

The graphs and tables presented in this section highlight the main statistics regarding the evolution of the transmission system in the period 2022-2031, considering the reference scenario.

As seen in **Chart 4 - 7**, the total amount of investments planned is BRL 100.7 billion, of which BRL 69.9 billion (69%) in transmission lines and BRL 30.8 billion (31%) in substations.

In the case of transmission lines, the total investment of BRL69.9 billion can be broken down as follows:

- BRL 37.6 billion (54%) refers to investments in transmission lines that have already been granted, while BRL 32.3 billion (46%) are related to facilities without a defined concession, as shown in **Chart 4 - 8**.
- BRL 36.1 billion (52%) refers to estimated investments in the Southeast/Mid-West submarket, with investments of BRL 15.6 billion still expected in the South submarket (22%), BRL 10.0 billion in the North submarket (14%) and BRL 8.2 billion in the Northeast submarket (12%), according to Chart 4 - 9. It should be noted that, in the case of regional interconnection lines, the investments were divided equally between the affected submarkets, since the facilities bring benefits for both.
- BRL44.1 billion (63%) refers to investments in 500 kV transmission lines, while BRL16.0 billion (23%) refers to investments in 230 kV, as illustrated in Chart 4 - 10. These two voltage levels account for almost 90% of the total investment in TLs.

From the point of view of physical evolution, an expansion of approximately 35 thousand km in new transmission lines is expected by the year 2031, as indicated by **Chart 4 - 11** and **Table 4 - 3** , a figure that represents an increase about 20% of the total of existing lines.

The total investment of BRL 30.8 billion in substations, which includes not only transformer costs, but also costs of land, buildings, control rooms, reactive compensation equipment, connection modules and others, can be divided as follows:

- BRL 14.2 billion (46%) refer to investments in substations already granted, while BRL 16.6 billion (54%) are related to assets not yet granted, as shown in **Chart 4 - 8**.
- BRL 14.2 billion (46%) refers to estimated investments in the Southeast/Mid-West submarket, with investments of BRL 6.6 billion still expected in the South submarket (21%), BRL 5.7 billion in the North submarket (19%) and BRL 4.3 billion in the Northeast submarket (14%), according to **Chart 4 - 9**.
- BRL14.5 billion (47%) refers to investments in 500 kV transmission substations, while BRL7.7 billion (25%) refers to investments in 230 kV, as illustrated in Chart 4 - 10. These two voltage levels account for almost 70% of the total investment in substations.

Finally, from the point of view of physical evolution, an expansion of approximately 120 thousand MVA in new transformers is expected by the year 2031, as indicated by **Chart 4 - 14** and **Table 4 - 4** , a figure that represents about 30% increase considering the total of existing system.

Box 4 - 1: Differences between PDE and PET/PELP

Due to differences in assumptions, the comparison of the amounts indicated in the Ten-Year Energy Expansion Plan (PDE) with the amounts presented in the Transmission Expansion Program (PET) / Long-Term Expansion Plan (PELP) report must be carried out with caution, which may even lead to inaccurate conclusions.

Overall, PDE involves much higher investments than PET/PELP. On this issue, it should be noted that the scope of works of PDE is greater than that of the PET/PELP, also covering works already authorized and tendered. On the other hand, the PET/PELP comprises works in DITs and works that transcend the ten-year time frame of PDE.

Chart 4 - 6: Transmission system expansion scenarios

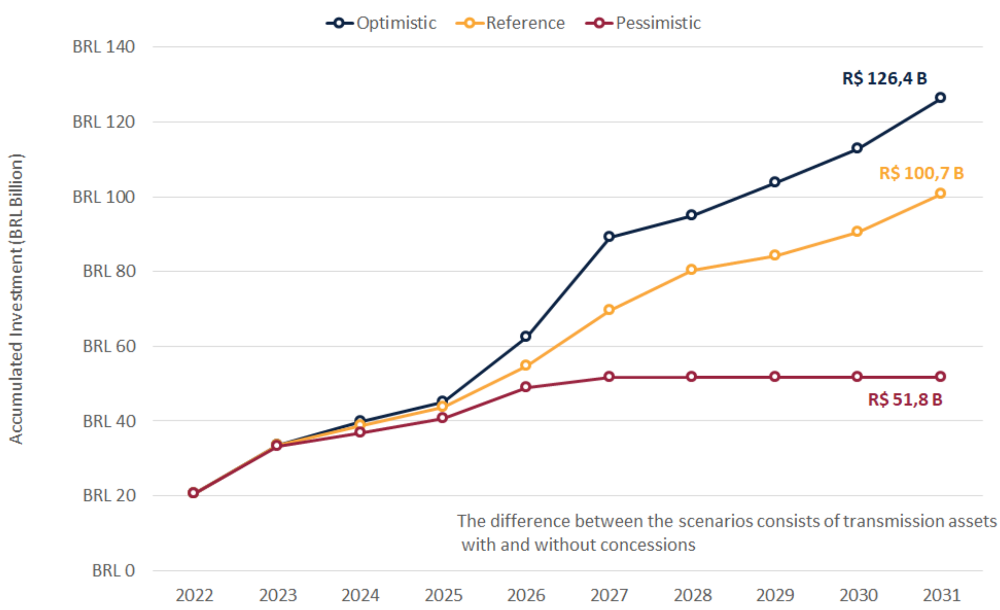


Chart 4 - 7: Reference scenarios: overview

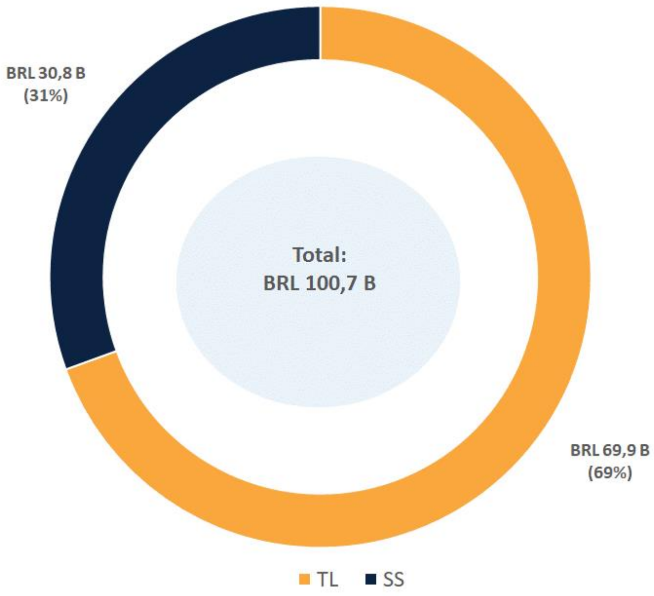


Chart 4 - 8: Reference scenarios: TLs with and without concession

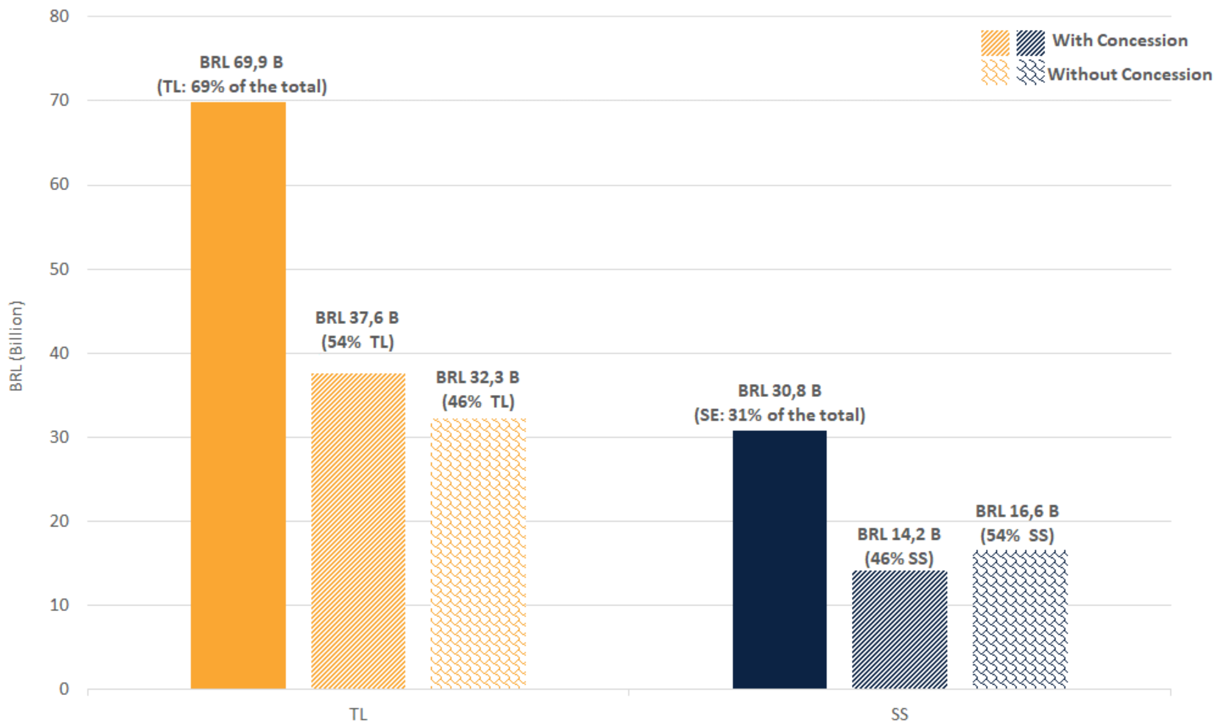


Chart 4 - 9: Reference scenarios: TLs by submarket

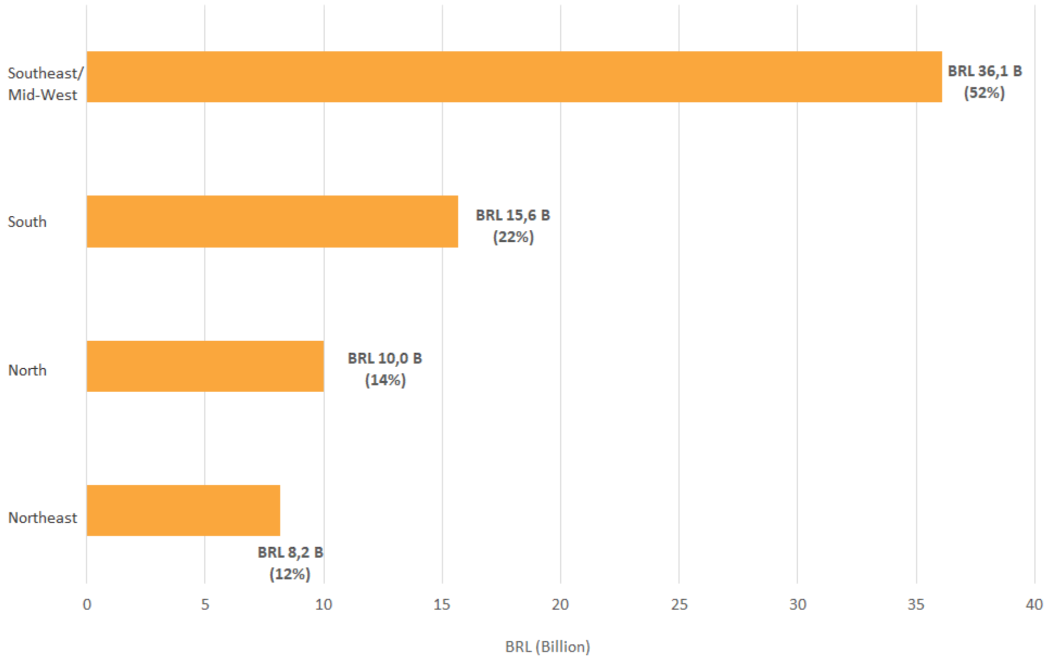


Chart 4 - 10: Reference scenarios: TLs per voltage level

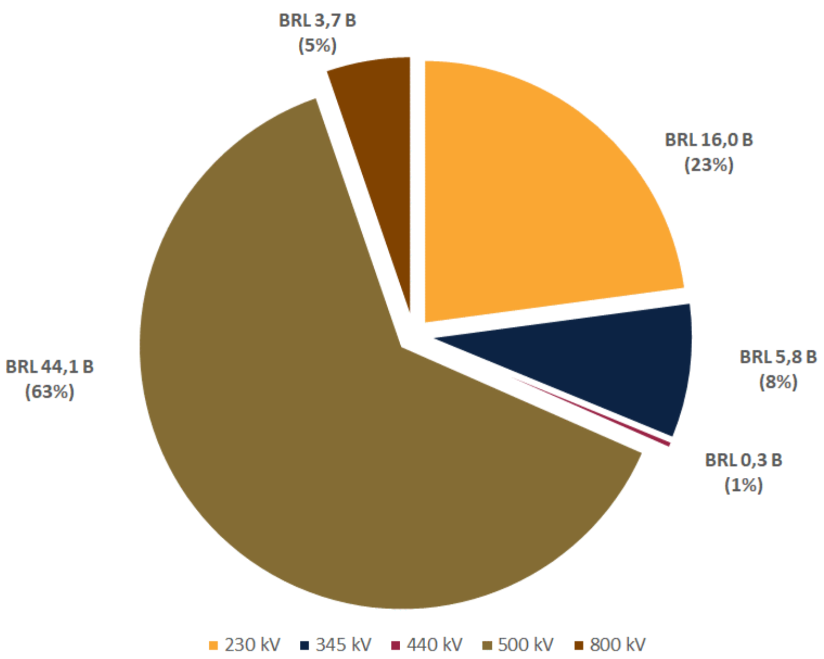


Chart 4 - 11: Reference scenarios: TL physical expansion

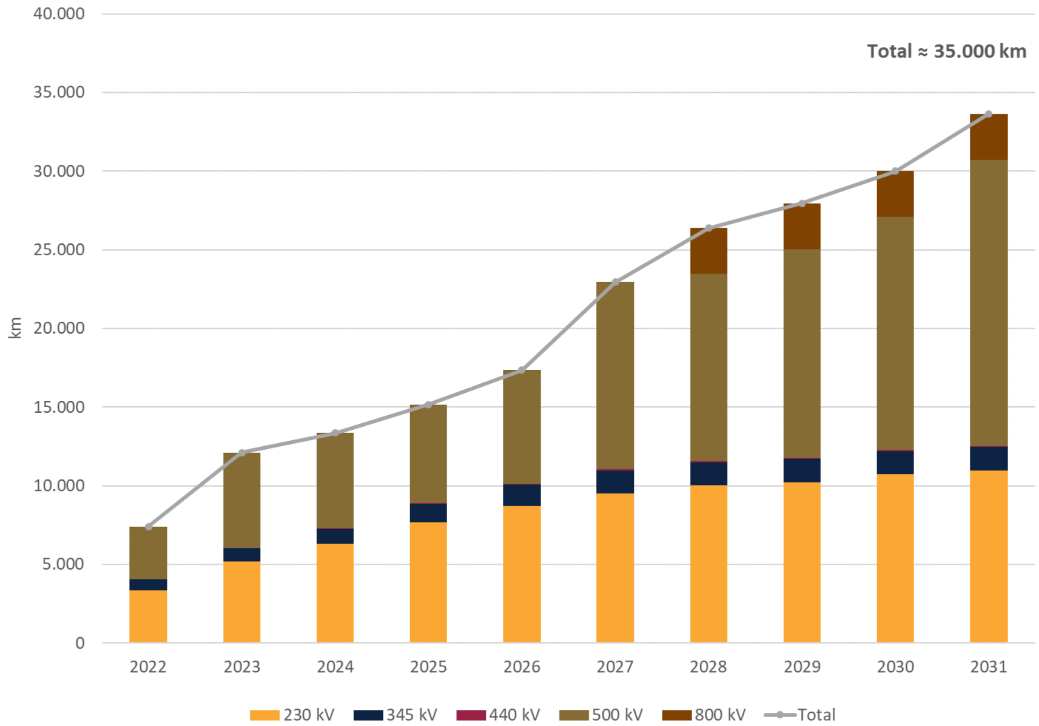


Chart 4 - 12: Reference scenarios: SSs by submarket

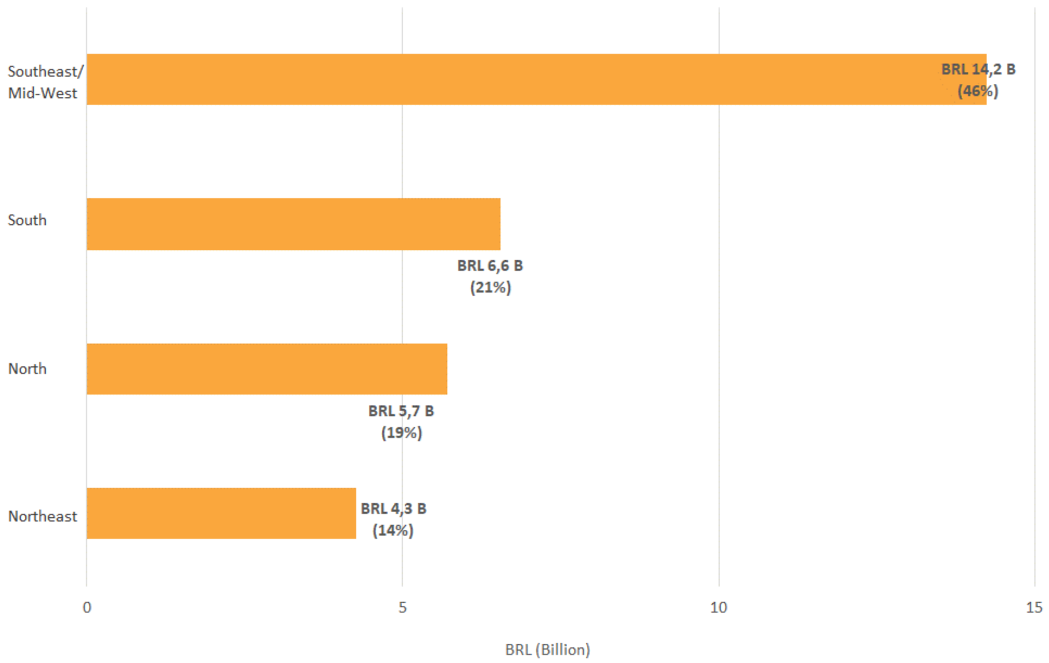


Chart 4 - 13: Reference scenarios: SSs per voltage level

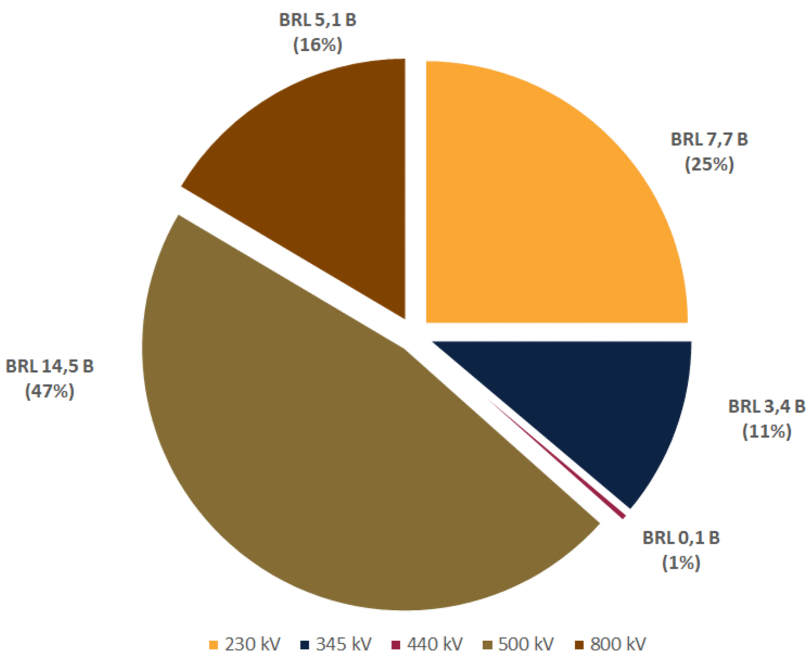


Chart 4 - 14: Reference scenarios: SS physical expansion

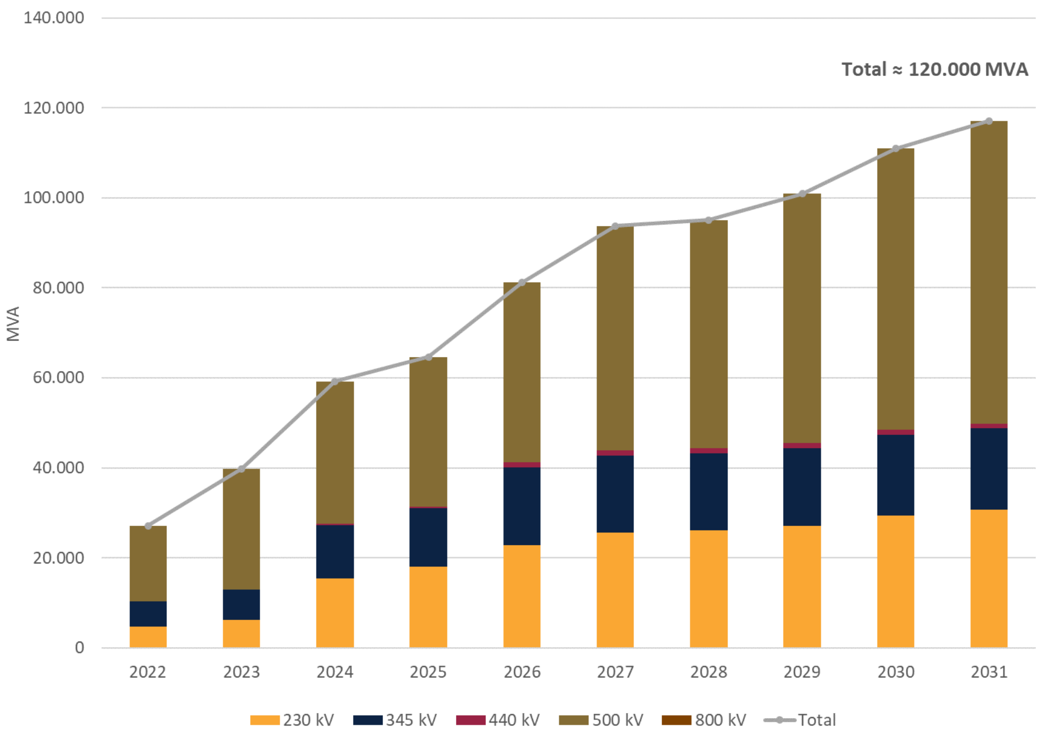


Table 4 - 3: Reference scenario: physical progress estimation of the NIS transmission system - transmission lines

Voltage	±800 kV	750 kV	±600 kV	500 kV	440 kV	345 kV	230 kV	TOTAL
	km							
Dec/2021 estimate	9204	2683	12816	68583	6869	10397	64721	**175273**
Evolution 2022-2031	2920	0	0	18180	77	1488	10968	**33633**
Evolution 2022-2026	0	0	0	7228	66	1354	8713	**17361**
Evolution 2027-2031	2920	0	0	10952	11	134	2256	**16273**
Dec/2031 estimate	12124	2683	12816	86763	6946	11885	75690	**208907**

Note: (1) In cases of LTs in a double circuit or direct current bipoles, extensions were calculated by circuit and by pole.

Table 4 - 4: Reference scenario: physical progress estimation of the NIS transmission system – transformation

Voltage	750kV	500kV	440kV	345kV	230kV	TOTAL
	MVA					
Dec/2021 estimate	24897	196552	30892	54820	114718	**421879**
2022-2031 progress	0	67280	1098	17979	30769	**117126**
2022-2026 progress	0	40015	1098	17180	22909	**81202**
2027-2031 progress	0	27265	0	799	7860	**35924**
Dec/2031 estimate	24897	263832	31990	72799	145486	**539004**

Notes: (1) Includes boundary transformers.

(2) Does not include converter station transformers.

4.4.2 ASSETS AT END OF REGULATORY SERVICE LIFE

A major challenge to be faced in the coming years will be the replacement of the electrical system infrastructure due to its aging. It is necessary to ensure a more effective methodology, viable from the technical and economic-financial aspects, for the replacement of the electrical system infrastructure at the end of its service life so that the transmission grid can continue operating with the levels of reliability and quality required by society.

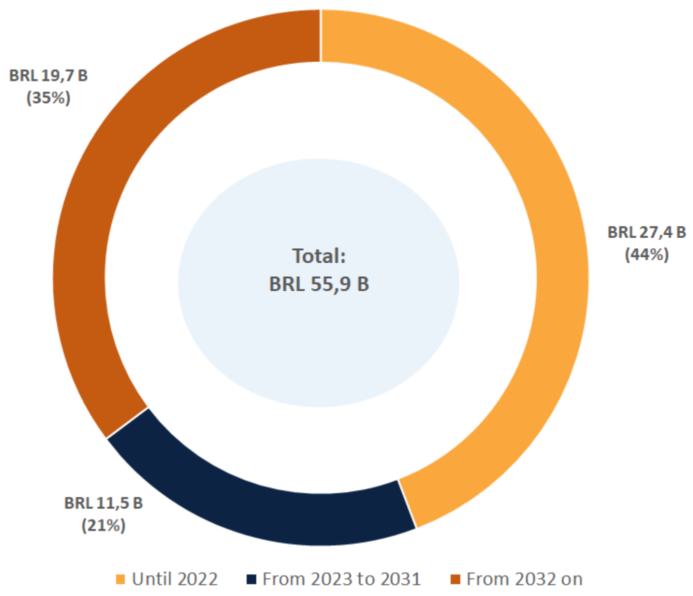
Currently, Module 3 of the ANEEL Electricity Transmission Services Rules establishes that transmission companies must submit to ANEEL, ONS, EPE and MME, by February 1st of each year, the list of equipment with remaining regulatory service life up to four years, including those whose physical service life has expired and which, therefore, need to be effectively replaced (technical overcoming).

Naturally, the physical service life of an asset depends a lot on the asset management and maintenance schedule throughout the asset's operation, normally being longer than the regulatory service life, as stated in the AIR Report No. 5/2019, of 09/23/2019, made available by ANEEL at the time of Public Consultation No. 005/2020. Nevertheless, the regulatory service life is an important reference to be monitored in the scope of sectorial planning, constituting an important input for the transmission system expansion strategies.

From the primary data provided by ANEEL under Public Consultation No. 005/2020, it appears that, by the year 2031, several assets of the transmission system will have their regulatory service life expired. In this sense, it is estimated that nearly BRL 35 billion investments would be necessary to replace all the equipment related to substations at once, according to **Chart 4 - 15**.

On the other hand, it should be noted that these investments are only potential, as they are not associated with the end of life of the facilities, but only with the temporal reference of the regulatory service life. For this reason, they are not included in the investments planned for the system within the time frame of 2031, presented in item 4.4.1.

Chart 4 - 15: Potential investments in end-of-life regulatory assets



Source: Asset Control Report, Selected Broadcasters, ANEEL, 2018

4.4.3 TARIFFS FOR THE TRANSMISSION SYSTEM USE

With the objective of characterizing the impact of the investments associated with the expansion of the transmission grid planned in the reference scenario on the charges for the use of the electric system, an estimate was made of the evolution of the TUST (transmission tariff) values within the time frame of PDE 2031.

The simulations were carried out based on the constraints currently considered in the application of the Nodal Methodology, which result in the predominance of the contribution of the seal portion of the TUST. That is, the suggestions in item 4.2.5 were not simulated in this item.

The calculations were performed using the Nodal Program v.54, which uses the NIS configuration and the total Allowed Annual Revenue – (total RAP) to be collected in the cycle as input data.

The RAP considered in the first analyzed year of PDE - year 2025, was derived from the 2021-2022 tariff cycle (current cycle), which has a value of BRL 28.33 billion, according to Technical Note No. 151/2021- SGT/ANEEL.

The evolution of the RAP in the ten-year period was calculated considering the estimated revenues for the planned transmission assets for the period 2022-2031, in the reference scenario, based on the RAP/investment ratio of 12%, as shown in Table 12 of Technical Note No. 151/2021-SGT/ANEEL.

It should be noted that at each tariff cycle the annual revenue to be recovered by tariff is shared between the load and generation segments in the proportion of 50% - 50%, and no existing adjustment mechanisms which could have affected this proportion were applied.

On this issue, it should be noted that the final proportion of the annual revenue recovered by the load and generation segments in the 2021-2022 tariff cycle was 47.49% - 52.51%, respectively, which is a number close to the standard proportion.

Thus, it is understood that the simplifications adopted in the analyses of this chapter can reach ist goal, that is, to present estimates of the evolution of the TUST within the time frame of PDE 2031.

Chart 4 - 16 and **Chart 4 - 17** illustrate the distribution of TUST-generation in each of the submarkets in the years 2025 and 2031. In general, it is observed that tariffs are concentrated around average values, around 7.0 BRL/kW.month in 2025, and 8.0 BRL/kW.month in 2031. In addition, according to **Chart 4 - 18**, no major differences are observed between the tariffs of each submarket.

Similar observations apply to the case of TUST-load, whose results are presented in **Chart 4 - 19**, in **Chart 4 - 20** and in **Chart 4 - 21**. In this case, tariffs are concentrated around 11.0 BRL/kW.month in 2025, and 12.0 BRL/kW.month in 2031.

In summary of the results obtained, it is highlighted that the constraints currently considered in the application of the Nodal Methodology result in a strong concentration of TUST around average values, not being observed great differences between the submarkets.

This condition causes predominance of the contribution of the stamp portion of the TUST and “socialization” of the system's remuneration, as discussed in item 4.2.5.

Chart 4 - 16: Reference scenarios: TUST-generation in the year 2025

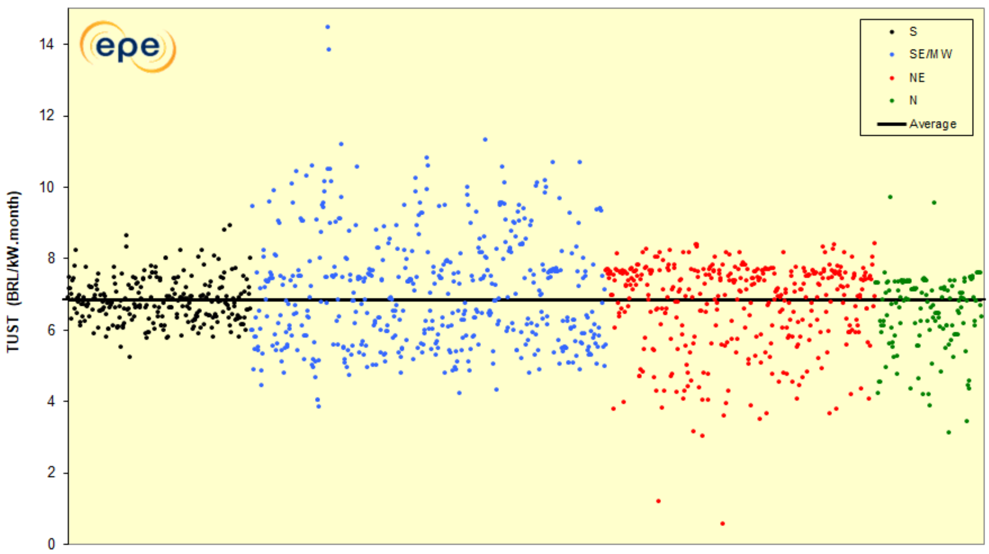


Chart 4 - 17: Reference scenarios: TUST-generation in the year 2031

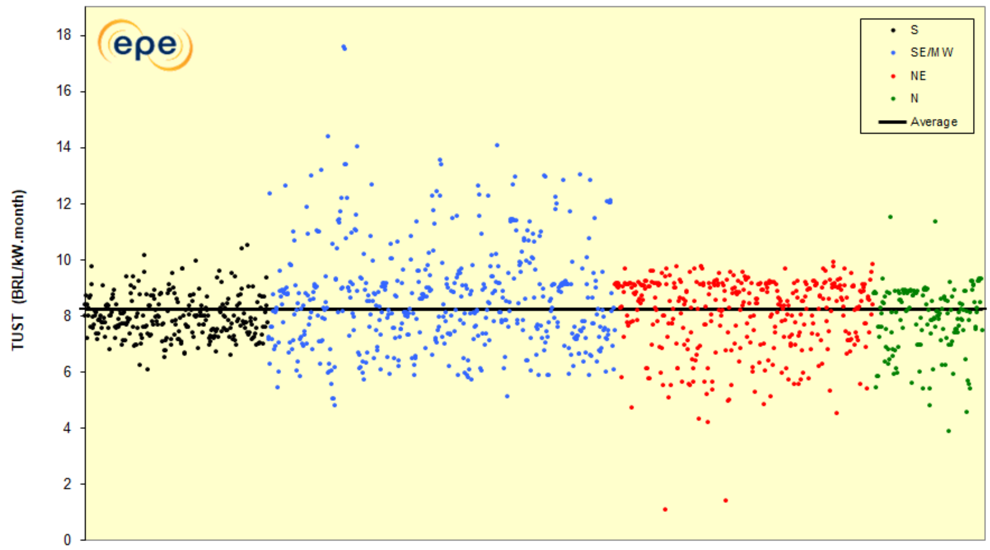


Chart 4 - 18: Reference scenarios: TUST- average generation in 2025 and 2031

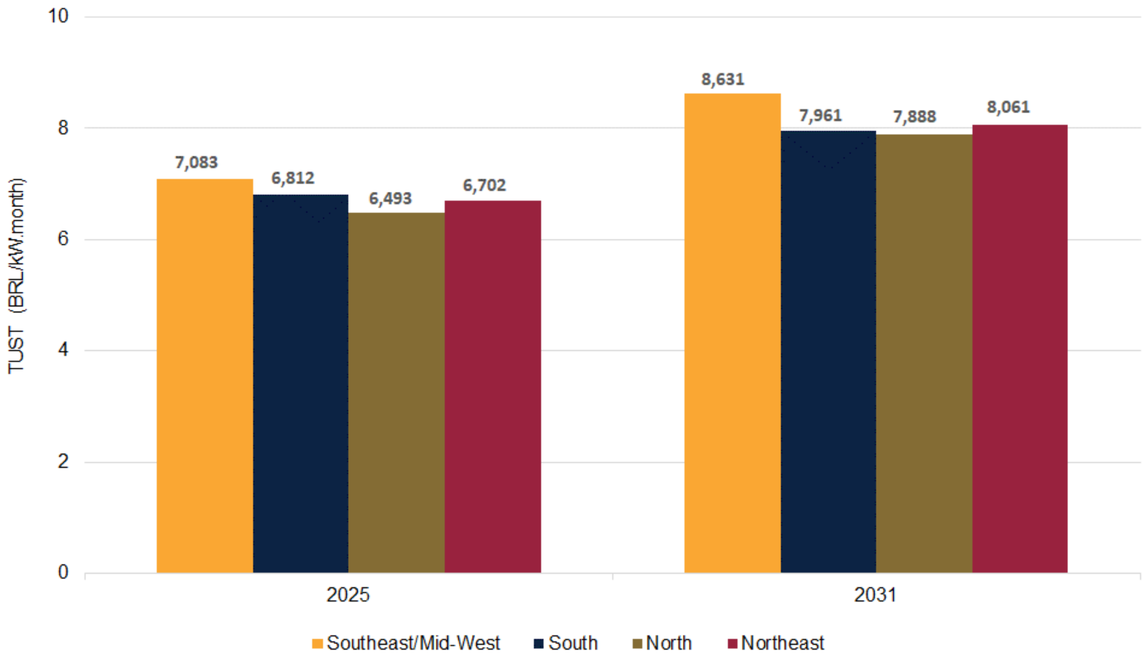


Chart 4 - 19: Reference scenarios: TUST-load in 2025

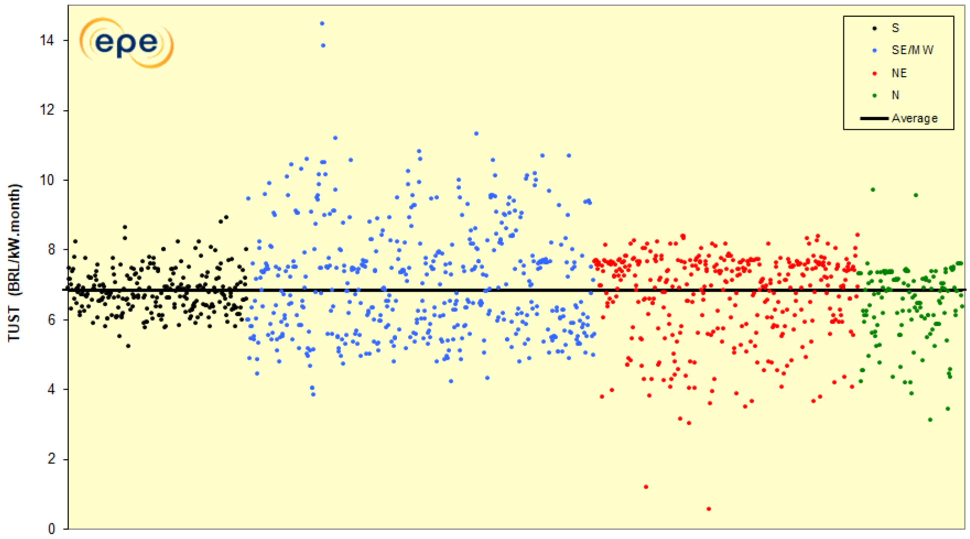


Chart 4 - 20: Reference scenarios: TUST-load in 2031

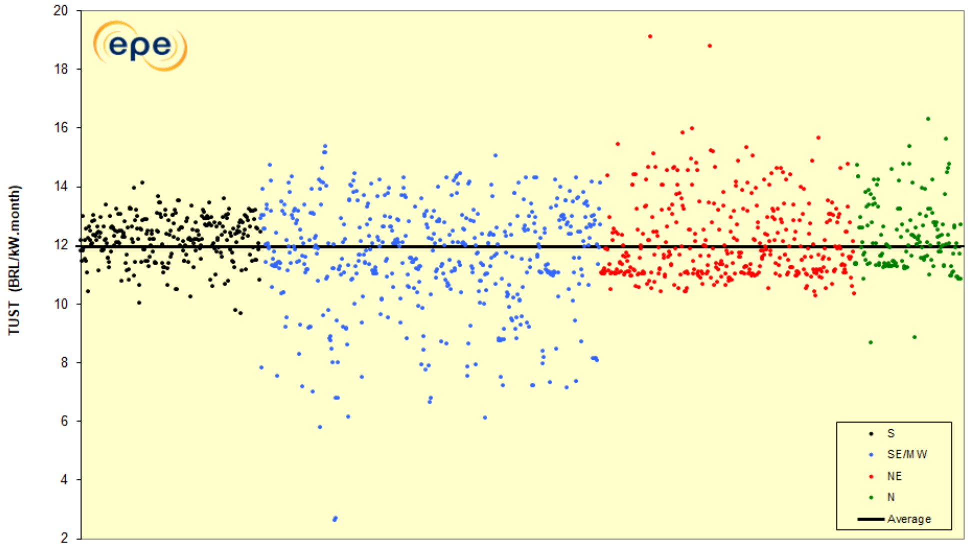
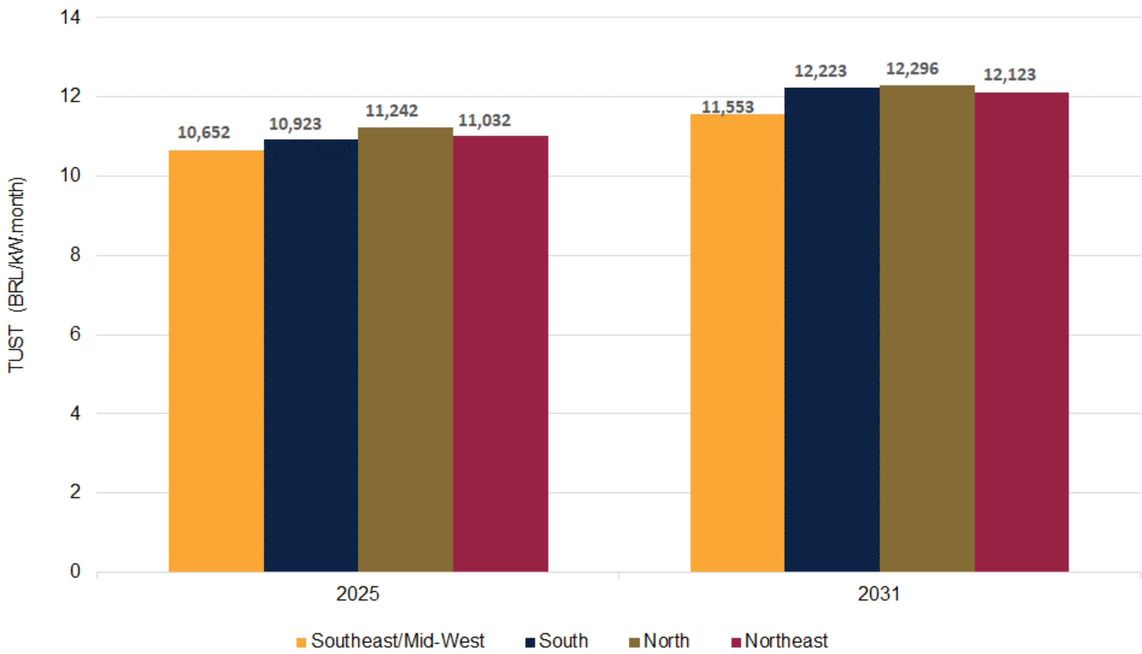


Chart 4 - 21: Reference scenarios: TUST- medium load in 2025 and 2031



MAJOR POINTS OF THE CHAPTER
POWER TRANSMISSION

- *With the reduction of investment values for wind and photovoltaic projects and the consequent greater competitiveness and protagonism of renewable sources in the expansion of the generation supply in the Free Contracting Environment - ACL, new challenges were launched to transmission planning, which began to have greater difficulty in managing the uncertainties related to future generation projects, reducing the predictability of amounts and their location. In response to this new scenario, EPE began to improve the systematics applied in proactive transmission studies, especially regarding data management.*
- *There is global recognition that flexibility is an essential component to guarantee the reliability, stability, and energy security of the NIS as the proportion of renewables increases and the new energy market consolidates. EPE is aware of this issue and seeks to guide the studies of expansion of the transmission grid, notably of regional interconnections, in order to enable an efficient management of the global resources available in the system. To add flexibility to the interconnected system, expansion can take place considering different technologies applied to the grid, such as FACTS devices (Flexible AC Transmission System) and energy storage, which can contribute to controllability and increase in transmission capacity, optimizing the expansion of the power grid. From another perspective, flexibility can be added to the NIS through the provision of ancillary services.*
- *The integration of the potential of 8,000 MW of thermoelectric generation established in Law 14,182/2021 represents a major challenge for the effective coordination of the expansion of generation and transmission assets. The singularities associated with the contract of these plants make it difficult to adopt anticipatory planning strategies such as those that have been adopted in proactive transmission studies, oriented towards the integration of renewable sources, where it is possible to estimate the dynamics of potential realization from consolidated databases. Thus, in the case of thermoelectric plants under Law 14,182/2021, EPE understands that the transmission expansion planning studies must be carried out after the energy auctions have been held.*
- *In addition to the binational Itaipu project, involving Brazil and Paraguay, Brazil also has electrical interconnections with Argentina, Uruguay, and Venezuela. The possibility of modernizing or expanding these interconnections, and even deactivating some of the current interconnection points, has been the object of joint analysis by EPE and the ONS in recent years in response to requests from the MME.*
- *The TUST calculation, currently carried out based on the Nodal Methodology, requires the establishment of conditions that have a significant impact on the results obtained. Within this context, the consideration of a single energy scenario, elaborated from the application of proportional dispatch between submarkets, results in the predominance of the contribution of the seal portion of TUST (approx. 100%), which consists of inadequate signaling for the efficient use of the transmission grid. EPE understands that it is appropriate for the TUST to be calculated based not only on a single generation dispatch scenario but using different scenarios taking into consideration their probabilities of occurrence derived from energy studies, respecting known electrical restrictions in the system.*
- *The works recommended by EPE in planning studies already completed will provide a significant expansion of the capacity of regional interconnections by the year 2031. By 2026, the evolution of the total export capacity of the Northeast Region stands out 150% of the existing limit in 2020, reaching a total capacity of 15 GW. It*

MAJOR POINTS OF THE CHAPTER POWER TRANSMISSION
should be noted that additional expansions, still under analysis in planning studies to be completed by March 2022, will increase this capacity to 30 GW. ▪ *In this edition of PDE, considering the uncertainties inherent in the planning process, EPE evaluated three scenarios for the implementation of projects that still have no concessions granted. The transmission expansion plan associated to the reference scenario includes total investments of BRL 100.7 billion, of which BRL 51.8 billion refer to projects that have already been granted.*