

The Brazilian Public Policies for Rd & I in the Brazilian Electrical System (SEB), in Light of the Commitments of the Agenda 2030

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Abstract— The purpose of this article is to analyze whether the Brazilian public policies (PP), materialized in the innovation program (RD&I) of the SEB through the R&DP and EEP, contribute or not to the Brazilian government's fulfillment of the commitments made with Agenda 2030 and the NDC goals, together with the Paris Agreement, concerning SDG 7. The methodological procedures adopted were bibliographic and documental research, involving the legislation that guides the RD&I regulated by ANEEL, as well as the analysis of 30 R&DP projects and 1,026 EEP projects. The R&DP has proven not to be aligned with the goals of Agenda 2030, especially with regard to the development of a culture of innovation in the SEB, besides being disconnected from the rest of the world in terms of the type and model adopted for innovation, patent generation, and continuous improvement. It showed improvement only in the profile of human resources used in the program. The EEP presented results aligned with Agenda 2030 and SDG 7 and Brazil's NDC, through the following indicators: i) investment avoided in energy generation; ii) energy saved; iii) demand withdrawn from the peak; iv) energy conserved. In addition, there are results in line with SDG 9 and 13 such as an increase in the supply of renewable energy and reduction of CO₂e emissions in the system. The R&DP and the EEP together contribute R\$ 1.1 billion per year in innovation in the SEB, making an expected value of around R\$ 12.1 billion from 2020 to 2030.

^a In memoriam

I. INTRODUCTION

Implemented two decades ago and regulated by the Brazilian National Electric Energy Agency (ANEEL), the Research and Development Program (R&DP)^b and the

Energy Efficiency Program (EEP)^c have been consolidated as a Public Policy (PP) of innovation for the Brazilian Electric Sector (SEB).

^b The Research and Development Program (R&DP) is regulated by ANEEL, according to Law 9.991/2000.

^c The Energy Efficiency Program (EEP) is regulated by ANEEL, according to Law 9.991/2000.

The SEB is in a structural transition process that started in the 1990s (Castro; Brandão, 2019). The electricity sector is an economic activity recognized as a natural monopoly, which until the 1980s, in Brazil, was purely state-owned. In the following decade, the privatization process in the SEB began, but without the removal of the monopoly condition, which makes the regulation of the sector essential (Castro; Brandão, 2019).

It is necessary to clarify that the electric power sector is still a monopoly, moving towards oligopoly in some federative units (FU) because it is characterized by the presence of market failures that do not allow the sector to reach an efficient Pareto equilibrium on its own (mankiw, 2001; Tirole, 2020). Regulation emerges as a force to try to reduce or even eliminate these failures when possible. The main characteristics for maintaining a monopoly or oligopoly are the high initial investment required (high infrastructure costs) and low marginal costs, which hinder the interest of more players offering the same good and service. Besides having financial entry barriers (because it is a capital-intensive sector), there are also other types of entry barriers, such as legal and regulatory (Tirole, 2020).

The peculiarities of this new condition led, in 1996, to the creation of ANEEL, which from the beginning of its regulatory activities began to be concerned with the evolution of the SEB companies. In 1999, actions coordinated by the Agency began to implement the R&D program in the sector, which culminated with Law 9.991/2000, the first legal framework for innovation programs in the SEB (ANEEL, 2020b; BRASIL, 1996).

Regulated by ANEEL, the R&DP and the EEP have undergone several evaluations, which identified, for example, that ANEEL adopted a linear perspective model of innovation, at least in what is called the first and second phase of the program: from 2000-2007 and 2008-2015, respectively (ANEEL, 2020; Binet *et al.*, 2015; Castro; Brandão, 2019). In 2016, the technological innovation programs of the SEB, regulated by ANEEL, entered their third phase, in search of an evolution of the innovation model, leaving the linear perspective to the systemic view, which includes an approach of a National Innovation System (NIS) (Castro *et al.*, 2017).

The concept of NIS is based on the systemic approach of knowledge, associated with innovation and "interactive learning as factors of sustained competitiveness" (Castro *et al.*, 2017). Thus, the aim is to promote a culture of innovation, stimulating RD&I in the SEB, through the creation of new equipment and improving the provision of services, in a way that can

contribute to energy security, moderation of tariffs, reducing the environmental impact of the sector, and Brazil's commitments to the Paris Agreement, Agenda 2030 (ANEEL, 2020b).

With Brazil's adhesion to the Paris Agreement, SEB's innovation PPs must align with the goals of Agenda 2030, according to SDG 7: Affordable and clean energy, SDG 9: Industry, innovation and infrastructure, and SDG 13: Climate action (IPEA, 2018, 2019).

A gap has been identified in the sense of analyzing the Brazilian RD&I PPs of the SEB, in light of the commitments made by Brazil, with the United Nations (UN) Agenda 2030 and in particular, the goals established in the Nationally Determined Contribution (NDC), with the Paris Agreement.

Thus, this study has as its research problem the following question: How will Brazilian public policies for the SEB innovation, developed through the Research and Development Program (R&DP) and the Energy Efficiency Program (EEP), regulated by ANEEL, impact Brazil's commitments to the 2030 Agenda?

To answer the proposed problem it was established as the objective of this article: to analyze whether the Brazilian public policies (PP), materialized in the SEB's R&DP and EEP, contribute or not to the Brazilian government's fulfillment of the commitments made with the 2030 Agenda and the NDC goals, together with the Paris Agreement, concerning SDG 7.

The justification for conducting this study is the fact that the R&DP and the EEP, regulated by ANEEL, are responsible for the dynamics of innovation in the SEB, which aims to constantly seek "the innovations needed to meet the challenges of the electric power sector, either by promoting the efficient and rational use of electricity, associated with actions to combat waste" (ANEEL, 2020b). This is an extremely relevant public policy for the electricity sector, as the two together form the largest innovation program in the SEB.

This paper is structured in five parts, the first being this brief introduction. The second part presents a literature review on the main concepts of the study. The third section describes the methodological procedures step by step. The fourth section presents the results generated by the analysis of the R&DP and EEP projects and their discussion against the literature and the goals of SDG 7 - of Agenda 2030 - and the NDC goals of Brazil, along with the Paris Agreement. The fifth and last section describes the final considerations about the research conducted, according to Figure 1, below:

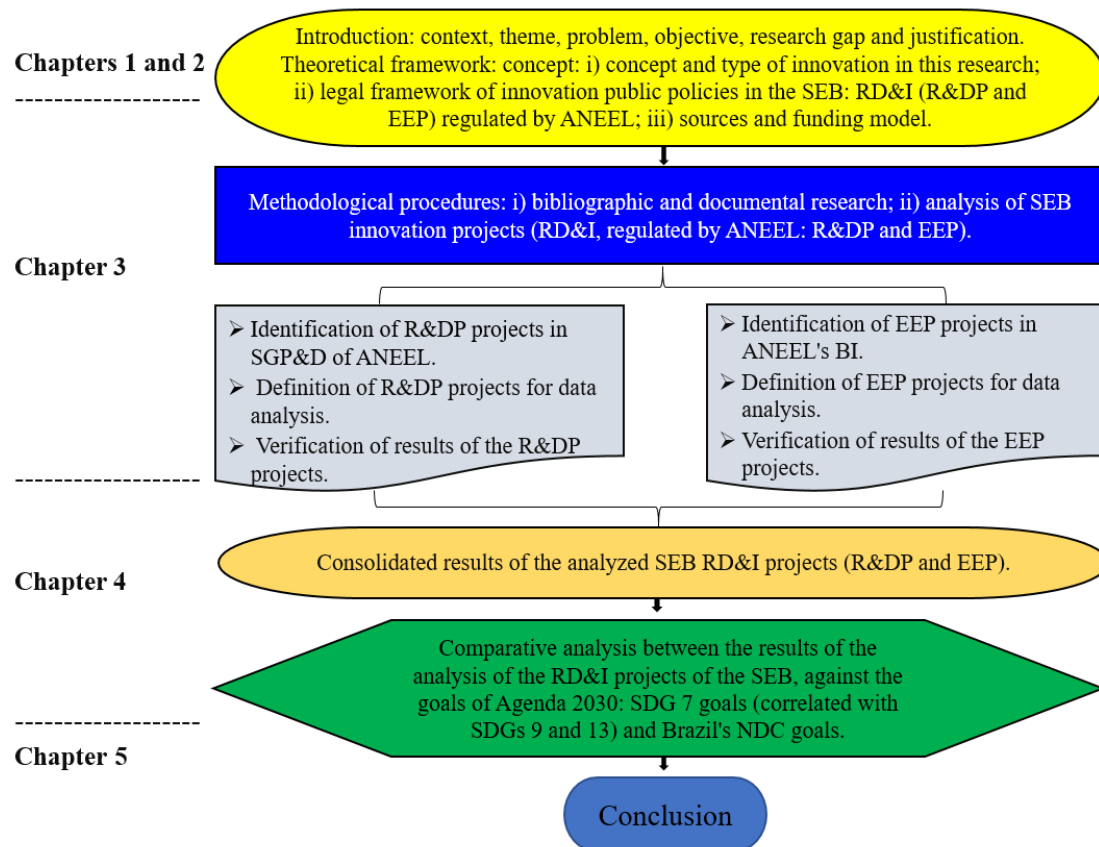


Fig.1: Structure of the method used in this article

Source: Elaborated by the authors.

II. LITERATURE REVIEW

2.1 Innovation: concept, model, and management strategy

The process of organizational change has been accelerating in the last decades, with innovation as the driving force that occurs in the public and private sectors, following a dynamic of conceptual evolution, supported by models or forms of implementation and management strategy of an innovation policy.

2.1.1 Innovation Concept

The concept of innovation in the context of this study follows that advocated by the Oslo Manual for the Organization for Economic Cooperation and Development (OECD), fourth edition, published in 2018, which includes the "requirement of measurability as an essential criterion for selecting concepts, definitions and classifications in this manual" (OECD/Eurostat, 2018, p. 20). According to OECD/Eurostat (2018, p. 20), innovation "is the implementation of a new or significantly improved product (good or service), or a process, or a new financial or business method, or a new organizational method in business practices, in the workplace organization, or

external relations."

For it to happen "product innovation must introduce a new or significantly improved good or service concerning its characteristics or intended uses", according to OECD/Eurostat (2018, p. 20). Significant improvements are understood to be: technical specifications, components, and materials, embedded software, ease of use, or other functional characteristics associated (OECD/Eurostat, 2018, p. 20).

The innovation of a process or innovation activity occurs from the "implementation of a new or significantly improved production or distribution method. Significant changes in techniques, equipment and/or software are included" OECD/Eurostat (2018, p. 21).

Besides product and process innovation, which is more frequent, there can still be marketing innovation and organizational innovation. In the former, the "implementation of a new financial or commercial method with significant changes in product design or packaging, product positioning, promotion, or pricing. In the second, the "implementation of a new organizational method in the company's business practices, workplace organization, or

external relations" occurs (OECD/Eurostat, 2018, p. 21).

The implementation of innovation programs necessarily involves the definition of models or ways to innovate, which depends on a careful analysis of the maturity stage of the market in which the organization operates (Christensen, 1997; OECD/Eurostat, 2018; Christensen, 2019).

2.1.2 Models or forms of innovation

As for implementation models, innovation can take the form of Schumpeter's creative destruction, incremental innovation, and radical or disruptive innovation (Christensen, 1997; OECD/Eurostat, 2018; Christensen, 2019).

When the form of innovation causes a technical change in the organization, it entails a redistribution of resources, including labor, across sectors and firms, which can generate creative destruction (OECD/Eurostat, 2018).

If the company operates in a stable and mature market, changes can happen continuously, following the rhythm of the market segment and moving in the incremental innovation model (OECD/Eurostat, 2018).

However, when the company operates in a volatile market environment, it needs to quickly introduce new products, new technologies, new processes, and new organizational models, and for this, it needs a form of radical or disruptive innovation (Christensen, 1997; Christensen, 2019). Even in stable markets that undergo major technological change, radical or disruptive innovation is recommended (Cabanese *et al.*, 2016).

After defining the model or form of innovation, the organization must adopt a strategy to manage the implemented innovation model.

2.1.3 Innovation management strategy

For the organization to be successful with its innovation program, besides defining models and forms appropriate to the stage of maturity of the market in which it operates, it is necessary to make important strategic choices for the management of the program. There are two possible options for innovation management strategies:

closed innovation and open innovation (Chesbrough, 2003, 2010).

By adopting the closed innovation strategy, the organization minimizes the potential for results, because the closed model is based on the view that innovation is developed internally, without interactions with the environment, which is practically impossible. Open innovation assumes that firms can and should use external as well as internal ideas and pathways as they seek to advance their innovation process, using knowledge input and output flows intentionally to accelerate internal innovation and expand markets for external use (Chesbrough, 2003; 2010).

As this article deals with innovation in the electric sector, more specifically in the SEB, it is necessary to investigate what are the trends of changes that have been occurring in the sector worldwide and transport them to Brazil, so that the Brazilian society can enjoy the benefits generated by these innovations. They are a) reduction of disbursements with investments in energy generation, increased efficiency in distribution and lower costs for the final consumer, which can be provided by energy efficiency; b) flexibility of regulatory standards to encourage distributed generation; c) encourage RD&I for the development of fuel cells (hydrogen from ethanol and natural gas) that can increase the efficiency of renewable sources of solar and wind energy making them deployable^d on a 24/7 or twenty-four hours a day, seven days a week basis (MME/SPE/EPE, 2018; Castro, Brandão, 2019; Miranda, 2019).

2.2 Institutional Structure of SEB

The SEB has an institutional structure, which is divided into the following segments: policies, regulation and supervision, institutional operation agents, and market agents, as shown in figure 2:

^dPower plant dispatch is the set of instructions, actions, and control done by ONS in the processes of planning and scheduling, real-time operation, and post-operation (ENERGÊS, 2021). Available at: <https://energes.com.br/>

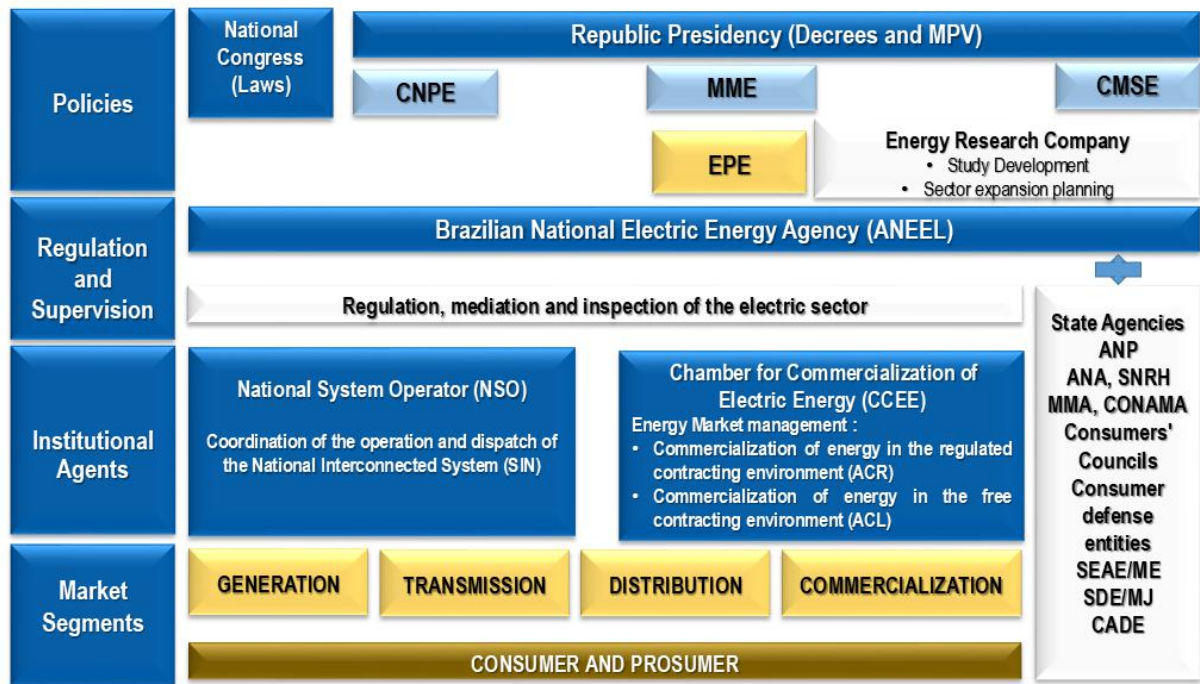


Fig.2: Institutional structure of the SEB

Source: elaborated by the authors, based on Brazil (1991; 2016) and ANEEL (2020).

The policy guidelines may be issued by the Brazilian National Congress (NC), through Laws; by the Presidency of the Federative Republic of Brazil (PR), through Decrees; by the National Energy Policy Council (NEPC), by the Ministry of Mines and Energy (MME), and by the Electric System Monitoring Committee (ESMC), through Resolutions, Ordinances, and Communications, respectively (ANEEL, 2018a).

ANEEL is responsible for the regulation, mediation, and inspection of the SEB, with the support of the National Water Agency (ANA), National Secretary of Water Resources (SNRH), National Petroleum Agency (ANP), Ministry of the Environment (MMA), National Environmental Council (CONAMA), State Electricity Agencies, Consumer Councils and consumer defense entities (ANEEL, 2018a).

The institutional agents of the SEB are the National System Operator (NSO), responsible for coordinating the operation and the dispatch of the National Interconnected System (SIN), and the Chamber for Commercialization of Electric Energy, which manages the energy market: a) energy commercialization in the regulated contracting environment (ACR); and b) energy commercialization in the free contracting environment (ACL) (ANEEL, 2018a).

The market agents are composed of the Generation (G), Transmission (T), Distribution (D), and

Commercialization (C) or (GTDC) companies and the consumers and prosumers of electricity (ANEEL, 2018a).

2.3 Public policies of innovation in the Brazilian electricity sector

The background of science and technology in Brazil is recent, since the university system is relatively new, having been consolidated during the first half of the 20th century. Brazilian public policies on innovation are even more recent and date from the end of the 20th century. For this study, only the PPs related to the electricity sector, this focus of this paper, will be analyzed.

2.3.1 Innovation in the Brazilian Electric Sector (SEB)

The innovation in the SEB had as its initial milestone the creation of the Center for Electric Energy Research (CEPEL), which was "established by Public Deed, published on 01.21.74, and entered into by Eletrobras, Chesf, Furnas, Eletronorte, and Eletrosul", with an allocation of around 0.5% of Eletrobras' capital stock (CEPEL, 2017).

According to the bylaws, updated in 2017, the CEPEL (2017) "has as its main and permanent objective to preserve the capacity in research, development, innovation, qualification, and training in the area of electrical systems and related disciplines [...]".

With the privatization program of companies in the power sector that began in the 1990s, the need arose to create ANEEL to deal with the scenario that began to be drawn in the market, where private companies were providing public service through concessions (BRASIL, 1996).

From the regulation of the market, there was a need to raise the level of efficiency of the companies that operated in the sector, both those controlled by the public sector and those whose capital had been transferred to the

private sector, but which operated in the Generation, Transmission, and Distribution (GTD) of electricity.

In this context, a new regulatory framework for R&D in the SEB emerged, with Law No. 9.991 of July 24, 2000, which established the Energy Sector Fund (CTEnerg) and created the R&D Program (R&DP) and the Energy Efficiency Program (EEP) (ANEEL, 2017). The same law established the resources to finance the programs, according to Figure 3.

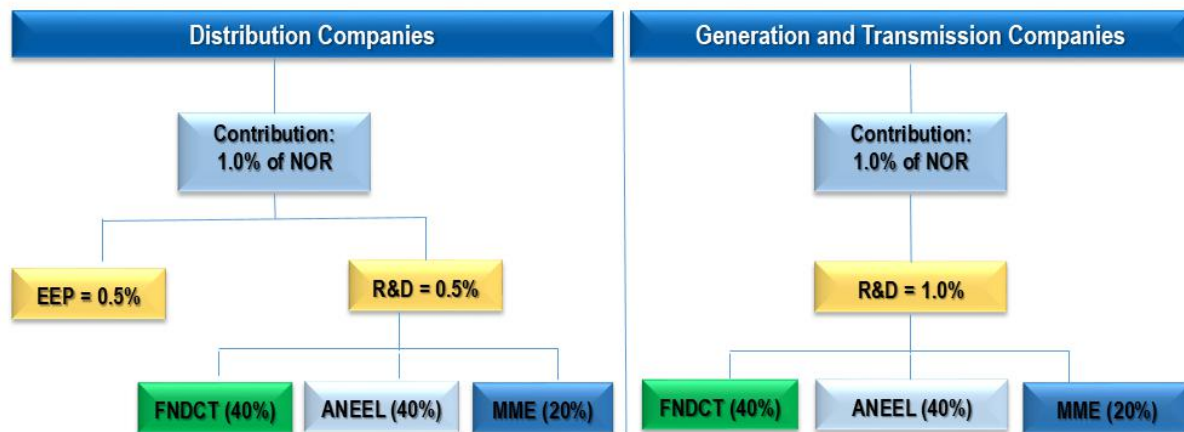


Fig.3: Origin and destination of resources to finance the SEB PP&D and EEP programs: contribution of the GTD segment companies

Source: elaborated by the authors, based on Brazil (1991; 2016) and ANEEL (2020).

As shown in figure 3, the Distribution companies contribute 1% of their Net Operating Revenue (NOR), being 0.5% for R&DP and 0.5% for the EEP. The companies in the Generation and Transmission segments contribute 1% to the R&DP of this niche market of G and T (BRASIL, 1991; 2016).

2.3.2 Research and Development Program (R&DP)

The objective of R&DP, regulated by ANEEL, "is to adequately allocate human and financial resources to projects that demonstrate the originality, applicability, relevance and economic viability of products and services,

in the processes, and end uses of energy" (ANEEL, 2020b).

The program seeks to promote a culture of innovation, stimulating research and development in the SEB, through the creation of new equipment and the improvement of services provision, in such a way as to contribute to energy security, tariff moderateness, the reduction in the sector's environmental impact and the country's technological dependence (ANEEL, 2020b). It should be noted that Law 9,991/2000 has been amended over time to meet the demands for updating R&DP, regulated by ANEEL. This can be seen in Table 1.

Table 1 – Minimum percentages of NOR that the SEB companies must invest in R&DP

Segment of operation	Legal framework - defines % of NOR for R&DP investment				
	Law No. 9.991/00 ^e	MPV No. 144/03 ^f	Law No. 10.848/04 ^g	Law No. 10.848/04 ^h	Laws ⁱ No. 11.465/07, 12.212/10, 13.203/15 and 13.279/16
Generation	0.50%	0.25%	0.40%	0.40%	0.40%
Transmission	0.50%	0.25%	0.40%	0.40%	0.40%
Distribution	0.25%	0.125%	0.30%	0.20%	0.20%

Source: Elaborated by the authors, based on ANEEL (2020).

^e Percentages in effect from 07/24/2000 to 12/11/2003.

^f Percentages in effect from 12/12/2003 to 03/14/2004.

^g Percentages in effect from 03/15/2004 to 12/31/2005.

^h Percentages in effect from 01/01/2006 to 03/29/2007.

ⁱ Percentages in effect from 03/30/2007 to 12/31/2022 - the laws change ways of operating the programs, but do not change the percentages of NOR set for investment in the R&DP program.

Currently, as far as the R&DP regulated by ANEEL is concerned, the regulation imposes that the resources be applied as follows: a) 40% of the resources must be collected to the National Fund for Scientific and Technological Development (FNDCT); b) 40% of the resources are destined to the execution of projects presented to R&DP, regulated by ANEEL, which are managed by the contributing companies themselves; and c) the rest of the resources, corresponding to 20%, must be passed on to MME (BRASIL, 1991; 2016).

2.3.3 Energy Efficiency Program (EEP)

According to the Procedures Manual of the Energy Efficiency Program (PROPEE), published by ANEEL, through the normative resolution 830/2018, the objective of the EEP is to "promote the efficient and rational use of electricity in all sectors of the economy through projects that demonstrate the importance and

economic viability of actions to combat waste and improve the energy efficiency of equipment, processes, and end uses of energy". This is aligned with the concepts of innovation recommended by the Oslo Manual such as innovation of products, services, and processes (ANEEL, 2018b; OECD/Eurostat, 2018).

In doing so, it "aims to maximize the public benefits of saved energy and avoided demand" under this program (ANEEL, 2018b). The actions of this program seek to implement efficient management of resources, with the "transformation of the electric energy market, stimulating the development of new technologies and the creation of rational habits and practices in the use of electric energy". (ANEEL, 2018b). See in Table 2 the changes in the legal framework of the EEP regulated by ANEEL.

Table 2 – Minimum percentages of NOR that the SEB companies must invest in the EEP

Segment of Operation	Legal framework - defines % of NOR for EEP investment	
	Law No. 9.991/00 ^j , Law No.11.465/07 ^k	Law No.13.280/16 ^l
Distribution	0.50%	0.40%

Source: Elaborated by the authors, based on ANEEL (2020).

^j Percentages in effect from 07/24/2000 to 2006.

^k Maintains the percentage in effect until April 2016.

^l Maintains the percentage, but allocates 80% to EEP and 20% to PROCEL.

As of Law 13,280 of May 3, 2016, there was a change in the allocation of resources of the EEP, which

remained at 0.50% since its creation until April of that year. As of May of the same year, the Energy Efficiency

Program began to keep 80% of the resource allocation and to pass on the other 20% to the National Electric Energy Conservation Program (PROCEL).

When the company does not make the investment or has project amounts disallowed in the innovation programs regulated by ANEEL, both in R&DP and the EEP, the amounts must be accounted for and kept at the disposal of the programs and subject to the *Selic* rate remuneration (ANEEL, 2020b).

2.5 The Brazilian Electric Sector and the 2030 Agenda - Paris Agreement

To meet the commitments made by Brazil, with Agenda 2030 –The Paris Agreement - the RD&I PP of SEB should meet the following targets set in the NDC of Brazil: i) expand the use of renewable sources other than hydropower in the total energy matrix from a 28% to 33% share by 2030; ii) increase the use of non-fossil energy sources, expanding the share of renewable energy (wind, biomass and solar) other than hydropower in the electricity matrix to at least 23% by 2030; and iii) achieve 10%

efficiency gains in the electricity sector by 2030 (BID, 2017; Brasil, 2016). These goals will affect SDG 7 - accessible and clean energy - whose objective is to ensure reliable, sustainable, modern, and affordable energy for all and, by correlation, with SDG 9 - industry, innovation and infrastructure and SDG 13 - action against global climate change, due to the commitments made by Brazil with the 2030 Agenda (IPEA, 2018, 2019).

From this theoretical framework, it was sought to structure a set of methodological procedures to develop the research and reach the proposed goal.

III. METHODOLOGICAL PROCEDURES

The methodological procedures used in this study consist of a combination of methods and instruments, as a result of the different demands of analysis. Initially, support was pursued from the theoretical framework, especially with regard to the concept and type of innovation studied in this article, which has as its base the Oslo Manual (OECD/EUROSTAT, 2018; Marques, Diase Vianna, 2020). See the model in Figure 4, below.

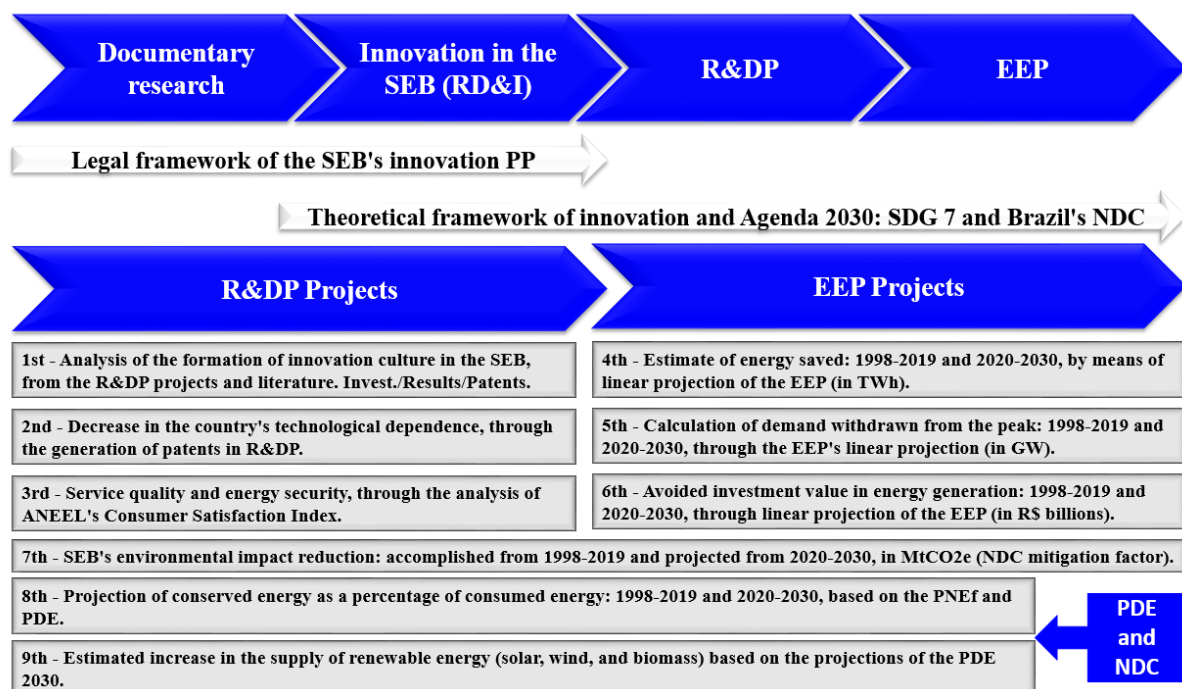


Fig.4: Graphic representation of the method used in the article

Source: elaborated by the authors.

The documental research began with the study of the theoretical framework that regulates innovation in the SEB or in the R&DI of SEB, which is divided into two programs: the R&DP and the EEP regulated by ANEEL, in

the period from 1998^m to 2019ⁿ. The data survey for the mentioned period was carried out based on documents released by ANEEL.

^m 1998 is the starting year of the R&DP and EEP Programs, regulated by ANEEL.

The projections of results of the R&DP and EEP of the SEB, from 2020 to 2030, were elaborated based on available literature and documents from the MME, EPE, and ANEEL, notably PDE, PNEf, and data released by ANEEL. The estimates for Energy Savings (ESA), Demand Withdraw from the Peak (DWP), Energy Savings Index (ESI), CO₂ Emission Reduction (RECO₂), in megaton of CO₂ equivalent (MtCO₂e) and Energy Conserved (ECON), were calculated according to the formulas and calculation memory described in items 3.1 and 3.2, below.

3.1 R&D Program (R&DP) regulated by ANEEL

Documentary analysis^a was performed of the R&DP, through reports of projects registered in ANEEL's R&D Project Management System (SGP&D), for the period 2008 to 2019. A total of 2,918 projects have been registered, of which 905 are now in completed status. Of this total, 875 projects are from 2008 to 2016, before the ratification of the NDC (aNDC), and 30 projects from 2017 to 2019, after Brazil's ratified the NDC (dNDC). The option to analyze the 30 projects with completed status in SGP&D since they have results registered in the system. The justification for the division into two periods is the fact that Brazil's NDC with the Paris agreement was ratified by the Brazilian National Congress in 2016. Therefore, as of 2017, the RD&I PPs could legally incorporate actions aligned with the goals set in that commitment and that align with the objectives of the SEB innovation PP.

The analysis of the SEB R&DP results followed the analysis model in figure 4, items 1 to 3, as follows:

The first item of the model, which aims to identify whether the R&DP has been able to promote the culture of innovation in the SEB, was analyzed through a survey conducted on the website of 40 companies that account for 99.6% of the electricity supply market, to identify: i) if RD&I is structured in the company; ii) if the company publicizes RD&I on the website; iii) if the company advertises the public announcements of the RD&I editions; iv) if it publicizes the results of RD&I; v) if it announces that RD&I is open to startups. The formation of an organizational culture of innovation depends basically on four factors: whether it has a

structured innovation program, whether the program is disclosed on the organization's website, whether the company regularly publishes announcements of the program, and whether it discloses results from previous editions (Bin et al., 2015; CGEE, 2015; Castro et al., 2019). To check if the innovation model is open one should check if the program is open to startups (Cabanes, 2016; Chesbrough, 2003, 2010; C. Christensen, 1997; Christensen, 2019).

The second item of the analysis model, which is to create/develop new equipment and decrease the country's technological dependence, was the identification with the survey of the number of patents applied for the R&DP in the period from 1998 to 2019.

Next, the results of the third, which is to improve the provision of service and contribute to energy security, were calculated through the ANEEL Customer Satisfaction Index (ACSI), identified in the period from 2000 to 2019, released annually by ANEEL.

The survey of the profile of human resources involved in the program was carried out from the analysis of 30 projects, from the period 2017 to 2019, with completed status in ANEEL's SGP&D.

3.2 Energy Efficiency Program (EEP) regulated by ANEEL

The document analysis of the EEP projects was performed from 2008 to 2019 since the data available dates back to this period. This program is properly aligned with the commitments agreed in Brazil's NDC - Agenda 2030. This analysis was done by accessing ANEEL's Microsoft Power BI^p and a spreadsheet with a list of ANEEL's EEP projects (2020). In both the BI and the spreadsheet, it was possible to filter the information: the number of projects, amounts invested per project and per year, amount of energy saved, and amount of energy withdrawn from the peak, resulting from the implementation of this program. It has been analyzed 1,026 EEP projects, which corresponds to the total number of projects available in the BI of ANEEL's program.

The analysis of the EEP projects contributed to generate data for three items of the analysis model (fourth, fifth, and sixth). The fourth, energy saved (ESA) in TWh, which includes ESA_{TWh(1998-2019)} and ESA_{TWh(2020-2030)} was obtained using equation 1:

^a2019 is the year that ANEEL presents consolidated results of the R&DP and EEP Programs.

^pThe documentary research carried out in the R&DP project reports, where filters were performed in a spreadsheet from ANEEL's SGP&D, for projects with CONCLUDED status, which were separated into two periods: from 2008-2016 bNDC and 2017 to 2019 aNDC.

^p Microsoft Power BI reports are under construction and may change at any time from June 2020. Available at: <https://www.aneel.gov.br/pt/programa-eficiencia-energetica>

$$ESA_{TWh(1998-2030)} = ESA_{TWh(1998-2019)} + \sum_{i=2020}^{2030} \left(\frac{VlrTotalInvest_i}{VlrInvest_{R\$/MWh_i}} \right) \times \frac{1}{1,000,000} \quad (1)$$

Where:

$ESA_{TWh(1998-2019)}$ and $ESA_{TWh(2020-2030)}$ —is the amount of energy saved (ESA), for the period 1998 to 2019, added with the amount of ESA linearly projected for the period 2020 to 2030, obtained by analyzing the EEP projects (in TWh).

The demand withdrawn from the peak (DWP), which is the fifth analysis item, should be in GW, which includes $DWP_{GW(1998-2019)}$ and $DWP_{GW(2020-2030)}$ was obtained through equation 2:

$$DWP_{GW(1998-2030)} = DWP_{GW(1998-2019)} + \sum_{i=2020}^{2030} \left(\frac{VlrTotalInvest_i}{VlrInvest_{R\$/kW_i}} \right) \times \frac{1}{1,000,000} \quad (2)$$

Where:

$DWP_{GW(1998-2019)}$, and $DWP_{GW(2020-2030)}$ —is the amount of demand withdrawn from the peak (DWP), annually, for the period 1998 to 2019, added with the linearly projected DWP, for the period 2020 to 2030, using data from the analyzed EEP projects (in GW).

Energy savings, as well as off-peak demand, resulted in the sixth component of the proposed analysis model, investment avoided in energy generation (IAEG) in billions of reais (R\$ bi), referring to two periods: $IAEG_{inR\$ bi(1998-2019)}$ and $IAEG_{inR\$ bi(2020-2030)}$ according to equation 3:

$$IAEG_{inR\$ bi(1998-2030)} = IAEG_{inR\$ bi(1998-2019)} + \sum_{i=2020}^{2030} (DRPinkWxVlrInvest_{inR\$/kW}) \times \frac{1}{1,000,000} \quad (3)$$

Where:

$IAEG_{inR\$ bi(1998-2019)}$ and $IAEG_{inR\$ bi(2020-2030)}$ —is the value of the avoided investment in energy generation (IAEG), in the period from 1998 to 2019, added to the IAEG projected linearly, for the period from 2020 to 2030, based on the data of the analyzed EEP projects (in billions of Reais).

The seventh analysis item is the reduction of SEB's environmental impact and was verified from the reduction of CO_{2e} emissions that occurred in the period from 1998 to 2019 ($RECO_{2e}$ in $MtCO_{2e(1998-2019)}$) and ($RECO_{2e}$ of $MtCO_{2e(2020-2030)}$) according to equation 4:

$$RECO_{2e_{inMtCO_{2e}(1998-2030)}} = RECO_{2e_{inMtCO_{2e}(1998-2019)}} + \sum_{i=2020}^{2030} \left(ESA_{in \frac{MWh}{year}} \times NDC \text{ Emission Factor in } tCO_{2e}/MWh \right) \times \frac{1}{1,000,000} \quad (04)$$

Where:

$RECO_{2e_{em MtCO_{2e}(1998-2019)}}$ and ($RECO_{2e_{de MtCO_{2e}(2020-2030)}}$ — is the amount of CO_{2e} emissions avoided in the period 1998 to 2019, added with the amount of CO_{2e} avoided for the period 2020 to 2030 projected linearly, according to the NDC per emissions scenario.

The eighth item is the amount of conserved energy (ECON), which was calculated for the years 2020, 2025, and 2030 as provided in the NDC, equation 5:

$$ECON_i = \frac{ESA_i}{ECON_{acum_i}} \times 100 \quad (05)$$

Where:

ECON corresponds to the percentage of energy conserved (ECON), obtained from the amount of ESA in the year under analysis, divided by the amount of energy saved accumulated until the year of analysis ($ECON_{acum}$), multiplied by 100 (in GWh), in period $i = 2020, 2025$ and 2030.

At last, the new goal, which foresees an increase in the supply of renewable energy, will be analyzed against what was projected in the 2029 PDE, with added projections based on the premises of the 2030 PDE, since this document has not been released yet.

3.3 Analysis of R&DP and EEP results versus Literature, Agenda 2030 (SDG 7) and Brazil's NDC with the Paris Agreement

The data from the two programs (RD&P and EEP) were consolidated in tables, figures (graphics), and charts. This was done to allow a comparative and critical analysis of the results achieved by the projects, with the literature, with the legal framework that regulates the SEB's innovation PPs and, mainly, with the goals set in the NDC, as well as in the 2030 Agenda, especially SDG 7, which is correlated with SDGs 9 and 13. Next is the model for analyzing the results of this article.

The analysis of the results followed the methodological procedures in Figure 4, according to the model proposed in Chart 1, below:

Chart 1 - Analysis model: SEB's RD&I PP results versus Agenda 2030 - Paris Agreement

What?	How? Analysis and results	Goals: Agenda 2030
1) Promote a culture of innovation, stimulating RD&I in the SEB (R&DP).	Theoretical framework and the SEB innovation PP (R&DP). Invest./Results/Patents	SDG 7 - Target 7.a, in correlation with SDG 9.
2) Create/develop new equipment and decrease the country's technological dependence.	Theoretical framework and quantity of patents applied for (R&DP).	SDG 7 - Target 7.a, in correlation with SDG 9.
3) Improve service provision and contribute to energy security.	ANEEL's Consumer Satisfaction Index (ACSI)	SDG 7 - Target 7.1, in correlation with SDG 9.
4) Energy Saved.	Quantity in TWh.	SDG 7 - Target 7.3, correlated with SDG 9
5) Demand withdrawn from the peak.	Quantity in GW.	SDG 7 - Target 7.3, correlated with SDG 9.
6) Avoided investment in energy generation.	In R\$ in the period of ANEEL's RD&I.	SDG 7 - Target 7.3, correlated with SDG 9.
7) Reduce SEB's environmental impact	Reduction of emissions of CO ₂ e.	SDG 7, by correlation with SDGs 9 and 13.
8) Conserved Energy.	As % of the energy consumed, according to PNEE.	SDG 7 - Target 7.3 and NDC (10.0% target).
9) Increase the supply of renewable energy (solar, wind, and biomass).	As % of the Brazilian electric matrix.	SDG 7 - Target 7.2 and NDC (23.0% target).

Source: elaborated by the authors.

Therefore, the method and the analysis model are properly aligned with answering the problem situation and the objective of this article.

IV. RESULTS AND DISCUSSION

The results and discussion were conducted in such a way that the problem issue, which guides this article, was answered during the analysis of the results of the SEB's innovation PP, through the RD&I program regulated by ANEEL (RD&P and EEP). All this with regard to the literature and the goals of Agenda 2030, notably SDG 7 - Affordable and Clean Energy. Its goal is to "ensure reliable, sustainable, modern and affordable access to energy for all" and its five targets are the three finalists⁹: 7.1, 7.2, 7.3 and two implementation¹⁰: 7.a and 7.b (IPEA, 2018, 2019). It also includes the NDC targets

for energy conservation and increasing non-renewable energy sources (solar, wind, and biomass) (BID, 2017).

In this context, the correlation between SDG 7 and Brazil's NDC goals with the Paris Agreement, SDG 9 - Industry, Innovation and Infrastructure, and SDG 13 - Action Against Global Climate Change should be emphasized. Therefore, the results that impact these goals were highlighted in the analysis, but without addressing a specific goal (IPEA, 2018, 2019).

4.1 Results of the RD&P regulated by ANEEL and the goals of Agenda 2030

The analysis of SEB RD&P projects, regulated by ANEEL, was carried out in two periods: from 2008 to 2016 before the NDC (bNDC) and from 2017 to 2019 after the NDC (aNDC), given the goals of Agenda 2030 of the Paris Agreement.

4.1.1 RD&P Investments: Performed from 1998 to 2019 and Projected from 2020 to 2030

The data generated by RD&P is of great relevance to the innovation PP of the SEB, since in the period from

⁹ According to the Agenda 2030, the final goals are those whose object relates directly (immediately) to the achievement of the specific SDG (IPEA, 2018).

¹⁰ Implementation targets, in the 2030 Agenda document, the implementation targets refer to human, financial, technological, and governance resources (institutional arrangement and tools: legislation, plans, public policies, programs, etc.) needed to achieve the SDGs.

1998 to 2019 the data was- investment to the tune of R\$ 7.60 billion, in 4,247 projects that were approved by ANEEL, out of 6,061 (equivalent to 70.07% of the projects

submitted). From 2020-2030, the investment forecast is R\$ 550.00 million per year or R\$ 6.05 billion for the projected period (ANEEL, 2020b), as shown in Table 3, below.

Table 3 – R&DP data: 1998-2030^s

Consolidated R&DP data: 1998-2030	
R&DP Investment Value: 1998 to 2030	Values in billions of R\$
Investment in the period: 1998 to 2019 (accomplished)	7,60
Investment in the period: 2020 to 2030 (projected)	6,05
Total Investment (accomplished + projected)	13,65
Other R&DP data: performed from 1998 to 2019	Qty in Units
Presented projects	6 061
Approved Projects	4 247
Patents and Licenses	325
Active Researchers	1 200
Published Articles	3 900

Source: Developed by the authors based on data from ANEEL (2020), accomplished period (1998-2019). Projections elaborated by the authors in linear form (2020-2030).

^s 1998 is the starting year of the R&DP - Between 1998 and 2019: period considered fulfilled. From 2020 to 2030 - data were projected by the authors in a linear fashion.

The RD&P also involved 1,200 researchers and generated 3,900 articles that were published over the period 1998 to 2019(ANEEL, 2020b).

Patents and Licenses area very relevant aspect in practically all RD&I programs, which would be no different in the RD&P regulated by ANEEL, but shows relatively shy results, with 325 patents and licenses, in the analyzed period from 1998 to 2019. This figure indicates that 7.65% of the projects generated this benefit, which presents an advance concerning the results obtained by Guedes (2012) that were 2.00% of patents, for the period 1998-2007.

4.1.2 Innovation culture in the SEB and the reduction of the country's technological dependence

Promoting a culture of innovation and reducing the country's technological dependence through RD&I in the SEB is a great challenge for the program, since the Brazilian market has always had low participation of national content. That's because the electrical sector is a business segment known as "supplier follower" where suppliers are directly responsible for innovation in the production chain (Castro et al., 2017a; 2015). A large part

of this production chain is developed outside Brazil because most of the supplying companies are globalized.

Brazil's situation regarding innovation in the power sector is quite uncomfortable, according to the 2018 Global Innovation Index: energizing the world with innovation (GII 2018)(Cornell University, INSEAD and OMPI, 2018). In the three rankings: i) Global Innovation Index; ii) Innovation Inputs Sub-Index; and iii) Innovation Outputs Sub-Index, occupying the following positions: 64th, with 33.44 points; 58th, with 43.40 points; 70th with 23.49 points. This ranking is calculated for 126 countries and the scoring scale is from 0.00 to 100.00 (Cornell University, INSEAD and OMPI, 2018).

In the analyzed sample, between 2017 and 2019 aNDC, the percentage of patents stood at 5.95%, below the 7.65% seen between 1998-2019, therefore, it does not show evidence that the SEB innovation PP, concerning the RD&P, is aligned with SDG 9, which aims to build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation (IPEA, 2018, 2019).

The results of this ranking show that Brazil is far from the indexes of nations with similar economies. A way out of this uncomfortable position is to achieve at least one of the implementation goals of SDG 7, especially 7.a - "by 2030, strengthen international cooperation to facilitate

access to clean energy research and technologies, including renewable energy, energy efficiency [...] and promote investment in energy infrastructure and clean energy technologies”(IPEA, 2018, 2019).

Although there are paths to follow, this study shows that 62.5% of the 40 SEB companies surveyed make no mention of whether or not they adhere to Agenda 2030 or, in particular, to SDGs 7, 9, and 13, either on their website or in their socio-environmental report. On the other hand, 37.5% expose on their website and in their socio-environmental report their corporate commitment to the UN-led Global Agenda. It is noticeable that even five years after the conclusion of the Paris Agreement, some Brazilian corporations have not yet realized that they are part of a signatory country of this global pact, with 17 Sustainable Development Goals.

Brazil may experiment with other types and models of innovation in the SEB, such as open, radical, or disruptive innovation (Christensen, 1997; OECD/Eurostat, 2018; Christensen, 2019; Marques, Dias e Vianna, 2020). For this to happen, it is necessary to examine the research results of this study carefully, because when analyzing data from 40 SEB companies, which account for 99.6% of the electric power supply market, 10.0% do not even announce their RD&I program. Only 15.0% of the 40 companies surveyed inform that their RD&I is open to startups, therefore, they are aligned with the innovation model considered ideal by the literature (Christensen, 2019). 90.0% of the companies announce RD&I and publish calls for proposals on the website, which means that the programs are open, but as 85% of them do not inform that their programs are open to startups, it can be concluded that the concept of radical or disruptive innovation does not apply to the innovation model adopted by these companies. This puts them behind other countries and Brazil itself since in 2020, 46% of large companies invested in startups to speed up their innovation programs (MONEYREPORT, 2021).

4.1.3 Quality of services and energy security of the SEB

The ANEEL Customer Satisfaction Index (ACSI), created in 2000 by the regulator body to evaluate the performance of SEB companies, is composed of five variables, which are: i) perceived quality; ii) perceived value (cost-benefit ratio); iii) overall satisfaction; iv) trust in the supplier; and v) loyalty (ANEEL, 2020a). The data in figure 5 show there is nothing to celebrate, since over 19 years there has been practically no evolution.

In the two examples chosen: the company CPFL[†], which operates in the state of São Paulo, including part of the São Paulo megalopolis, in 2000 stood at 71.72 and in 2019 reached 76.81, improving only 4.99% over this period. LIGHT[‡] inaugurated the ACSI in 2000, with 62.88 and, closed 2019 with 56.43, representing a drop of 6.45% from end to end, in the period analyzed and, staying below the ACSI Average over half the time of the index's existence. The choice of the companies CPFL and LIGHT, third and fifth in the ranking of SEB companies in consumer's numbers of 2019[‡] is justified by the fact that they operate in the two largest metropolises in Brazil (the city of São Paulo and the city of Rio de Janeiro, respectively). The reason for excluding the companies CEMIG, ENEL, COPEL, first, second and fourth in the ranking is the fact that they operate in different environments (capital and countryside).

[†] CPFL is a large concessionaire and was chosen as an example since it is one of the companies that show good evaluation in the historical series from 2000-2019. CPFL is the 3rd largest company in the SEB in the total number of consumers in the 2019 ranking (Top 5).

[‡] LIGHT is a large concessionaire and was chosen for this analysis since it is one of the underperforming companies in the assessment in the 2000-2019 historical series. CPFL is the 5th largest company in the SEB in the total number of consumers in the 2019 ranking (Top 5).

[‡] Ranking calculated by the authors based on data from the Brazilian Association of Electricity Distributors (ABRADEE), 2019 data (ABRADEE, 2021).

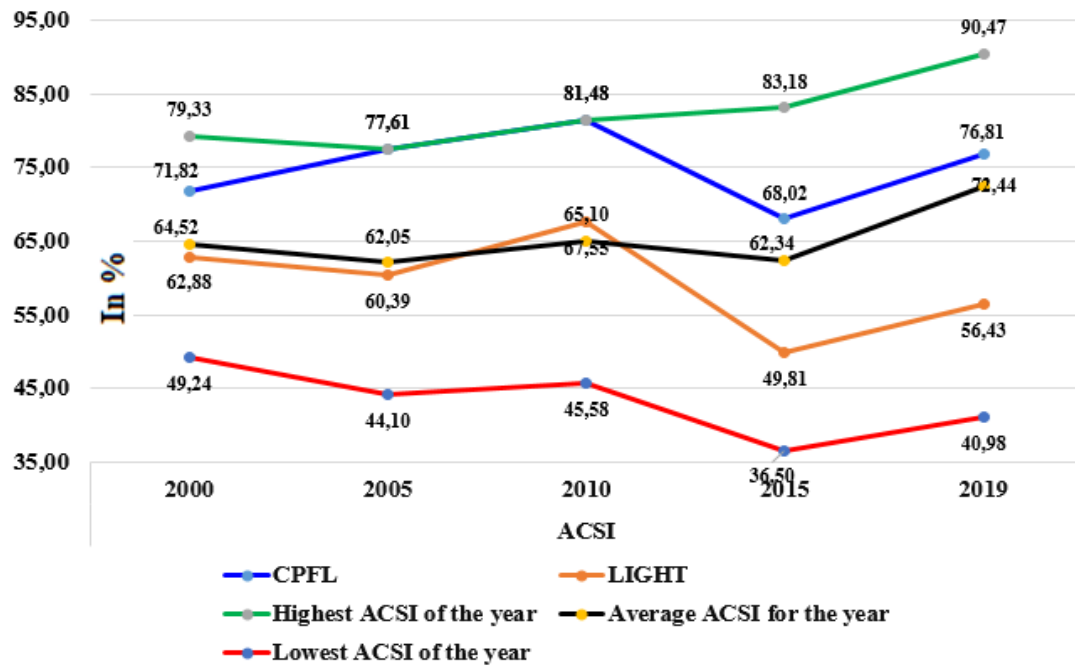


Fig.5: Evolution of ANEEL's consumer satisfaction index (ACSI), scale: from 0 to 100

Source: Elaborated by the authors based on data from ANEEL (2020).

It is also necessary to comment on the largest ACSI in each year since the line is ascending, from 79.33 in 2000 to 90.47 in 2019. Despite being increasing, the companies that occupy the first place in each year are small companies, with very low market share, that is, it is illusory information because the large companies with significant market share are around the score of CPFL (in the upper band) and LIGHT (lower band).

The ACSI results from its inception in 2000 to 2019 show that the SEB lacks a continuous improvement strategy for both service level and system reliability, and aligning with the goals of Agenda 2030 can be an important step towards quality improvement. SDG 7 has both an implementation target and an outcome target on this front: i) the implementation target is 7.b "by 2030, expand the infrastructure and improve the technology for

delivering modern and sustainable energy services for all"; ii) the outcome target is 7.1 "by 2030, ensure universal, reliable, modern and [...] access to energy services"(IPEA, 2018, 2019).

4.1.4 Human resources profile and integration with the market and academy

The analysis of the profile of human resources involved in the RD&P, considering the 30 projects analyzed, with completed status in the SGP&D of ANEEL, for the period 2017 to 2019, identified 510 professionals. They are 107 (one hundred and seven) PhDs, 110 (one hundred and ten) masters, 82 (eighty-two) specialists, 157 (one hundred and fifty-seven) higher education level and 54 (fifty-four) technical level, according to Table 4, below:

Table 4: Profile of human resources involved in the 30 projects analyzed from 2017 to 2019

Titration	Quantity	Professionals per project	% by titration
PhD	107	3.57	20.98
Master	110	3.67	21.57
Specialist	82	2.73	16.08
Higher	157	5.73	30.78
Technical	54	1.80	10.59
Total	510	17.50	100.00

Source: elaborated by the authors, based on a sample taken from the SGP&D of ANEEL (2020)

It should be noted that the 30 (thirty) projects analyzed were executed in partnership with Universities, Federal Institutes, Research Institutes, Foundations, and Consultancies, whose teams are mostly composed of masters and doctors, which account for approximately 60% of the staff.

These results show that there is an ongoing movement towards increased participation of academia in the innovation programs regulated by ANEEL. 100% of the projects in the sample analyzed are linked to academia, contrary to what was detected by the studies Laplane and Cavalcanti (2015) and CGEE (2015), which indicated low integration between academia and companies in the execution of innovation programs.

However, it should be noted that no international partnership was identified seeking support for R&D in the area of energy, as provided for in SDG 7 - target 7.a - "by 2030, strengthen international cooperation to facilitate access to clean energy research and technologies, including renewable energy, energy efficiency [...]" (IPEA, 2018, 2019). To improve the RD&P performance it is necessary to accelerate the transition to the open innovation model, as proposed in the literature (Cabanes, 2016; Chesbrough, 2003, 2010; Christensen, 2019).

4.2 Results of the EEP of the SEB regulated by ANEEL

The results of the EEP, carried out from 1998 to 2019, and the projections of investments to be made from 2020 to 2030, presented below are i) investments in the EEP and investments avoided in energy generation (IAEG) by the EEP and; ii) energy saved (ESA) and demand withdrawn from the peak (DWP).

4.2.1 EEP Investments versus EEP IAEG: 1998 to 2030

The EEP had 4,850 projects executed, where R\$ 5.90 billion were invested, in the period from 1998 to 2019, and investments^w of R\$ 6.05 billion are foreseen for the period from 2020 to 2030, which is equivalent to R\$ 550.0 million per year, for the next 11 years (ANEEL, 2020b). The values of the two cycles amount to R\$11.95 billion.

Investment in energy efficiency (EE) should be a priority for the SEB and Brazilian society since it generates an interesting synergistic effect since it can expand the use of the current installed capacity and avoid new investments in energy generation, as demonstrated in this study (De Castro *et al.*, 2015, 2019).

The values invested in the EEP, in the period from 1998 to 2019 (accomplished) avoided investments in energy generation, of about R\$ 1.00 to R\$ 2.80, with IAEG in the amount of R\$ 16.56 billion. For the period from 2020 to 2030, the projections of this study indicate that the IAEG^x for the period is of the order of R\$ 25.38 billion, raising the cost versus benefit ratio (RCB) to the ratio of R\$ 1.00 to R\$ 4.19. The IAEG for the period from 1998 to 2030 is R\$ 41.94 billion, enough to build an enterprise with an installed capacity of approximately 5,100 kW. See in figure 5 the benefit generated by the EEP by period: investment made in the EEP versus the value of the IAEG by the EEP.

^w The value of the EEP investment from 2020 to 2030 was projected based on values corrected by the IPCA, referring to 1026 EEP projects analyzed in this study.

^x The IAEG from 2020 to 2030 was projected based on values corrected by the IPCA, referring to 1026 EEP projects analyzed in this study.

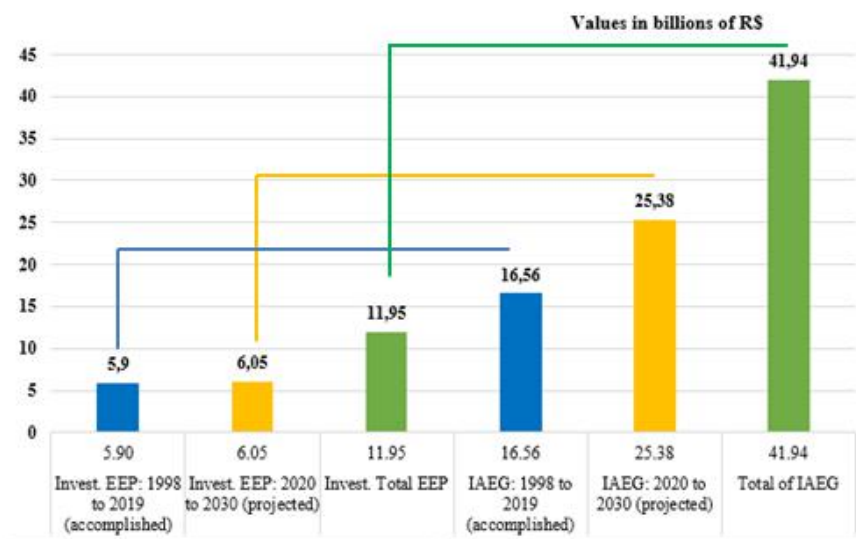


Fig.6: Investment values in the EEP versus IAEG by the EEP: 1998 to 2030

Source: Elaborated by the authors based on data from ANEEL (2020) and projections elaborated by the authors

Since the basis for expanding the production capacity of the SEB is still the HPP model, by avoiding investments in new large undertakings, the EEP is aligned with SDG 13, reducing the environmental impact of the sector.

4.2.2 Energy saved (ESA) and demand withdrawn from the peak (DWP): 1998 to 2030

The EEP is prodigious in generating combined results such as, for example, ESA and DWP. In the period from 1998 to 2019, the ESA is 63.0 TWh and allowed

power withdrawal at the peak or DWP of the order of 2.8 GW, which is equivalent to 40% of the power load of the northern region of Brazil or the corresponding to the consumption of 32.4 million households in Brazil for one year (ANEEL, 2020b). The projected ESA for the period 2020 to 2030 was estimated at 4.39 TWh and the DWP 1.07 GW, as the estimates in this study. The total ESA for the period 1998 to 2030 is expected to reach 67.39 TWh and the total DWP is expected to be 3.87 GW. See the data in Table 5.

Table 5 -Energy saved by the EEP: 1998-2030^y(accomplished and projected)

Energy Saved (ESA)	Qty. (in TWh)
ESA - accomplished from 1998 to 2019 (in TWh/year)	63,00
ESA - projected from 2020 to 2030 (in TWh/year)	4,39
Total ESA (accomplished + projected) in TWh/year	67,39
Demand withdrawn from the peak	Qty. (in GW)
DWP in the period 1998 to 2019 (accomplished)	2,80
DWP in the period from 2020 to 2030 (projected)	1,07
Total DWP (accomplished + projected) in GW	3,87

Source: Elaborated by the authors based on data from ANEEL (2020) and projections elaborated by the authors.

^y The Analysis involves the period 1998-2030, and from 1998-2019 the data released by ANEEL (2020) was used. From 2020-2030 the data were projected by the authors in a linear fashion.

EEP results in ESA and DWP meet SDG targets 7 - 7.3 "by 2030, increase the rate of energy efficiency improvement of the Brazilian economy" and 7.1 - "by 2030, strengthen international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency [...] and promote investment in energy infrastructure and clean energy technologies"(IPEA, 2018, 2019). However, one should be aware of the fact that the monitoring of the results forecast for the period from 2020 to 2030 is fundamental to plan for possible course corrections since the projections are linear and any accident along the way can alter the expected results.

4.3 Energy conserved during the PNEf: 2011 to 2030 - achieved and projected

Energy conservation is one of the goals of Brazil's NDC with the Paris Agreement, which is present in the RD&I of the SEB, through the EEP regulated by ANEEL, which by saving energy plays the role of energy conservation. The projections of the 2010 National Program for Energy Efficiency (PNEf), which served as the basis for the NDC, predicted energy consumption of 439,548 GW in 2011, the year of the starting point of the

energy conservation program (MME, 2011).

In 2020, the forecast was for consumption without conservation of 674,693 GW, versus consumption with conservation of 638,700 GW. In 2025, consumption without conservation would be 832,775 GW, and consumption with conservation would be 767,067 GW. In the year 2030, energy consumption without conservation would reach 1,027,896 GW, and energy consumption with conservation would reach 921,273 GW, commitments of the NDC for the years 2020, 2025, and 2030 (BID, 2017).

This study verified what occurred in the period from 2011 to 2020 and then made projections for the period from 2020 to 2030, based on the PDEs of the same period, according to Figure 6, below. In the same period, energy consumption with conservation and without conservation was more or less on the same level due to long periods of economic crisis, including recession in the years 2015 and 2016, followed by low growth years between 2017 and 2019, and another recession in 2020 due to the Coronavirus pandemic (COVID-19). Therefore, in 2020, final energy consumption should be around 530,590 GW, practically the consumption level of mid-2014 (MME/EPE, 2018, 2020).

In 2025, projections indicate the energy

consumption without conservation would be 642,652 GW, and energy consumption with conservation would be 617,004 GW. In 2030, energy consumption without

conservation would reach 770,673 GW, and energy consumption with conservation would reach 716,795 GW. See Figure 7.

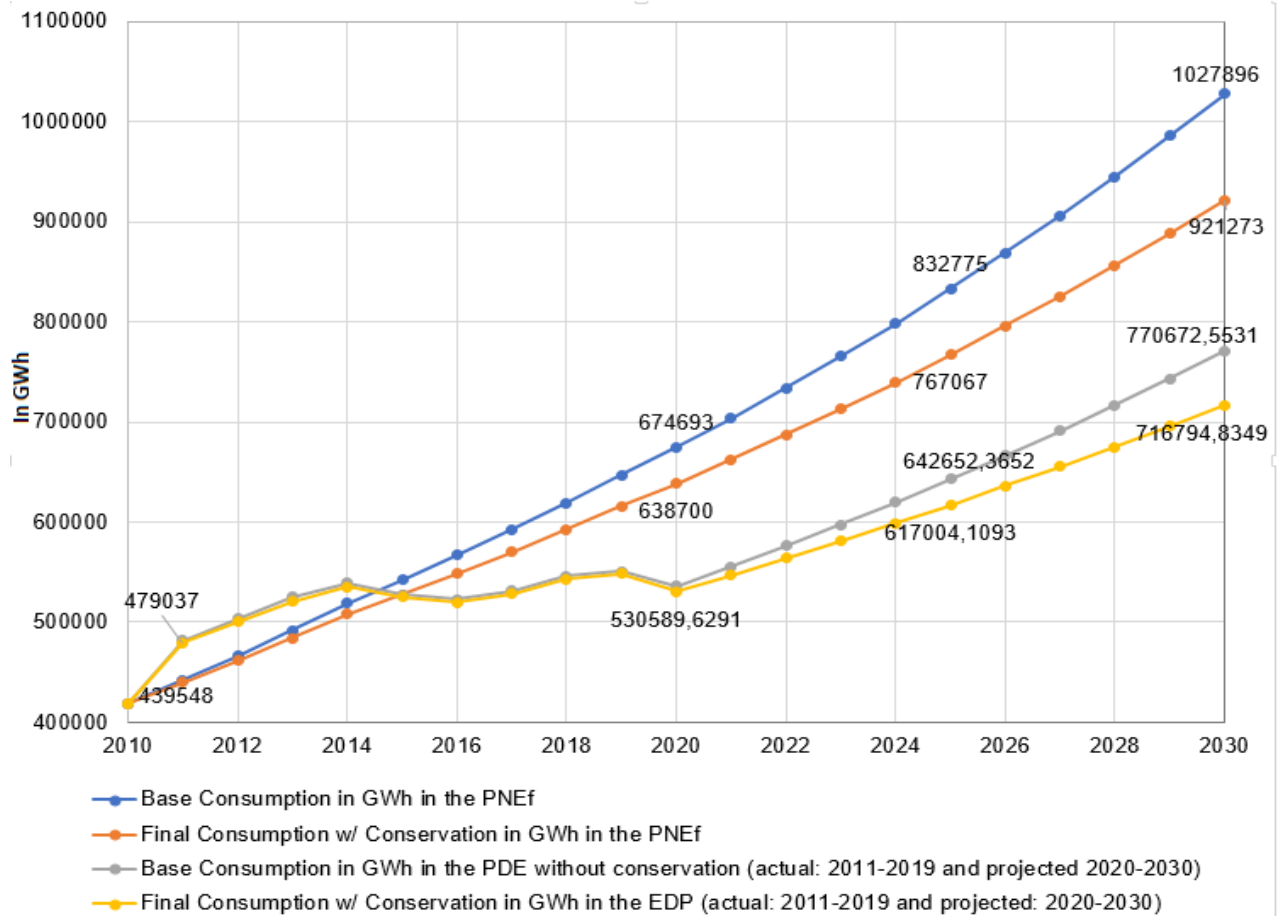


Fig.7: Energy consumption and conservation: 1998 to 2030 - accomplished and projected

Source: Prepared by the authors based on data from the PNEf (2011) and EPE (2020) and projections made by the authors based on the PDE 2030 (EPE, 2020).

The NDC targets for the years 2020, 2025 and 2030 are 4.0%, 8.0% and 10.0%, respectively (BID, 2017). The PNEf forecasted electricity conservation in 2020 of 5.33%, in 2025 of 7.89%, and 2030 of 10.37% (MME, 2011). The goal set in the NDC is compromised because the

projections of this study indicate that energy conservation should end 2020 with 0.99%, in 2025 it should reach 3.99%, and in 2030 with 6.99%, compared to the NDC goal: 4.0%, 8.0%, and 10.0%, for the respective years (BID, 2017; MME, 2011). As shown in Figure 8.

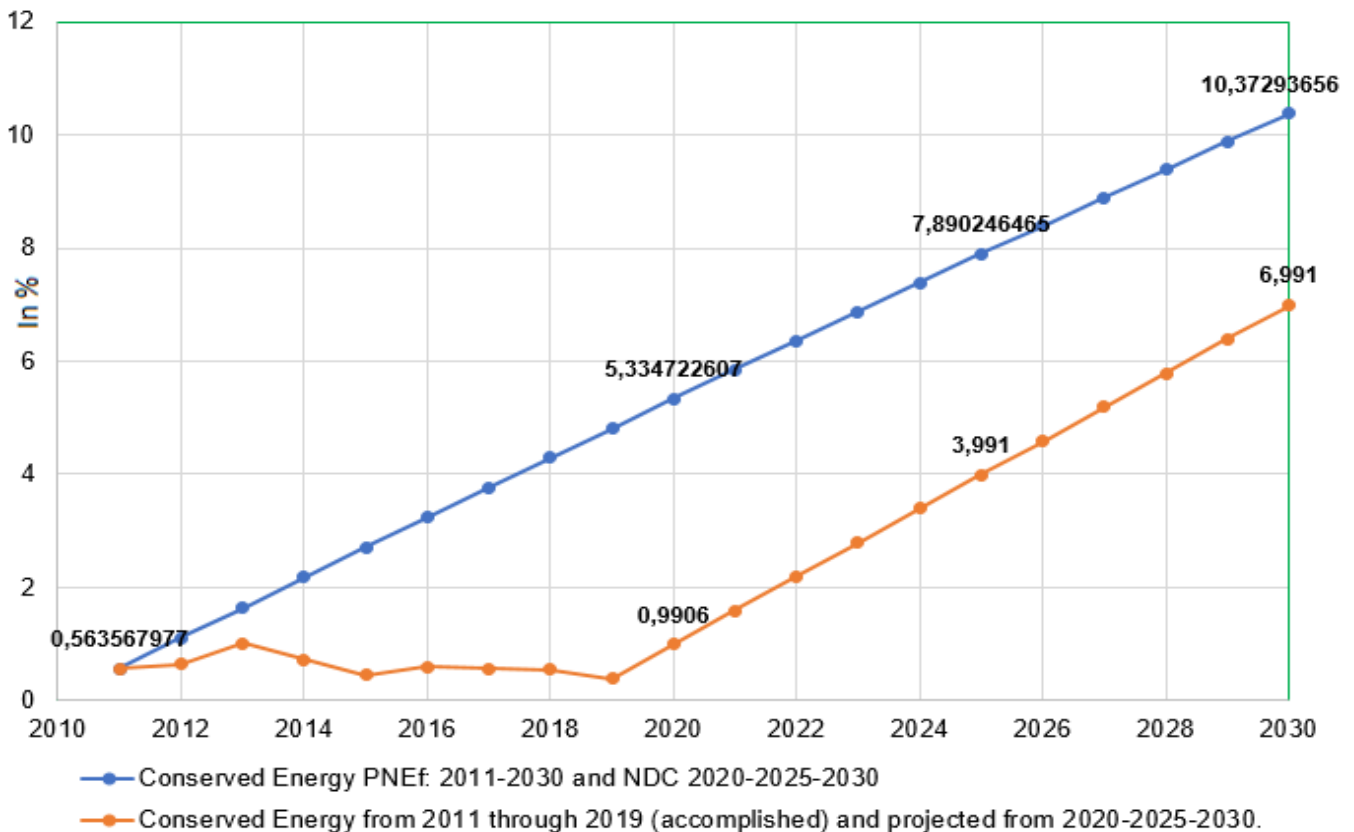


Fig.8: Electricity conservation: NDC target versus accomplished/projected

Source: Prepared by the authors based on the PNEf (MME, 2011), data from the PDE (MME/EPE, 2020) and projections prepared by the authors based on the PDE 2030 (MME/EPE, 2020).

4.4 Increase the supply of renewable energy (solar, wind, and biomass)

The increase in renewable energy supply from solar, wind, and biomass sources is foreseen in the commitments of Agenda 2030, both in the NDC and in SDG 7 - "by 2030, maintain a high share of renewable energy in the national energy matrix"(IPEA, 2019, p. 5). The NDC targets for renewable sources are as follows: i) expand the use of renewable sources other than hydropower in the total energy mix to a 28% to 33% share by 2030; ii) increase the use of non-fossil energy sources by expanding the share of renewable energy (wind, biomass and solar) besides hydropower in the electricity

mix to at least 23% by 2030 (BID, 2017; Brasil, 2016).

The projections made based on the PDE 2030 (MME/EPE, 2020) indicate that the participation of renewable energy sources - excluding hydroelectric power, therefore including only wind, biomass, and solar - should reach a total of 24% in 2030, according to a linear projection of the total variable of the Brazilian electricity matrix. This is against 23.00% of variable Brazil's NDC Target with the Paris Agreement, which meets target 7.2 of SDG 7, adjusted for Brazil, which is "by 2030, maintain a high share of renewable energy in the national energy matrix" (IPEA, 2019, p. 5;). See data in Figure 9.

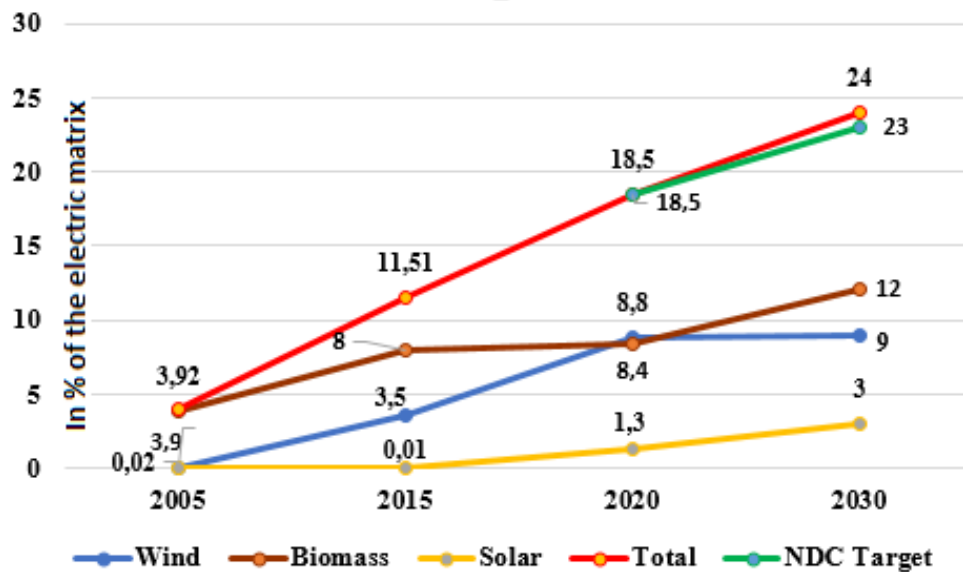


Fig.9: NDC target for renewable energy (wind, biomass, and solar) for 2030

Source: Prepared by the authors based on NDC (Brazil, 2016) and IBRD (2017), and MME/EPE (2020).

Thus, it can be inferred that the target set in the NDC for renewable energy (wind, biomass, and solar) for 2030 should be met if the pace of investment is maintained.

4.5 Reducing the environmental impact of SEB: 1998 to 2030

The reduction of CO₂e emissions verified in the EEP projects, despite not being explicit as one of its objectives, should be seen as a positive externality of the program. That is also aligned with clean energy (SDG 7), to build resilient infrastructure, promote sustainable industrialization, and foster innovation (SDG 9) and take urgent action to combat climate change and its impacts (SDG 13), by correlation (IPEA, 2019).

According to the Brazilian Forum for Climate Change (FBMC), the key role of SEB is to contribute to the "reduction of emissions of the other sectors of the economy", since the sector is a net exporter of GHG emissions for the other business segments of the market (FBMC, 2018, p. 24).

Hence, for the SEB to be able to fulfill its role, it is fundamental that the Brazilian electricity matrix becomes increasingly cleaner and that the participation of

solar, wind, and biomass energy increases. That is especially considering the impact of climate change on the capacity to produce energy from hydric sources, due to the alteration of the rainfall regime, which impacts the volume of water in the reservoirs. Table 6 presents the estimates for the periods 1998-2019, as well as the projections of this study for the period from 2020 to 2030 (ANEEL, 2016, 2020b).

The emission reduction estimates of this study showed that in the worst-case scenario - pessimistic - the RECO₂e is 1.617369 MtCO₂e and in the best case scenario - optimistic - is 4.852106 MtCO₂e, considering the scenarios and emission factors used in Brazil's NDC (BID, 2017). The FBMC, in 2018, predicted that energy efficiency actions at the consumption end, had a mitigation potential of the order of 2.33 MtCO₂e, a value that occupies a midpoint between the worst and best case scenario estimates of this study (FBMC, 2018).

Therefore, it can be said that the SEB is aligned and well-positioned in relation to the rest of the world, when it comes to the global trend of decarbonization of the electricity sector, since the Brazilian electricity matrix has a high share of renewable energy, ending the year 2020 with a share around 85% and should reach 89% in 2030 (MME/EPE, 2020).

Table 6—Estimated CO₂e emissions avoided with the EEP - accomplished: 1998-2019 and projected: 2030

		Periods	Qty.Estimated (in tCO ₂ e)	Total Estimate (in MtCO ₂ e)
S C E N A R I O S	Pessimistic	1998-2019	1.512.000	1,617369
		2020-2030	105.369	
	Pessimistic - Efficiency	1998-2019	1.701.000	1,819540
		2020-2030	118.540	
	Reference	1998-2019	3.276.000	3,504299
		2020-2030	228.299	
	Reference - Efficiency	1998-2019	1.764.000	1,886930
		2020-2030	122.930	
	Optimistic	1998-2019	4.536.000	4,852106
		2020-2030	316.106	
	Optimistic - Efficiency	1998-2019	2.079.000	2,223882
		2020-2030	144.882	

Source: Prepared by the authors based on data at ANEEL (2020) - accomplished, and projections by the authors based on the expectations of ANEEL's EEP, for the period 2020 and 2030.

V. CLOSING REMARKS

The contribution of this article was to analyze the impact of the Brazilian innovation PPs of the SEB, more specifically on the research and development and energy efficiency programs, coordinated by the sector's regulatory agency, in the face of the goals set in Agenda 2030, especially in SDG 7 and Brazil's NDC.

The discussions held from the analysis of the SEB innovation PP - through the RD&I program regulated by ANEEL, which involved RD&P and EEP projects - show that there are considerable advances, with clear results accounted for. Nevertheless, there are also doubts, which fall mainly on the RD&P. For example, it was not identified research with a hydrogen-based fuel cell that is considered the RD&I frontier, capable of potentiating the renewable energy production units (solar and wind).

With regard to technological trends and challenges of the electricity sector in the world: digitalization, decentralization, and decarbonization, Brazil has advanced, but with a certain mismatch. In the first trend, digitalization, the RD&P of the SEB has contributed to the advancement of digital technologies that aim to improve the operational efficiency of the electricity system. This means investing in smart grids and preparing them for a new configuration, which includes the spread of distributed generation and energy efficiency. However, Brazil is still lagging behind the EU and the US (Marques, Dias e Vianna, 2020; ANEEL, 2020b; Castro, N. J.; Brandão, 2019; De Castro et al., 2015).

In the second trend, the decentralization of the electrical systems, the SEB should use it in a complementary way to the SIN, which is considered a

model with a good level of efficiency. However, with time the tendency is for integration to increase thanks to technological evolution, to smart grids, which allow bidirectional flows. The change from unidirectional to bidirectional flow facilitates the process of decentralization and makes it possible to add new sources of generation, including renewable ones such as solar and wind, which can be produced close to the final consumer (Castro *et al.*, 2017; WORLD ENERGY COUNCIL, 2017; MIT, 2016; NYISO, 2016; Collaço *et al.*, 2016; Schwab, 2018; Rifkin, 2012).

The third and last of the global trends, the decarbonization of the electric system, has already been overcome by Brazil, due to the concentration of hydro sources based initially on HPP and SHP. Today, the country is expected to move quickly to other renewable energy sources, such as wind, solar, and biomass, to reduce the dependence on hydroelectric power, due to climate change.

It is also observed that the results of the RD&P, which is in its third cycle - especially in the sample of projects analyzed in this study - are configured in at least three findings: i) the program is not aligned with the 2030 Agenda, especially with the goals of SDG 7, correlated with SDGs 9 and 13 and the NDC goals; ii) the innovation model does not contemplate open innovation, to take better advantage of the innovation potentials in the SEB; iii) the cost-benefit relationship or the impact of the program throughout the 21 years of existence is not proven (ANEEL, 2020b; IPEA, 2019; De Castro *et al.*, 2015; Cabanes, 2016; Chesbrough, 2003, 2010).

The EEP presented results aligned with the goals of Agenda 2030, both in the targets of SDG 7, correlated

with SDGs 9 and 13, and with the goals of Brazil's NDC, along with the Paris Agreement.

The R&DP projects are concentrated in the products: i) Concept or Methodology; ii) System; and iii) Software, which accounts for 76.67% in the period 2017 to 2019, against 53.54% in the period 2008 to 2016. The products generated in R&DP, when they reach the market and are associated with the supplies made by the international supply chain of inputs for the SEB, contribute to the EEP by providing process innovation, which meets the goals of energy efficiency: reduction of energy consumed, investments and environmental impact of the sector.

As for the financing sources of the SEB's innovation PPs, one can infer that it is one of the few programs with guaranteed resources through the R&DP and EEP since the resources for these programs have not been affected by contingencies from the national treasury (ANEEL, 2016, 2020b). This research has shown that there are other lines of credit available for RD&I in SEB, both at the National Bank for Economic and Social Development (BNDES) and the Study and Project Financing Agency (FINEP), either through non-reimbursable and reimbursable resources (BNDES, 2020; FINEP, 2020).

One of the limitations of this study was not dealing with tariff moderation. This is one of the goals of the RD&I of the SEB, and is aligned with Agenda 2030, SDG 7 - target 7.1 "by 2030, ensure universal, reliable, modern and affordable access to energy services", which due to its extent and importance will be presented in another article in the sequence (IPEA, 2019, p. 5).

It remains as a suggestion for future research the indications made by the FBMC (2018) to the Federal Government so that the SEB could meet the commitments signed in Brazil's NDC. This study did not identify actions in the innovation PPs of the SEB to i) expand centralized electricity generation from renewable sources, both centralized and distributed, in the interconnected system and isolated systems, as well as energy storage capacity; ii) repowering of hydroelectric plants; and iii) expansion of renewable energy in isolated locations (FBMC, 2018). All three indications have the potential to reduce the SEB's environmental impact and thus increase the sector's convergence with the 2030 Agenda.

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