Renewable and Sustainable Energy Reviews 162 (2022) 112449

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Influence of public policies on the diffusion of wind and solar PV sources in Brazil and the possible effects of COVID-19

Evaldo Costa [a,*], Ana Carolina Rodrigues Teixeira [b], Suellen Caroline Silva Costa [c], Flavia L. Consoni [d]

[a] Instituto Universitário de Lisboa (ISCTE-IUL), Centro de Estudos Sobre a Mudança Socioeconómica e o Território, Lisboa, Portugal
[b] University of São Paulo, Sao Paulo, Brazil
[c] Pontifical Catholic University of Minas Gerais, Belo Horizonte, Minas Gerais, Brazil
[d] University of Campinas (UNICAMP), Sao Paulo, Brazil

A R T I C L E I N F O

Keywords:
Solar PV
Wind power
Public policy
Renewable energy
COVID-19
Brazilian electricity grid

A B S T R A C T

Renewable energy is crucial to achieving carbon neutrality and supporting sustainable development, but its success depends on effective policies. This study aims to evaluate public policies and their influences on the use and diffusion of wind and solar PV into the Brazilian electricity grid and to understand if, and how, the two renewable sources could be affected by the post-COVID-19 pandemic scenario. This work plays an important role in the decarbonization of the electricity sector, highlights the need to modernize the Brazilian industrial park, and addresses new barriers to the development of renewable sources in the country. To carry out the analysis and answer the research questions, a mixed methodological approach was adopted covering the quantitative and qualitative aspects, led by a rigorous systematic review of the literature and semi-structured interviews with Brazilian stakeholders. The results revealed that 1/4 of the policies, characterized by socio-economic drives, were responsible for the growth of the share of wind and solar PV supply in the electrical mix, contributing to the decarbonization of the Brazilian energy mix. The results also suggest that new policies will be needed to ensure a greater presence of both sources in the electricity mix. The findings of the study reveal unpublished and valuable information capable of supporting policymakers and stakeholders in the diffusion of renewable sources. Further studies are needed to highlight other aspects, such as the need to modernize the "distribution" network and storage system for renewable technologies.

1. Introduction

Renewable energy sources (RES), such as wind and solar PV, need on public policies to overcome barriers to market diffusion [1,2]. Among the main mechanisms for expanding the market for both wind and solar PV sources is the favorable return on investment [3]. When drawing up the investment plan for wind and solar PV generation, policies should ensure transparent information for stakeholders to allows for an accurate assessment of attributes such as system integration costs, infrastructure-related costs in addition to other fixed and variable costs,

Abbreviations: ANEEL, Brazilian Electricity Regulatory Agency; BNDES, National Bank for Economic and Social Development; CAPEX, Capital Expenditure; CDC, Direct Consumer Credit; CDE, Energy Development Account; COFINS, Contribution for Social Security Financing; CONFAZ, Brazilian National Finance Policy Council; DG, Distributed Generation; EEAL, Use of Electric Energy in the Legal Amazon; ERN, Energy in the Northeast Region; FINEP, Brazilian Innovation Agency; GHG, Greenhouse Gases; ICMS, Tax on the Circulation of Goods; LPT, Light for All Program; MMDEE, Incentive Program for Distributed Micro-Mini Generation; NDC, Nationally Determined Contribution; NGO, Non-government Organization; PADIS, Support Program for the Technological Development of the Semiconductor Industry; PASEP, Public Service Employee Savings Program; PDG, Global Spending Program; PEC, Citizen Energy Programs; PEEAC, Emergency and Exceptional Support Program for Concessionaires of Public Electricity Distribution Services; PIS, Social Integration Program; PMCMV, My House, My Life Program; PNMC, The National Policy on Climate Change; PNUA, National Program for Universal Access; PRODEEM, State and Municipal Energy Development Program; PROINFA, Incentive Program for Alternative Sources of Electric Energy; PRONAF, National Program for Strengthening Family Farming; PV, Solar Photovoltaic; R&D, Research and Development; REIDI, Incentive Regime for Infrastructure Development; RES, Renewable Energy Sources; SHP, Small Hydroelectric Plants; TUSD, Tariff for the Use of Distribution Systems; TUST, Tariff for the Use of Transmission Systems.

* Corresponding author.
E-mail addresses: ev.costa@outlook.com, Jose.Costa@iscte-iul.pt (E. Costa).

https://doi.org/10.1016/j.rser.2022.112449
Received 24 December 2021; Received in revised form 9 March 2022; Accepted 5 April 2022
Available online 12 April 2022

and operational risks [4]. Therefore, policies should address techno-socio-economic aspects encompassing (i) technological substitution (disruptive innovations); (ii) necessary changes when the innovations are not sufficiently developed; (iii) reconfiguration incorporating innovations; (iv) misalignment and realignment when the regime is destabilized [5], especially when considering different technology pathways towards investing in the expansion of the renewable energy sources (RES) in the electricity sector.

The proliferation of RES in Brazil has been taking place due to several factors. Public policies, as occur in other Latin-American countries [6,7] have a positive and significant effect to encourage the expansion of RES. Besides, the attractive value of the electricity tariff, which on average increased by about 30% between 2015 and 2019 [8], and the natural resources favorable to the diffusion of renewable energy [9], such as constant winds from the Atlantic Ocean, a many hours of sunshine fill the positive aspects. It is not by coincidence that the country has a predominantly clean electricity mix – dominated by hydro generation (65%) – in which RES represent around 83% of the country's internal electricity supply [9]. Among the benefits of these two renewable sources, the environmental aspects stand-out [10], such as the mitigation of greenhouse gas (GHG) emissions recognized as one of the major problems of the country [11]. Therefore, the increase in wind and solar PV sources should provide a better balance in the mix of RES in electrical network, contributing to support the expansion of electric mobility, and the GHG emissions mitigation [12].

The challenges for the diffusion of wind and solar PV sources in Brazil, such as the lack of infrastructure, high import costs due to low internal "production" of equipment, the inefficiency of logistics, and limiting operating conditions [13,14]. All these factors limit the expansion of the domestic supply of electricity from solar PV sources (around 1%), and wind (around 8%), in 2019 [9]. Another deadlock is associated with competition from power generation systems that are predominant in the Brazilian electrical matrix (hydroelectric and thermoelectric). In Brazil, most of the electricity "production" comes from the complementarity system between hydroelectric and thermoelectric, so that in dry periods there is greater "production" by thermoelectric plants. Although, the diversification of the electrical matrix would allow for greater security in the system, which could reduce the probability of energy crises, a current scenario in the country that has been facing uncertainties regarding energy supply due to the low historical levels of the reservoirs [15].

From the electrical system perspective, wind and solar PV sources, has been finding support in a set of policies such as The National Policy on Climate Change (PNMC) and Nationally Determined Contribution (NDC) to the Paris Agreement sets goals to increase the share of non-hydro renewable sources, mainly wind and solar PV, to a minimum of 23% of the national energy supply, as well as the reduction of its GHG emissions by 37% below the levels of 2005 until 2025, and 43% below from 2005 to 2030 [15]; set the tone for other policies, such as (i) Incentive Program for Distributed Micro-Mini generation (MMDEEE); (ii) Auctions to regulate the "commercialization" of energy and encourage the installation of plants, contracting and supply of renewable energy; (iii) Incentive Program for Alternative Sources of Electric Energy ("Programa de Incentivo às Fontes Alternativas de Energia Elétrica" – PROINFA).

Besides that, the fall in the values of equipment (solar PV module prices have fallen by around 90% since the end of 2009, and wind turbine prices have fallen by around 60% since 2010 [16]) contributed to the expansion of the two renewable sources in Brazil. In 2010, there were around 200 wind energy power plants (public service + self-production) generating around 2,700 GWh in the country. In 2020, this number surpassed 4,900 units, generating more than 57,000 GWh, a growth of almost 2,500% in the number of power plants in just a decade [17]. Despite that, there is the COVID-19 pandemic that may or may not impact renewable sources. Globally, the results of the first year of COVID-19 (2020) reveal the resilience of renewables, with a growth of almost 50% compared to 2019. In 2020, solar PV energy grew by around 22% and wind energy almost doubled its growth compared to 2019, but the pandemic situation generates uncertainties and requires vigilance.

Within this framework, this study aims to evaluate public policies and their influences on the use and diffusion of renewable sources (wind and solar PV) into the Brazilian electricity grid and to understand if, and how, the two renewable sources could be affected by the COVID-19 pandemic. The analysis concentrates to answer the questions (i) Which policies contributed to the most to the expansion of the use of wind and solar PV sources for electric power generation? (ii) Could, and how, the COVID-19 pandemic affects the expansion of wind and solar photovoltaic in the country? This study is based on a systematic review of the public policies developed in Brazil regarding the RES (wind and solar PV), its connections in electricity network, interviews with stakeholders to evaluate the main public policies in this area and possible interference from the COVID-19 pandemic in RES.

The next section presents the main public policies implemented since 2000 that may have encouraged the use of wind and solar PV sources in Brazil. The third section describes the methodology used, detailing how the interviews were conducted and how the data were collected and analyzed. The fourth section is dedicated to sharing the results of the study. The fifth and last section refer to the conclusions, addressing the limitations of the research and a set of recommendations for future studies.

2. Background

In the early 2000s, Brazil experienced an energy crisis, making it necessary to apply stringent measures of the electric power rationing. This occurred due to the increased demand for electricity, while the energy "production" by hydroelectric plants, including during dry periods, remained the same. Due to this deadlock and the concern with the country's energy security, discussions were initiated aiming to identify and elaborate government actions that could promote the diversification of the national electrical matrix.

However, in the early years of this program, a modest increase in the installed power of wind plants was observed, which can be justified due to the need of importation of the technologies, in addition to the relatively high investment cost [16]. The adoption of energy generation systems such as wind power and PV in Brazil is seen as attractive, due to the high levels of solar irradiance throughout its territory and high wind variability, especially in the Northeast and South regions of the country, reaching values in around 8.22 m/s [17–19], attractive to centralized and decentralized production systems.

Centralized generation systems (CG) are characterized by large electricity "production" plants (mostly hydroelectric or thermoelectric plants), usually located far from large "consumption" centers, being dependent on "transmission" lines. While for the distributed generation (DG), the electricity generation is carried out together or near to the consumer from renewable sources or qualified co-generation, being able to supply the surplus to the local "distribution" network. In this scenario, considering the abundance of natural resources for the application of photovoltaic and wind systems and the need to insert new generation systems into the electrical matrix, some incentive measures for the insertion of energy generation systems that use renewable energy as a primary source were created by Brazilian government, among this is the PROINFA created in 2002 [20], and modified in 2003 [21], being the first incentive program for grid-connected systems in Latin America [22,23]. PROINFA aims to increase the share of alternative renewable sources, such as small hydroelectric plants, wind, and biomass thermoelectric plants (not covering photovoltaic systems), in the "production" of electricity, favoring investors without a relationship with the electric utilities [24].

In 2003, it was created the National Program for Universal Access and Use of Electrical Network ("*Programa Nacional de Universalização de Acesso e Uso da Rede Elétrica* – LPT)", better known as the Light for All

Program ("*Programa Luz para Todos*"), aiming the rural electrification in isolated communities, no access to electricity from the utility, where the long distances made extending the electricity grid unfeasible [25–27]. In the first moment, a deadline was established until 2008 for serving households without electrification, but during the execution of the LPT was identified a larger number of households should be included in the program, resulting in its extension until 2022 [28–33]. Data indicate that more than 3 million consumer units located in rural regions in Brazil were served by the LPT, with a greater number in the North and Northeast regions due to lower rates of rural electrification. Of the systems installed by LPT, more than 6 thousand installed systems were isolated PV and 19 collective PV systems [34]. Several central government actions can promote incentives for the use of renewable sources for electricity generation, as auctions, quotas, direct subsidies, tax reductions, and tariff compensation system [35].

In 2004, Brazil's electric energy market was reformed through the Law 10,848/2004 [23,24] creating the contracting for "energy auctions". The auctions can be considered as one of the primary policy instruments for expanding and diversifying the renewable power supply in Brazil [16,36]. The Brazilian market reform of 2005 introduced several types of energy contract auctions such as (i) existing energy auctions, (ii) new energy auctions, and (iii) alternative source auctions, this being common for both types' plants, existing or new [37]. There are also the reserve auctions that are held sporadically to contract reserve capacity, to increase the security of supply of the Brazilian electricity system. This type of auction has been extensively used to promote renewable energy in the country, being used by the government for the first time in 2008 to contract new energy from the co-generation of sugarcane bagasse, in 2009 to contract wind power was carried out, and then, in 2014 to contract solar PV power [36–39].

In 2007, the PIS/PASEP and COFINS charge on goods and services levied on energy projects, including wind and solar PV plants, were suspended, being this incentive called the Special Incentive Regime for Infrastructure Development (REIDI) [55,56]. In the same year, the Support Program for the Technological Development of the Semiconductor Industry (PADIS) was created and regulated as a set of federal fiscal incentives aimed at contributing to the attraction of investments in the semiconductor areas, benefiting the solar PV industries [57–59]. In Brazil, the companies must make transfers to the government referring to tax contributions called the Social Integration Program (PIS), Public Service Employee Savings Program (PASEP), and Contribution for Social Security Financing (COFINS), being used in the fund for worker support and Brazilian social security.

In 2011, an important economic incentive for research and development (R&D) of solar PV energy in Brazil was launched through the Strategic Call for R&D nº 13 (Call 13/2011) of the regulatory agency, Brazilian Electricity Regulatory Agency ("*Agência Nacional de Energia Elétrica* – ANEEL"). This Call aimed to propose technical and commercial arrangements for solar PV generation, encouraging the insertion of this technology in the Brazilian electrical matrix. This Call mobilized 17 companies, including electric utilities and the oil industry, which registered strategic projects which presented data related to the analysis of technologies for electricity generation in the country, potential impacts on the electricity network and studies regarding the most suitable locations for the installation of PV plants considering solar irradiance levels [40].

In 2012, the ANEEL published the Normative Resolution 482 which officialized the compensation system for micro ($\leq$75 kW) and mini ($>$75 kW and $\leq$5 MW) distributed generation (DG) that uses qualified co-generation or renewable sources, the net-metering system, allowing the system owner to inject excess energy into the electrical network, obtaining energy credits (measured in kWh, non-monetary) that can be used until 60 months [41,42]. This resolution is considered a regulation mark for distributed generation of solar PV energy in Brazil.

Among the incentives for the expansion of electric energy generation systems that use renewable energies as a primary source is the adequate availability of financing, aiming to support enterprises and "production" chains more independently of the fluctuation of international prices [16]. The Brazilian National Bank for Economic and Social Development ("*Banco Nacional de Desenvolvimento Econômico e Social – BNDES*") can be considered as the main institution responsible for providing public funding to support wind and solar PV plants, but the rigid process for obtaining loans, the lack of specific financing line for DG and the increased demand for loans, have driven the emergence of new financiers to attend the demand of investors [13,43,44]. Construcard is the financing line provided by "*Caixa Econômica Federal*", which is a financial institution in the form of a public company, which aims to provide subsidies for the purchase of materials, including wind turbines and components of PV systems, which can be used for residential applications (DG) by investors classified as a physical person [45]. Like this one, there is the Direct Consumer Credit ("*Crédito Direto ao Consumidor* – CDC") of the private bank, such as Santander aimed at installing PV systems in residence and small businesses [46].

There is also the FNE SOL Program created by Northeast Bank ("*Banco do Nordeste*"), which aims to contribute to the environmental sustainability of the energy matrix of part of the State of Minas Gerais and Northeast of Brazil, offering credit lines for micro and mini-generation distributed from renewable sources, for self-consumption or intended for lease, provided at companies (legal entities), rural producers and physical person [47]. Unlike other financing lines, it is important to highlight the existence of the "*Inova Energia*" Program that was created with the aim of supporting actions to foster innovation and improve the integration of support instruments provided by FINEP (Brazilian Innovation Agency), BNDES, and ANEEL. Thus, "Inova" provides financial support to Brazilian companies for the development and technological mastery of "production" chains of the following renewable energies such as solar PV, thermosolar, and wind for electricity generation [48].

Besides that, the fiscal incentives deserve to be highlighted, among the main ones are the discounts on the Tariff for the Use of Transmission Systems (TUST) and on the Tariff for the Use of Distribution Systems (TUSD); and the Brazilian National Finance Policy Council (CONFAZ) [49]. Hydroelectric, solar PV, wind, biomass, or qualified co-generation projects with a power of up to 30,000 kW could have a reduction of 50% to be applied to TUST and TUSD, focusing on the "production" and "consumption" of energy sold or destined for self-production [21,50,51]. However, the policy that establishes this incentive was changed after the Law 14,120, establishing that this discount will prevail for (i) existing projects granted until the end of its term; (ii) new projects only to those who request authorization or expansion of their generation capacity within 12 months after the publication of this law, and start the operation of all their generating units within 48 months, and (iii) new projects of hydroelectric generation with an installed capacity of up to 30 MW, maintaining discounts at 50% for five additional years and at 25% for another five years from the date of publication of the law [52].

In 2015, the PIS/PASEP and COFINS rates levied on energy supplied by the electric utilities related to net-metering were reduced to zero. Besides that, the States had the option to exempt ICMS on transactions related to the circulation of electric energy, subject to billing under the net-metering system [53]. The fact is that the set of policies aimed at the solar PV source was decisive in boosting investments in this type of renewable source.

In 2018, covenant 101 was published can also be considered an important fiscal incentive as it exempts the incidence of the tax on the circulation of goods and services (ICMS) – a tax levied on various products, regardless of national or imported – intended for the electricity generation by PV cells and by wind projects [49].

In 2020, there were almost 1,000 plants, mainly in the Northeast and Southeast regions of Brazil, generating around 11,000 GWh [9], and PV solar source should increase its contribution in the coming years, to reach 5% of the total electricity generation in 2030" [54], but the changes arising from Law 14,120/2020, especially the part that withdraws the TUST and TUSD discounts, may impact future plant installation. Besides that, COVID-19 viral pandemic is a global phenomenon that has caused much concern since March 11, 2020, when the World Health Organization (WHO) declared the novel coronavirus (COVID-19) to have emerged in Wuhan, China, as a pandemic [55], on December 31, 2020, accounted for around 83 million confirmed cases of the disease, and almost 2 million deaths (around 283 deaths per million people) with the pandemic situation quickly spread to other continents taking global proportions [56]. The pandemic framework quickly revealed itself with the potential to trigger an unprecedented cross-border economic disaster, as it threatened disruptions to supply chains, affecting industry, energy sector and destroy the main pillars supporting the economies of the modern world [57]. The economic damage to the pandemic is still being determined, as the virus requires constant attention from the public power to avoid worsening supply to populations and even greater socioeconomic damage.

On December 31, 2020, there were about almost 8 million confirmed cases of COVID-19, and around 640 thousand deaths (around 911 deaths per million people), in Brazil [56]. The effects of the pandemic are largely impacting the Brazilian economy, which has experienced the biggest drop in GDP (−4.1% in 2020) in recent history. In addition, the indicators reveal lower employment levels compared to the pre-pandemic period, less access to technology, and increased inequality between families [58]. Solar and wind sources, the COVID-19 pandemic has not proved to be an obstacle to the expansion of the two renewable sources, especially in the electricity sector, where market share continues to increase. In 2020, wind and solar sources increased by 7.6% reaching 11.5% of share in the Internal Electricity Supply [9]. The growth of the two RES is due to the investments made before the pandemic as well as their attractiveness for new investments, but the post-pandemic situation reveals uncertainties and requires constant monitoring by governments.

3. Methodology

This section was performed considering a parallel study between public policies, and data from interviews conducted with qualified professionals in the solar PV and wind fields.

3.1. Overview

To evaluate public policies and their influence on the use and diffusion of renewable sources (wind and solar PV) into the electricity grid in Brazil, the methodological approach was separated into two parts 1) data acquisition from the energy "production" and auctions developed in the period analyzed; and 2) a systematic review considering the legislation applied to the country, and interviews with stakeholders to evaluate the main national policies and programs related to the RES in Brazil and the impacts due to the COVID-19 pandemic.

First, a systematic review of the policies guided from national legislation was performed to identify the regulation applied in the country, considering the period from 2000 to 2020, and to understand its evolution through the years and the relationship between the policies and data from energy "production" and auctions. This information was sought manually in the Brazilian Federal Legislation directory from December 10th to 20th, 2020. To search and select the information, keywords in Portuguese were used, which were: "*energia*" (energy), "*eolica*" (wind), solar, "*fotovoltaica*" (PV), and "*renovavel*" (renewable).

The limits of this research include only the policies applied to wind and solar photovoltaic sources by types of policies (Table 1) from "production" to "consumption" according to Fig. 1 and Appendix B. The choice for the type of politics, grouping and analysis by segment of "transmission", "distribution", "commercialization", and "consumption" was due to the high relevance of these attributes in the RES activities. In addition, these attributes are widely explored for analysis of the energy sector, specially by the Brazilian Energy Research Corporation (EPE).

Table 1
Overview of the types of policies analyzed.

Area	Objective
Production	Aimed at supporting the production of energy from renewable sources
Transmission	Intended to support electricity transmission services and infrastructure
Distribution	Aims to support the distribution of electricity
Commercialization	Aims to support the commercialization of energy
Consumption	Policies to reduce energy consumption and changes in energy prices
Other	Other policies regarding environment measures, research and development, creation of council and commissions, and creation of programs

Data extraction and compilation were performed using a spreadsheet.

Second, interviews enabled us to identify three aspects, a) critical factors and opportunities for the diffusion of wind power and solar PV in Brazil; b) mechanisms, in the COVID-19 scenario, that can affect the use and generation of RES sources in the country; c) identify the most important policies, according to the stakeholders' perception, for the diffusion of both wind and solar PV sources in Brazil. Thus, it will be possible to identify specific elements that may have an impact on the production and consumption of the two renewable sources in the post-COVID-19 pandemic period, not revealed in the literature review, as well as the policies that contributed most to the expansion of wind and solar sources from the point of stakeholder view. A qualitative research method with semi-structured techniques using the approach of grounded theory analysis was selected and tested before real interviews applications (the interview material is available in Appendix A). Forty-nine stakeholders were selected and approached by e-mail (whom to the best of the knowledge include all stakeholders in this field in Brazil), working for the government, private companies, academia, non-government organization (NGO), associations and unions, suppliers, and retailers, investors, and advisory companies. Sixteen stakeholders, around 33%, were interviewed. The interviews were performed by video conference in the period from May 11, 2021, to June 11, 2021, and lasted around 60 min on average.

The qualitative method, instead of the quantitative research, identifying critical factors and opportunities for RES under the COVID-19 pandemic scenario, was chosen because it best meets the characteristics of the research. To build a quantitative questionnaire, it is necessary to have already an established theory. Regarding the proposed research (understanding the impacts of the COVID-19 pandemic on RES), research is at an early stage because the pandemic is an incipient event. Furthermore, qualitative research allows for more depth and possibilities of perception of the investigated issues, e.g., during interviews researchers have the flexibility to explore certain topics in-depth, extracting more information from the interviewees.

The choice of semi-structured techniques occurred because it was the most effective one to achieve the objective of the study. It is an easy technique to apply, and it provides many benefits for the interviewee and interviewer. Among the main advantages in using semi-structured techniques, are a large amount of detail generated; relatively flexible and sensitive; interviewers can prepare questions beforehand to help guide the conversation; allows for open-ended responses for more in-depth information; encourages two-way communication, and it is reliable and easy to analyze. However, some disadvantages need to be overcome, such as the cause, and effect cannot be inferred; flexibility of interview may lessen reliability, and open-ended questions are difficult to analyze [59]. The methodology scheme used in this work is shown in Fig. 2.

3.2. Recruitment

To identify stakeholders, a search was carried out on public, private

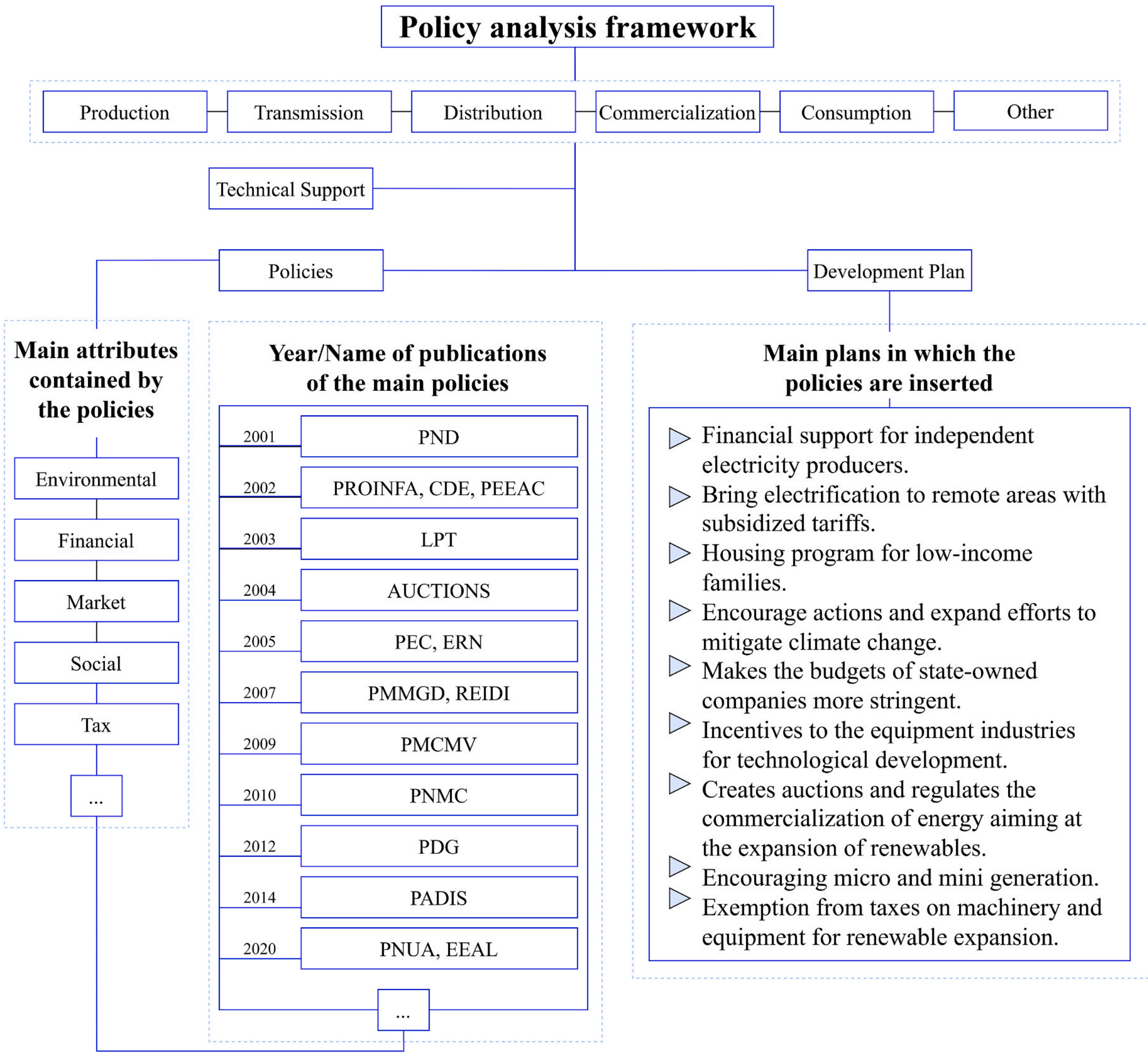

Fig. 1. Scheme of the Brazilian policy analysis framework (2000–2020).

and non-profit sector databases related to RES activities. The interview's location was all Brazilian territory since they were by virtual interactions. Respondents were recruited by e-mail, telephone, and through entities with a direct connection with the sectors of RES. Guests received a minimum of three contacts – one to forward the invitation letter and a minimum of two additional follow-up contacts. Those who accepted the interview invitation received a minimum of three additional contacts – an email thanking him/her for accepting the invitation and requesting information about interview preferences; another one to confirm the appointment of the interview, and forwarding the interview connection link; finally, an e-mail reminder.

In the preparatory phase of the study, it was expected that the number of interviews would be between 25% and 45% of the guests. Therefore, 33% of the sample, considering they are very busy professionals in a limited context of stakeholders, is representative and compatible with other qualitative studies [60–65].

3.3. Sample characterization

Although most wind and solar PV sources are dominant in the Northeast and Southeast of Brazil, most interviewees were based in São Paulo (31%), the country's main financial and business city, and Brasília (25%), the capital of Brazil, and the center of political decisions. The others were in Rio de Janeiro (19%), Minas Gerais (19%) and Fortaleza (6%), concentrating the largest participation of stakeholders located in the Southeast region. Most interviewees are men (87%). The majority held highly prestigious positions such as President (56%) or Executive Director (19%), as well as Professor and Researcher (13%), Global Manager (6%) and Specialist in Regulators (6%) as shown in Table 2.

3.4. Questionnaire of survey

The selection of topics and organization of the questionnaire was decided after the identification of the main policies performed in the literature review. Then, to identify the main mechanisms capable of impacting the expansion of RES, a database of the government and organizations representing the interests of RES was used. The questionnaire mixed scale and open-ended questions and sorted into three sections (1) specific aspect of policies that consists of sixteen questions; (2) mechanisms and general aspects of policies that consists of twenty-three questions; and (3) possible impacts of COVID-19 pandemic that consists of eight questions. All sections considered were applied for solar PV and wind separately, since there are policies that cover both and other that covers each one individually. To quantify each aspect, a 6-point Likert scale was used for the questions, which the researcher asked the respondent to rate from zero to five – zero, the policy (or mechanism), was not important for the diffusion of both wind and solar PV power, and five it was extremely important for the diffusion of both

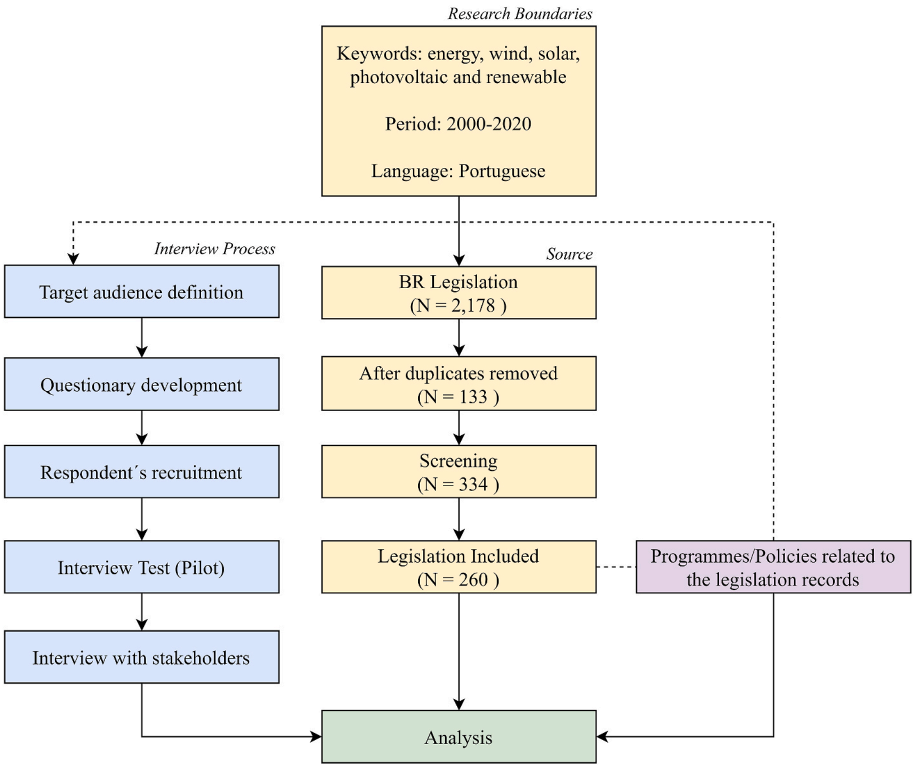

Fig. 2. Methodology flowchart.

Table 2
Respondent's profile – Interviews performed in the period from May 11, 2021, to June 11, 2021.

Interviewed	Place	Sector	Title	Gender
1	Brasília	Regulatory body	President	Male
2	Brasília	Regulatory body	Regulation expert	Male
3	Brasília	Representative body	President	Male
4	Brasília	Representative body	President	Male
5	Fortaleza	Representative body	President	Male
6	Minas Gerais	Education Research	Professor	Female
7	Minas Gerais	Service	Director	Male
8	Minas Gerais	Service	Director	Male
9	Rio de Janeiro	Education Research	Professor	Male
10	Rio de Janeiro	Education Research	Director	Male
11	Rio de Janeiro	Service	President	Male
12	Sao Paulo	Industry	President	Male
13	Sao Paulo	Industry	Global manager	Male
14	Sao Paulo	Representative body	President	Male
15	Sao Paulo	Service	President	Female
16	Sao Paulo	Service	President	Male

PV and wind technologies.

3.5. Interview procedure

All interviews were undertaken by the same interviewer to prevent any inter-interviewer variability. Firstly, the researcher asked the interviewees' personal information, such as position, name of his/her organization, sector of activity, and workplace. This allowed an understanding of the interviewees' socio-demographic status. After that, the interviewee was asked to evaluate the main wind and solar PV energy policies. Open-ended questions were applied at the end of each section to maintain consistency with the topic at hand.

3.6. Grounded theory analysis

Grounded theory is a relatively recent systematic methodological approach to data collection. It is an "inductive method of theoretical development" that favors the use of an abstract heuristic process [66] to provide consistency in the systematic collection and analysis of data [67]. Grounded theory favors new insights and the possibility of developing new elements that complement the exploratory nature of the research towards a detailed understanding [66] of the energy sector. The main benefit of adopting the Grounded theory, is that the results can more accurately represent real-world phenomena. The method allows underlying issues to arise without being influenced by the researcher, so new information can arise spontaneously, without any bias. Grounded theory is widely used in various fields of science, including the energy sector [68,69].

4. Results

This section indicates the results from the systematic review, showing the evolution of Brazilian public policies over the years, and results from interviews with stakeholders. The review was base to build the questionnaire, which was applied in the interview with stakeholders. The last one helped to confirm the evidence found in the review process and report potential steps to wind power and PV diffusion post-COVID-19 pandemic period.

4.1. Systematic review analysis

The systematic review about the public policies developed from 2000 to 2010 in Brazil to support renewable sources (wind, and solar PV), resulted in 260 analyzed policies. It is important to highlight that several of the public policies were updated over the years, contributing to this elevated number. 25 relating to wind energy, 20 relating to solar PV, 234 relating to solar photovoltaic energy also included wind, 239 relating to wind energy also covered solar photovoltaic energy. There were 40 policies classified as alternative energy, but only one case referred to alternative energy (without considering the terms wind or solar PV). The analysis of policies by status reveled around 6% of the policies were revoked up to the end of our analysis due to the need for a regimental update, as show in Fig. 3.

The analysis between wind and solar PV policies did not reveal significant differences in the number of policies aimed at each of them. The analysis shows concentration (around ¾) in two categories: "transmission", and "others" (Fig. 4). This revealed a coherence with investments in renewables generation, since only the modernization, expansion, and maintenance of the "transmission" network can guarantee the delivery from "production" to "consumption" places. Only 7% of policies were to "production". It may seem like inattention of policymakers towards the sector, but here the logic is different, as most of the policies for "production" were aimed at holding "auctions" with a large investment capacity per policy, hence you don't need many policies to ensure satisfactory results. Policies aimed at "consumption" areas represent around 4% of both sources, suggesting greater attention from the policymakers to fill this gap, as shown in Fig. 4. Policies classified as "others" also revealed connections with the other analyzed sectors, with more than 50% destined for "production" and "transmission" (Fig. 5). That is, in addition to the "transmission" sector having led in a number of policies, they were also strongly contemplated with policies for other sectors to guarantee the delivery of "production" to consumer.

4.1.1. *Analysis of wind and solar PV source by geographic location and auctions' policy*

The Fig. 6 shows the data from installed power (centralized and distributed generation) for wind and solar PV, and the investments for these respective sources through auctions in Brazil from 2010 to 2020.

Both wind and solar PV sources received public policy support for their development in different period, but both became more consistent in the second half of the 2010 decade. The first wind plants were installed in mid-2006 and can be associated with the incentives. However, it is possible to notice that the annual installed power increased significantly after the first auctions, which demonstrates the impact of auctions in the scenario of insertion of renewable sources.

In the case of wind power, the auctions started in 2009 [38], encouraging the diffusion of this renewable energy in Brazil as can be seen in Fig. 6 (on the left). The power is prevalent in Northeast and South regions in Brazil, mainly due to the characteristics favoring the highest wind speed, as previously mentioned [17]. In other regions, the wind speed cannot be favorable for energy generation. Other aspect important to note is that the reduction in the number of auctions in 2012, and consequently, the investments. This fact causes uncertainties in the market such as the reduction in contracts, low prices, and the Provisional Measure 579/2012 [70], which announced a reallocation of the energy already existing in the concessionaries. In the period from 2013 to 2015, there was another drop in auctions due to the falling demand for electricity. However, since 2015 there was an increase in the investments due to the "New energy auctions", intended to meet the increased load of concessionaires.

In the case of solar PV, it is possible to note that the highest power installed comes from Northeast and Southeast regions due to the highest solar irradiance [18]. However, all the Brazilian regions present favorable irradiance, which contribute to spread the PV solar over the country (Fig. 6 - right). In addition, the modular characteristic of PV solar systems makes them attractive for decentralized installation, close to consumption centers. Thus, it is noted that the participation of PV solar systems is more diversified in relation to different regions of Brazil. As mentioned before, the Normative Resolution nº 482 [41], established in 2012, represents a milestone in the Brazilian solar PV since allowed the

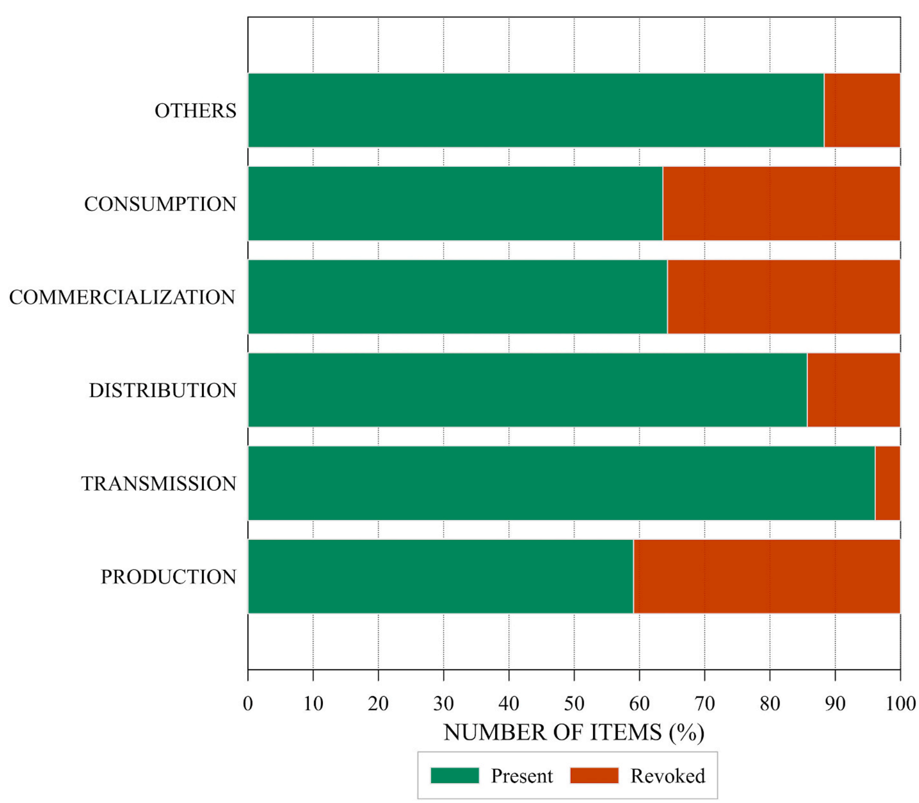

Fig. 3. Analyzed policies status by type (2000–2010).

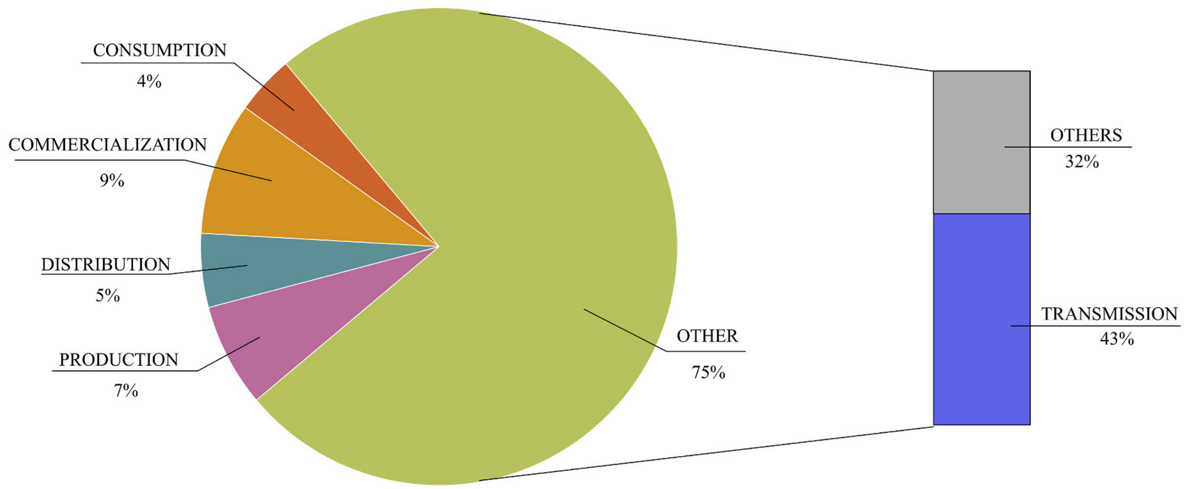

Fig. 4. Policies share by sector.

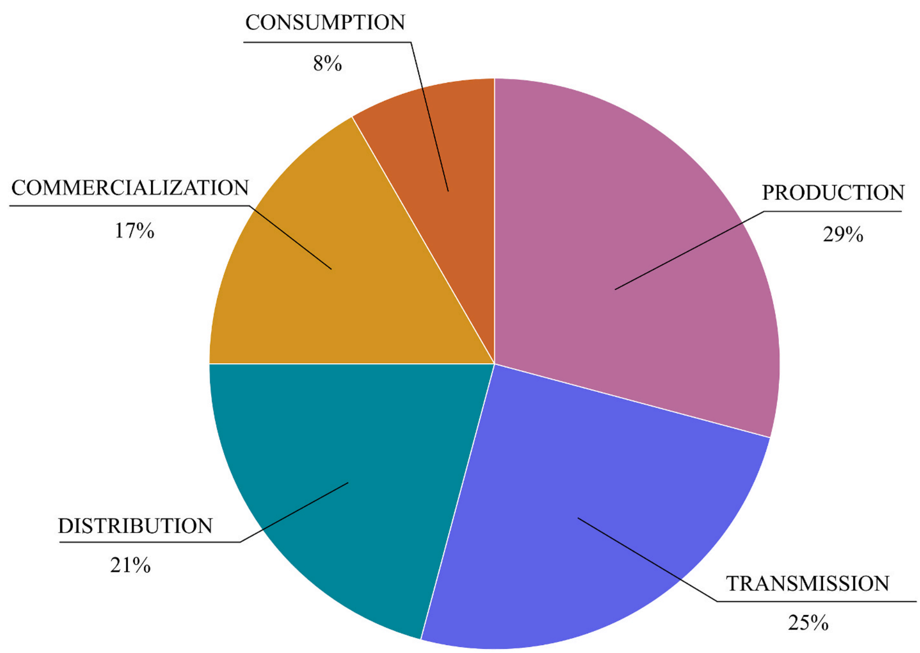

Fig. 5. Other policies connections.

consumer to generate their energy, enabled the creation of energy credit systems, and established the criteria for connecting systems to the grid. It supported the production by microgenerators and mini-generation, boosting the market and energy production. As for investments in auctions, it is possible to observe a considerable increase after 2014, which was highlighted as the first year of participation of PV solar in this public initiative, showing a decrease between the years 2016 and 2017 due to the lower number of auctions implemented in the country.

4.1.2. Analysis of wind and solar PV sources by type of policy and power generation

The public policies analyzed were clustered according to different areas: production, transmission, distribution, commercialization, consumption, and others (research and development, environment, and administrative actions). Fig. 7 shows the number of items found in the review for each encouraged areas related with power installed over the years for wind (left) and solar PV (right). It can be observed that in the period from 2000 until 2009 the number of public policies related to the transmission area increased over the years, which were essential to support the implementation of the auctions for new energy in the consecutive years. Besides, in the same period, many public policies were created aiming to address the privatization of electricity transmission projects belonging to the basic network of the National Interconnected System (SIN) and issuing concessions for the exploration of these transmission lines, impacting all existing energy generation systems in the country.

Policies related to commercialization and consumption were also more numerous before the first auctions for both sources, addressing issues of energy rates and prices, the purchase process and regulations on free consumer access to the transmission network. After the release of ANEEL's RN 482 in 2012, there was an increase in the number of politics dealing with production, as this paved the way for Brazilian consumers to generate their own electricity from sources of renewables or qualified cogeneration. In this scenario, PP has been created to regulate energy production and the energy compensation system with the utility.

In addition, policies relating to research and the environment have been launched every year after the start of auctions, aiming to promote training and improvement in terms of technology, installation,

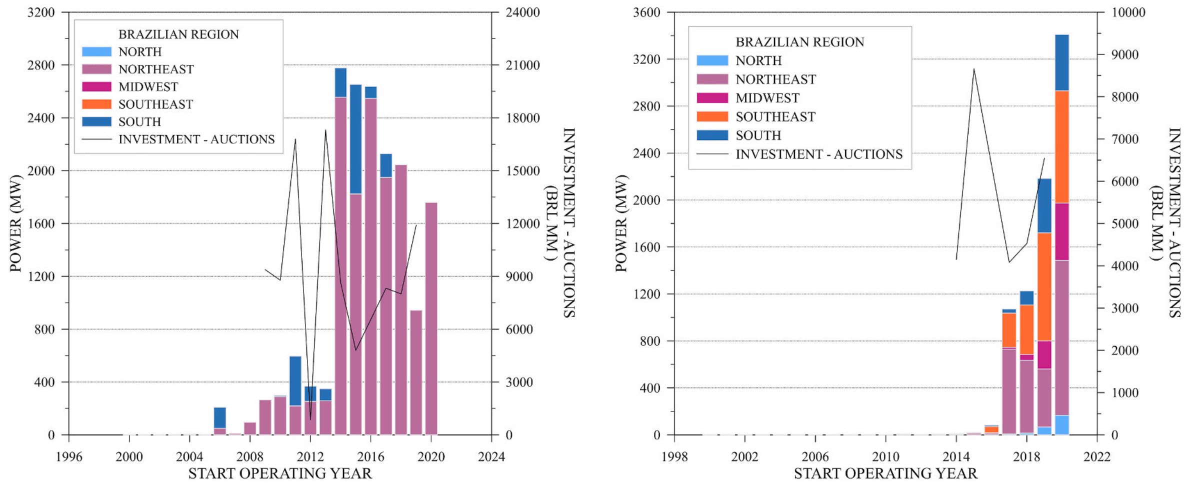

Fig. 6. Power and investments in wind sources (CG + DG) from 2000 to 2020 (left) and solar PV (right). Data from power generation (centralized and distributed generation) and investments through auctions in Brazil until 2020 - ANEEL [71].

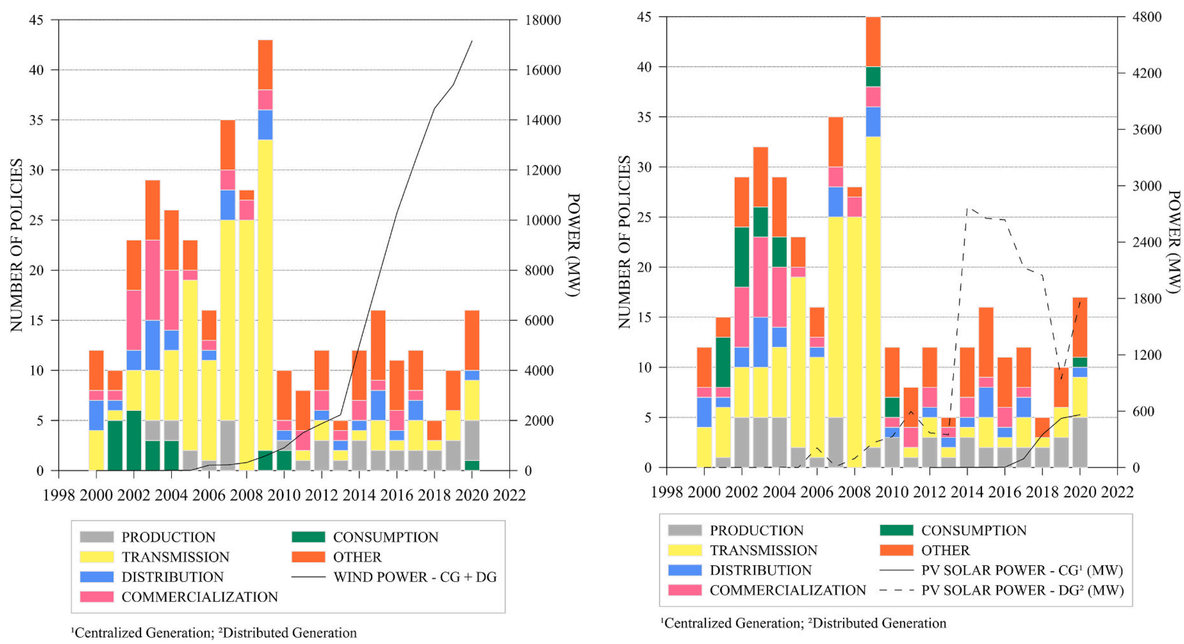

Fig. 7. Policies from wind power (left) and solar PV (right) by type and power generation.

operation and maintenance of plants, and to regulate the licensing process, environmental issues in general. It is noteworthy that in some cases, research projects financed by government institutions provide for the installation of systems that use wind and solar as the primary source for energy generation, contributing (even if in a small way) to the increase in installed power in the country.

The considerable increase in the installed power of solar PV and wind power in recent years, concentrated in the Northeast and Southeast regions of the country (Fig. 6), associated with the data indicated in Fig. 7 indicate that public policies should be created in the coming years to promote improvements in infrastructure in these regions, in order to overcome overload problems in the transmission and distribution system, not impacting the installation of centralized plants. This is an issue that has been discussed by specialists in the area, it could be an alternative to the creation of incentives through PP to expand the installation of CG in the country.

Regarding the policies adopted in Brazil to ensure net electric power capacity, the analysis revealed six policies were the more significant for the dissemination of wind and solar PV in the country (Fig. 8). The increase in the electrical capacity of wind farms between 2005 and 2007 can be attributed to PROINFA policies, which played a preponderant role in bringing electricity to remote areas of the country. The new growth peaks that took place in 2011, can be attributed to the energy "auctions" started in 2010 for the dissemination of wind energy, and in 2014 for solar PV when 109 PV projects were auctioned in Brazil (to start after 3 years).

In addition, in the period from 2013 to 2016, there was a significant increase in the growth of both sources, mainly due to policies from ANEEL (Normative Resolution No. 482/2012), which represents a milestone in the Brazilian solar PV since allowed the consumer to generate their energy, enabled the creation of energy credit systems, and established the criteria for connecting systems to the grid. It supported the "production" by microgenerators and mini-generation, boosting the market and energy "production", and refined in auctions rules. It might have powerful to allow for a reduction in the prices of technologies applied by both renewable sources and may also have contributed to

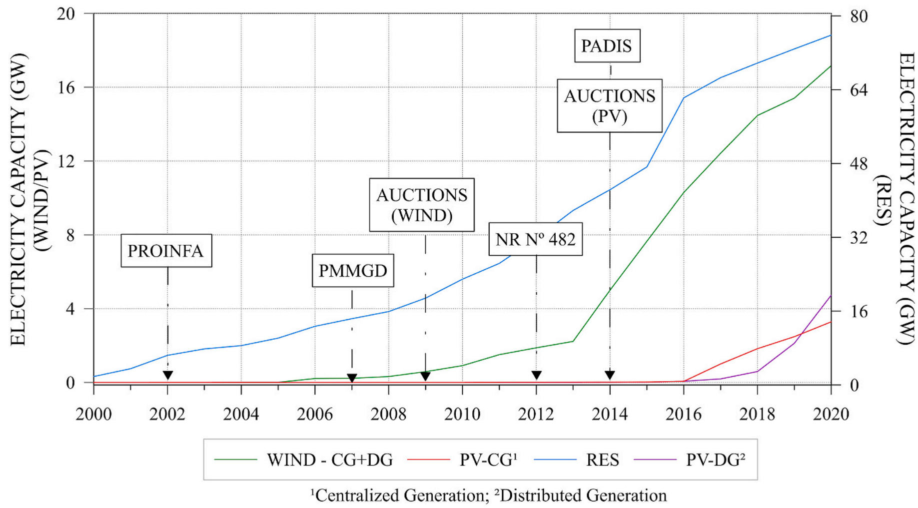

Fig. 8. Brazilian electricity capacity.

reducing the payback of investments made in solar PV and wind power plants, thus increasing the attractiveness of investments. PADIS also had a prominent role in the expansion of the renewable sources, above all for having encouraged the generation of renewable energy for independent energy producers.

Another favorable point for solar PV was that utilities, in the last 10 years, have reduced (and made more flexible) the technical conditions for distributed generation, which facilitates connections to the electricity grid and boosts the market diffusion of the renewable source. Besides that, from 2015 there was an increase of investments with respect to "Acquisition and Installation", especially the promotion of private non-profit companies dedicated to the acquisition and installation of solar PV systems. The assessment of the effects of policies on the diffusion of renewable energies were carried out by specialists through a survey and will be discussed in the next section.

4.2. Survey results: specific aspects of policies

The first section of the questionnaire, to analyze aspects of policies and mechanisms to the diffusion (in the Northeast) of wind and solar PV power, revealed that around half of the public policies played an important role in the diffusion of both technologies (Fig. 9). However, it was considered extremely significant by stakeholders. In general, the stakeholders identified "auctions", and "distributed mini and micro-generation" policies as the most important for the diffusion of both wind and solar PV sources, and "PROINFA" for the diffusion of RES.

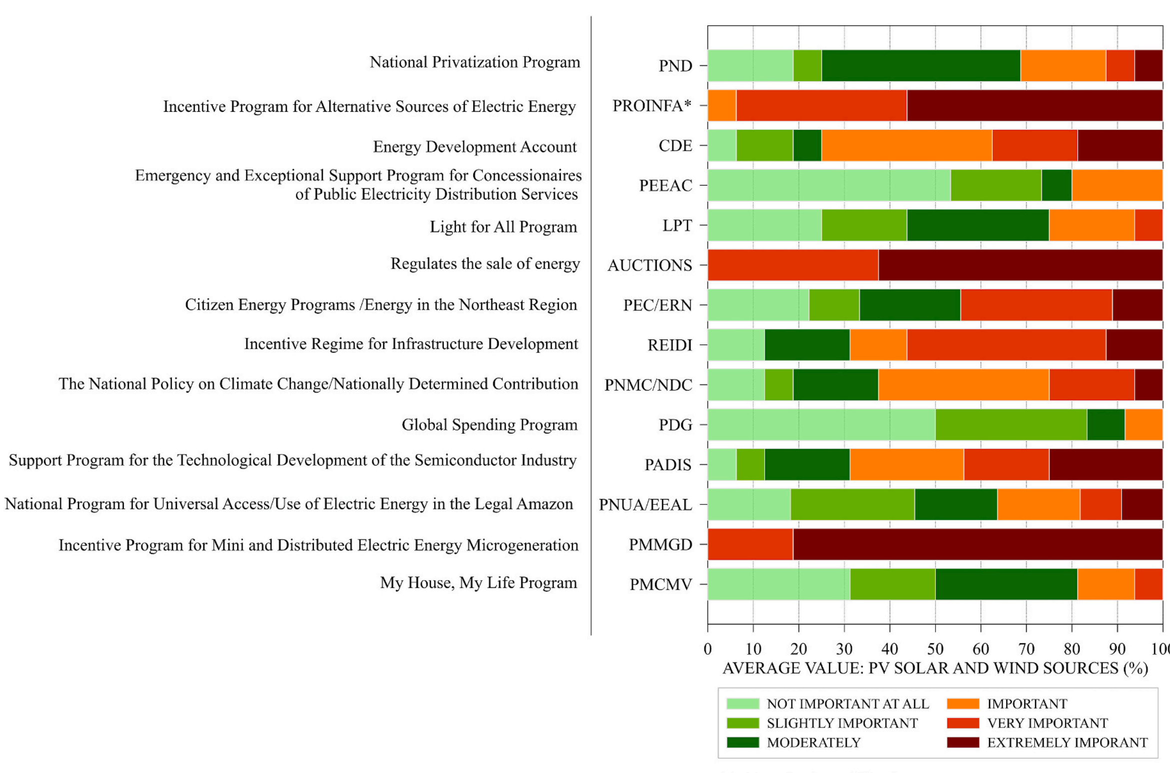

Fig. 9. Assessment of the public policies by stakeholders (wind and solar PV policies).

"Climate Change" and "Contribution to the Paris Agreement" policies were considered of moderate importance. Interviewees considered that both policies influenced the other policies. Light for All Program ("*Luz para Todos*") and My House, My Life Program ("*Minha casa, Minha Vida*") were important policies to support regional communities, especially those isolated from the grid, with solar PV energy generation, but in a low share in the national mix. Thus, they were not driving the diffusion of solar PV in the country.

4.2.1. Survey results: general aspects of policies and mechanisms

The analysis of the second section (Fig. 10), general aspects of the policies, revealed "Northeast region characteristics" and "Financing stimulus" (due to *Banco do Nordeste*'s strong presence in the energy field) as the most important mechanism for the diffusion of wind and solar PV sources, being classified as extremely important policies. Other moderate importance mechanisms highlighted were a) Auctions provided by "Federal Government Policies", although this is a national policy, it had outstanding importance for the Northeast of Brazil, as the set of other investment mechanisms in RES sources favor the Northeast, e.g., "Northeast region characteristics" – high wind speed and solar irradiance; b) "Lower initial investment cost". Capital Expenditure (CAPEX) is lower in the Northeast due to the lower cost of land (m^2) and labor; c) "Stimulus actions by state and municipal governments" with reduction or exemption of taxes and fees, among other benefits. One point to highlight is the supply of qualified labor in the Northeast, which is an aspect with low importance (in general) reported by the stakeholders. This means that this aspect could not represent a barrier to the diffusion of both sources there.

Fig. 11 shows the results for aspects that could contribute to the low market share of PV and wind power in Brazil. For the PV, in general, the analysis revealed: "High-level CAPEX investment" (from 2011 to 2017, the initial period of solar energy diffusion in Brazil) has been had the most affected on the market share, which 75% of the stakeholders classified it as, at least, an important aspect. CAPEX has raised due to the high costs of imported equipment (solar panels, inverters, etc.). However, in recent years (after 2017) equipment prices have significantly reduced, making investments more attractive. "Lack of access to information" was, at least, an important aspect cited by 50% of the stakeholders. This fact is extremely relevant since it draws attention to the needs of information diffusion in the country and public policies to help it. "Infrastructure" (e.g., transporting energy from the generation site to the "transmission" lines) was the third mechanism identified as an obstacle for solar diffusion, reported by 46% of the stakeholders, at least, as an important aspect. Interviewees considered mechanisms such as "hydroelectric competition" and "environmental issues" as less significant obstacles to the expansion of the solar PV as well. Interviewees highlighted that these mechanisms hinder, but do not prevent, the expansion of solar PV in Brazil.

The wind source's evaluation took place to identify the reasons for the small market share of wind energy in Brazil. The result revealed no significant differences compared to the solar PV source results (Fig. 11). Basically, the evaluated mechanisms obtained similar ratings. The main difference is related to the "operational limitations" mechanism that was rated as a more important obstacle in wind energy than in the solar PV source. The reason for this lies in the complexity and difficulty in transporting heavy and large wind equipment such as shovels and towers to places without access by land or difficult to access (mountain tops).

The third section, dedicated to evaluating the future effects of the COVID-19 pandemic in both wind and solar PV sources in Brazil, revealed the "imports limitation" mechanism as the main obstacle for wind and solar PV growth (Fig. 12). By the stakeholders' view, 81% of the interviewees considered this factor, at least, important and believe that the unfavorable exchange rate variation and supply disruption, due to import restrictions imposed by COVID-19 pandemic, can be a problem as well. Other mechanisms, such as "reduction of investments", "reduction of profitability", "increased of operational risks", and "change to unfavorable regulation" were considered of lower risk potential. Interviewees do not believe RES penetration will slow down due to the strong political commitment (national and international) to

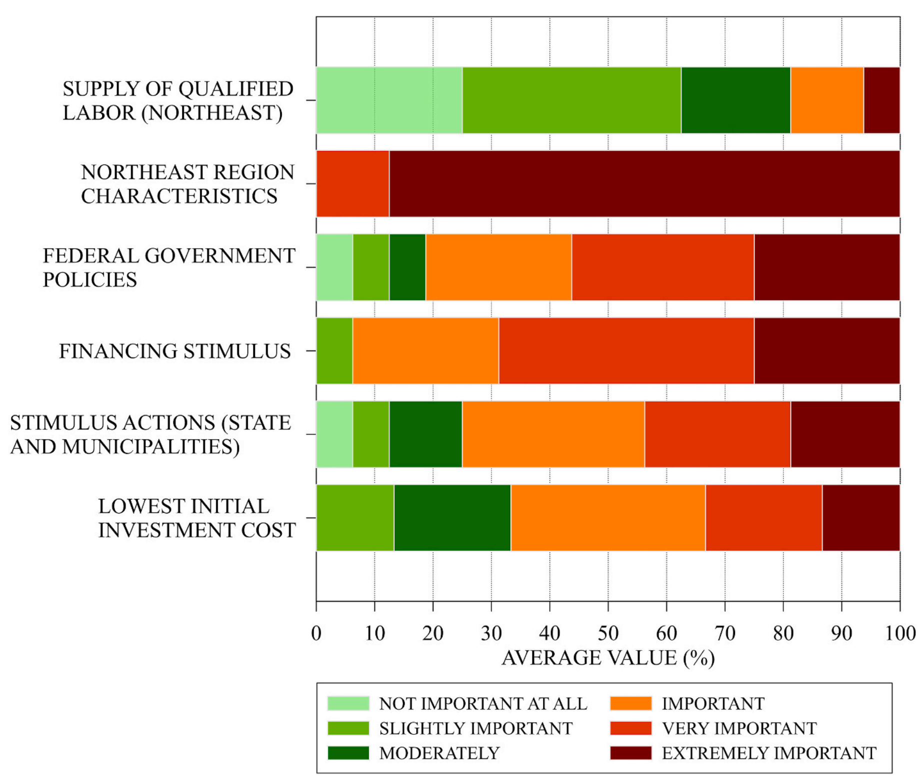

Fig. 10. Assessment of the mechanisms which the effects of the diffusion of wind and solar PV sources by stakeholders.

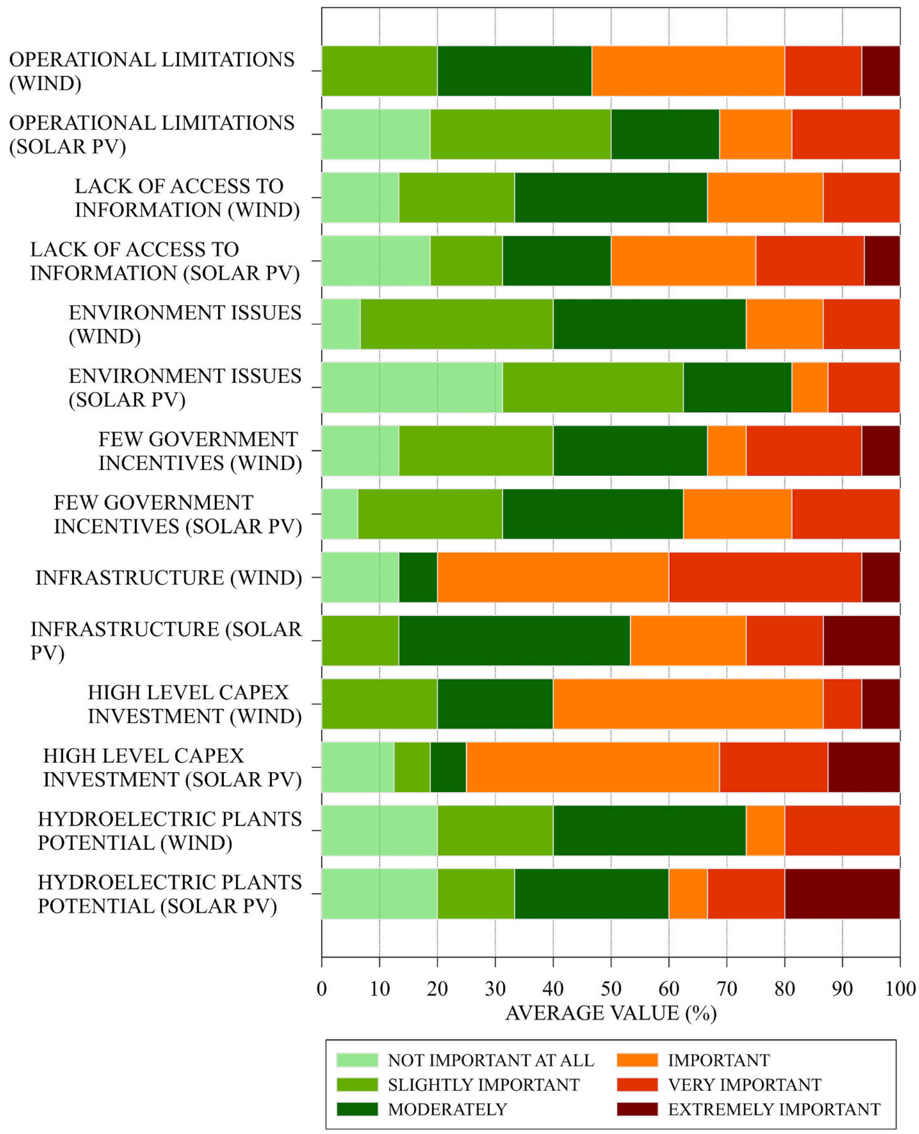

Fig. 11. Assessment of the aspects that contribute to the low market share considering wind and solar PV sources by stakeholders.

decarbonize the energy sector and mitigate climate change.

Most interviewees (75%) do not believe that the COVID-19 pandemic will significantly affect both wind and solar PV sources in Brazil. They consider that the effects of the pandemic will be minimized as most investments are guaranteed by long or medium-term duration contracts ("auctions"). In addition, the management of wind and solar PV plants is operated with few people and in places far from urban centers, therefore less susceptible to contagions that could compromise the park's operation.

4.2.2. Survey results: open-ended questions analysis

The open-ended questions aimed to understand what respondents could add to the results and try to notice new information. This section approach specific and policies, as well as the COVID-19 pandemic and other issues.

4.2.2.1. Specific policies section. In addition to the presented specific policies, interviewees indicated some that contribute to the diffusion of both wind and solar PV sources in Brazil. 1) "PRODEEM" – State and Municipal Energy Development Program is an important policy for isolated locations not supplied with electricity from the conventional grid. Solar PV source benefited the most from this program, especially after the year 2000; 2) "PRONAFA" – National Program for Strengthening Family Farming ("*Programa Nacional de Fortalecimento da Agricultura Familiar" – Eco e Mais Alimentos*), which was launched to strengthen family farming "production". It helps farmers to produce renewable energy by financing PV panels with the highest results recorded from the year 2000; 3) "Free Energy Market" ("*Mercado Livre de Energia*") or "Free Contracting Environment" ("*Ambiente de Contratação Livre*"), was a policy to encourage the expansion of generators from renewable sources limited to 30 MW of power, such as small hydroelectric plants (SHP); biomass; wind and solar PV. The consumer receives discounts (of 50%, 80%, or 100%) on the tariff for using the "distribution" system. Other less potential programs such as the "Climate Fund Program" ("*Programa Fundo Clima*") were released to guarantee resources to support research projects, and financing of enterprises to mitigate climate change. "ICMS Confaz" ("*Conselho Nacional de Política Fazendária*") is a subsidy that provides an exemption from ICMS tax, for energy from solar PV source distributed generation.

4.2.2.2. General policies section. Regarding the general part, interviewees indicated reducing bureaucracy and the lower cost of environmental licensing as favorable mechanisms to the diffusion of both wind and solar PV sources. They highlighted the licensing processes

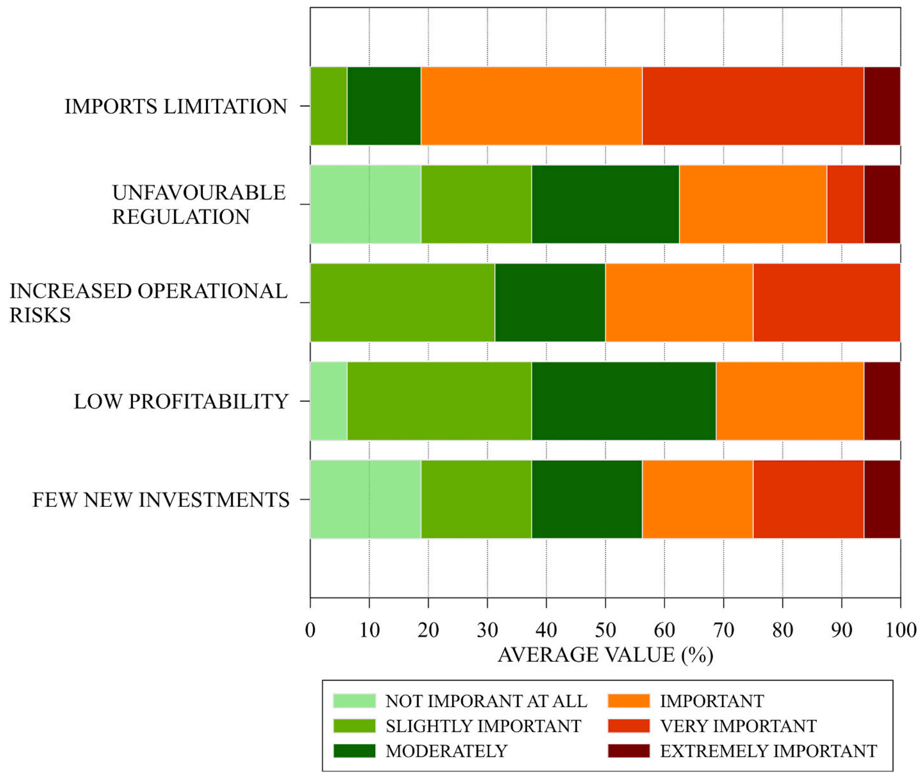

Fig. 12. Assessment of wind and solar PV sources by stakeholders, considering the future risks inherent in the COVID-19 pandemic.

have become faster and less costly in Brazil. Regarding mechanisms that limit the diffusion of both wind and solar PV sources, interviewees highlighted 1) high cost of photovoltaic modules (in the first years of operation); 2) Delay in the development of the local industry; 3) Ineffective of planning and coordination for the diffusion of both wind and solar PV sources; 4) Low political interest (biased to thermal, hydroelectric, and natural gas) to accelerate the diffusion of both wind and solar PV sources for the electric energy "production".

4.2.2.3. COVID-19 pandemic section. In the section, to analyze the future of both wind and solar PV sources in Brazil from the COVID-19 pandemic perspective, interviewees are concerned about entrepreneurs' requests for plants opening delay (for one or two years) guaranteed by auctions. They believe the delay could be an obstacle to the pace of growth of both wind and solar PV generation in the coming years.

4.2.2.4. Other open-ended questions. Regarding the recent regulation (Law 14.120/2021, MP 998/2020) [52] that changed the legislation on RES and generated some controversy, the interviewees revealed divergent positions. However, for the majority, Law 14,120 will not significantly affect the diffusion of both wind and solar PV sources in the country. Those who understand that the law limits the diffusion of both wind and solar PV sources argued that the loss of benefits, imposed by law 14.120, with the end of the network access discount (known as "*desconto no fio*"), and the reduction of budget for research and development, might compromise the growth of both wind and solar PV sources. Those who understand that Law 14,120 is beneficial for the diffusion of wind and solar PV sources argue the law may enable additional revenues such as carbon credits, rate of return on investment (simulations predicting the end of benefits) in PV plants remains favorable (5/6 years and plants are projected for 25 years), and the sector no longer needs the benefits withdrawn by Law 4,120.

Finally, the last point about mechanisms to boost both wind and solar PV sources in the post-COVID-19 pandemic, interviewees indicated: 1) regulation with a total market opening to allow consumers with demand up to 500 kW/month to have access to the free market (regulated by agreements signed directly between the consumer and the service provider). Currently, only consumers with demand above 500 kW/month can sell on the open market, which can be much more competitive; 2) Improvement of policies for DG so that the remuneration values of electricity generated by photovoltaic panels are competitive and the operation simplified. For example, PL 5829/2019 proposes that the consumer who generates photovoltaic energy will only pay the minimum subscription fee for the electricity point. In addition, the project suggests a 100% discount on charges and tariffs for the use of micro and mini-generation RES in electricity "transmission" and "distribution" systems.; 3) More investment for expansion and maintenance of "distribution" and "transmission" infrastructures; 4) Incentives for the development of energy storage technologies, such as batteries, and reversible hydropower; 5) Ensure that future auctions are more rigorous in terms of efficiency, social and environmental attributes.

5. Conclusions

Brazil has an ambitious target for the diffusion of wind and PV to diversify renewable generation sources and ensure low-carbon energy security. The country has made important progress, with a boom of the inauguration of new renewables parks, led by public policies and natural resources favorable to the expansion of wind and PV power (favorable index of wind speed and irradiance).

To realize the public policies that most contributed to the diffusion of renewable sources (wind and PV) in the Brazilian electricity grid in the period from 2000 to 2020 and to assess the possible post-COVID-19 pandemic effects on the wind and PV sources, around 16 h of interviews and a rigorous systematic review of the public policies and their types implemented in Brazil was conducted. It was revealed that the public policies that most contributed to the diffusion of wind and PV sources were guided by socio-economic drives and were not able to reduce the supremacy of the hydraulic source in the Brazilian electricity mix. For example, between 2015 and 2019, the hydraulic generation grew around 40 GWh (increased from 62% to 64% in the electric matrix share). In the same period, wind generation grew around 34 GWh and PV generation grew around 6 GWh [9]. However, what seems to be more relevant is that the market growth of wind and PV sources is reducing the share of non-renewables, contributing to decarbonize the Brazilian electricity sector.

There is great potential for the absorption of wind and solar PV sources in the Brazilian electricity grid, but for this, it will be necessary to overcome important barriers, such as political competition with other generation sources, to maintain an attractive investment environment capable of guaranteeing interest of investors in wind and PV sources. Although interviewed have not pointed out significant post-COVID-19 pandemic risks for both sources, except the external equipment dependence, the study highlights those policies that have ensured the expansion of the two renewable sources cannot be having the same effectiveness to attracting future investments, requiring a complete review of public policies.

The finding stems from the assessment that two key components responsible for attracting investments for wind and solar PV sources: the region's natural resources and availability of the "transmission" network, may be close to becoming growth constraints. Naturally, the first investments opt for the best generation locations (attributes that guarantee the highest return on investment). Therefore, the subsequent investments will have to select locations that may not have the same attractiveness as the first parks (profitability). Despite the success of public policies to the diffusion of wind and solar PV, maintaining the penetration growth of these two sources depends on punctual and constant political interventions, since there are no guarantees that the less noble geographic sites (area with a profile of bold investments and risks) will be consumed with the same dynamics of the first investments (noble sites of generation). Besides, another aspect that impacts the diffusion of both sources, which were discussed previously, is the existence of "auctions" and the balance between energy supply and demand.

Additionally, "transmission" networks, committed to ongoing investments (more attractive location), will have to make investments to modernize themselves, increase "transmission" capacity and be able to meet new demands, or the new investments will have to seek other "transmission" networks which may not have the same attractiveness for investors (lower return of investment).

Therefore, it is expected that both investments to enlargement the "transmission" network and the relocation of new parks to places with an available network (probably, with less economic appeal), require financial reengineering (public policies) capable of overcoming barriers, maintaining attractiveness of investments, and ensure the expansion of wind and solar PV sources.

Another aspect to be considered by the policies is the development of the local industry and the investments in R&D. To support the increased market share of wind and solar PV sources, it will be necessary to expand and development the national industrial park to reduce dependence, especially in wind sources, on imported components.

Also, the extreme weather events that have shown signs of intensification in recent decades cannot be ignored, such as variations in temperature patterns and long dry periods (which may affect hydraulic generation, with a reduction in the flow of water and capture for energy generation), and other moments, precipitation with floods, and extreme winds that can damage equipment and impact the availability of RES and the energy supply.

The study had some limitations regarding the approach to the target audience. Naturally, finding space for interviews on the agenda of very busy leaders who take the top of the important organizations, such as presidents, directors, and CEOs, is not an easy task. The unavailability of stakeholders prevented a more expressive number of engagements from being reached. It is recommended that future studies can assess the amount of generation (wind and solar PV) that do not reach the "transmission" networks due to technical or operational failures, as well as quantify the investments needed to upgrade the "transmission" networks and avoid energy losses. A second recommendation is to discuss how the policy instruments identified in this study relate to instruments widely discussed in the literature. Another line of research will be able to assess whether there is dissatisfaction and conflicts involving curtailment-type lawsuits involving the controllers of wind and solar PV parks in Brazil.

Finally, the findings of this study bring together unprecedented and valuable information with the potential to support policymakers, investors, and other stakeholders in the development of RES in Brazil.

Formatting of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors gratefully acknowledge the Faculdade de Ciências e Tecnologia da Nova Universidade de Lisboa, and ISCTE – Instituto Universitário de Lisboa – Centro de Estudos sobre a Mudança Socioeconómica e o Território both in Portugal, University of São Paulo (USP), University of Campinas (UNICAMP), and the Pontifical Catholic University of Minas Gerais (PUC-MG), all three in Brazil, for the support for the development of this research. The authors are also grateful for the collaboration of Brazilian public and private institutions that made their experts available to participate in the interview, which was of great value for this study. The authors would like to thank three anonymous reviewers as well as the editor of Renewable and Sustainable Energy Reviews for their highly valuable inputs.

Appendix A

Table A1
Assessment of the specific policy section for solar and wind sources

Please, rate the following policies from zero to five: zero, the policy is of no importance and five the policy is of maximum importance	
SOLAR	
PROINFA (Renewable Energy Sources Incentive Program/Alternative Electric Energy Sources)	4
SOLAR AND WIND	
PND (National Privatization Program)	2
CDE (Energy Development Account)	3
PEEACSPDEE (Emergency and Exceptional Support Program for Concessionaires of Public Electricity Distribution Services)	1

(*continued on next page*)

Table A1 (*continued*)

Please, rate the following policies from zero to five: zero, the policy is of no importance and five the policy is of maximum importance	
Light for all	2
PNMC (National Policy on Climate Change) and NDC (Nationally Determined Contribution to the Paris Agreement).	3
PADIS (Support Program for the Technological Development of the Semiconductor Industry)	3
Auctions (Regulates the sale of energy, encourages the creation of plants, contracting and supply of renewable energy)	5
PMMGD (Incentive Program for Mini and Distributed Electric Energy Microgeneration)	5
REIDI (Special Incentive Regime for Infrastructure Development)	3
PEC (Citizen Energy Programs) and ERN (Energy in the Northeast Region)	2
My House, My Life Program	1
Global Spending Program	1
PNUA (National Program for Universal Access) and EEAL (Use of Electric Energy in the Legal Amazon)	2

Table A2
Assessment of the general policy section for solar and wind sources

SOLAR AND WIND	
Which mechanisms most influence the diffusion, concentrated in the Northeast of Brazil, of solar and wind energy? (0–5, where 0 has no importance and 5 has maximum importance)	
Prioritization of the lowest initial investment cost (e.g., lowest cost area by m2 in the region)	3
Stimulus actions by state and municipality governments (reduction or exemption of taxes and fees)	3
Financing stimulus mechanism (subsidized rates, wide offer, less bureaucracy …)	4
Central government policies such as auctions	3
Natural calling of the northeast region (like the favorable winds from the Atlantic and the great number of hours of sunshine)	5
Supply of qualified labor (in case the Northeast region has a qualified and cheaper supply of labor)	1
SOLAR	
Why does solar energy have little market share in Brazil? (0–5, where 0 is of no importance and 5 is of maximum importance)	
Due the Brazilian government sees more potential in hydroelectric plants	2
High CAPEX investment	3
Infrastructure (e.g., obstacles such as the challenge of transporting energy from the generation site to the transmission lines).	3
Few government incentives.	2
Environmental issues (e.g., difficulty in creating power generation parks close to community areas; obtaining licenses for the construction of power generation parks).	1
Lack of access to information by stakeholders' perspective	2
Operational limitations (e.g., difficult access in selected areas for construction of parks, transport of equipment to remote areas …)	2
WIND (cont.)	
Why does wind energy have little market share in Brazil? (0–5, where 0 is of no importance and 5 is of maximum importance)	
Due the Brazilian government sees more potential in hydroelectric plants	2
High CAPEX investment	3
Infrastructure (e.g., obstacles such as the challenge of transporting energy from the generation site to the transmission lines).	3
Few government incentives.	2
Environmental issues (e.g., difficulty in creating power generation parks close to community areas; obtaining licenses for the construction of power generation parks).	2
Lack of access to information by stakeholders' perspective	2
Operational limitations (e.g., difficult access in selected areas for construction of parks, transport of equipment to remote areas …)	3

Table A3
Assessment of aspects related to the possible impacts of the covid-19 pandemic

How do you assess the possible impacts of the COVID-19 pandemic on the following topics involving wind and solar energy sources in Brazil?	
Reduction of new investments to expand wind and solar generation.	2
Reduction in the profitability of current investments in solar and wind farms.	2
Increased operational risks in investments due to unpredictability after the COVID-19 pandemic.	2
Unfavorable regulation (e.g., possibility of changing the legislation disfavoring the generation of solar and wind sources).	2
Possible limitation of product imports (due to unfavorable exchange rate variation or possible limitation in the supply of equipment due to import restrictions imposed by COVID-19 pandemic).	3

Table A4
Open-ended questions

I. SPECIFIC ASPECTS OF POLICIES	Are there any other programs, in addition to those presented, that have been important for the diffusion of wind and solar soiurces in Brazil?
II. GENERAL ASPECTS OF POLICIES AND MECHANISMS	Are there any other mechanisms, in addition to those presented, that were important for the diffusion of solar and wind sources in Brazil? Are there other mechanisms, in addition to those presented, that were important for the diffusion of solar energy in Brazil? Are there any other mechanisms, in addition to those presented, that were important for the diffusion of solar energy in Brazil that I didn't mention?

(*continued on next page*)

Table A4 (*continued*)

I. SPECIFIC ASPECTS OF POLICIES	Are there any other programs, in addition to those presented, that have been important for the diffusion of wind and solar soiurces in Brazil?
III. ASPECTS RELATED TO THE POSSIBLE IMPACTS OF THE COVID-19 PANDEMIC	Are there any other aspects, in addition to those presented, that were important for the development of wind energy in Brazil that I didn't mention? Could the Law 14,120 of February 3, 2021 (MP 998/2020), which deals with the reduction of energy tariffs and private exploitation of power plants, affect wind and solar energy? How? What mechanisms, after the COVID-19 pandemic, can be implemented or improved for the growth of market share of wind and solar sources in Brazil?

Appendix B

Table B1
Rating of policies

Policy [71,72].	Data	Wind	Solar PV	Other Alternative Energy	Production	Transmission	Distribution	Commercialization	Consumption	Other
Law 9991/2000	24-Jul	X	X	X						X
Decree 3520/2000	21-Jun	X	X	X						X
Law 9985/2000	18-Jul	X	X	X						X
Decree 3704/2000	27-Dec		X					X		X
Decree No number/2000	29-Nov	X	X	X		X				
Decree 3653/2000	7-Nov	X	X					X		X
Decree No number/2000	1-Sep	X	X			X				
Decree No number/2000	26-Jul	X	X			X	X			
Decree No number/2000	19-Apr	X	X			X				
Decree No number/2000	22-Mar	X	X				X			
Decree No number/2000	13-Jan	X	X				X			
Decree No number/2001	11-Dec	X	X			X				
Law 10310/2001	22-Dec	X	X						X	
Provisional Measure 2209/2001	29-Aug	X	X					X		
Provisional Measure 2198/2001	24-Aug	X	X							X
Decree 3894/2001	22-Aug	X	X			X				
Decree No number/2001	7-Aug	X	X			X				
Decree 3867/2001	16-Jul	X	X							X
Decree 3840/2001	11-Jun	X	X						X	
Decree 3818/2001	15-May	X	X						X	
Decree 3806/2001	26-Apr	X	X						X	
Decree 3789/2001	18-Apr	X	X		X				X	
Decree No number/2001	9-Apr	X	X			X				
Decree 3748/2001	8-Feb	X	X			X				
Decree No number/2001	15-Jan	X	X				X			
Decree 4562/2002	31-Dec	X	X	X	X	X	X	X	X	
Decree 4541/2002	23-Dec	X	X		X			X		X
Provisional Measure 88/2002	20-Dec	X								X
Law 10604/2002	17-Dec	X	X						X	
Law 10438/2002	26-Apr	X		X	X	X	X	X	X	X
Decree 4538/2002	23-Dec	X	X					X	X	
Decree 4505/2002	11-Dec	X	X						X	X
Decree No number/2002	9-Dec	X	X			X				
Decree No number/2002	4-Dec	X	X			X				
Decree 4475/2002		X	X		X					X

(*continued on next page*)

Table B1 (*continued*)

Policy [71,72].	Data	Wind	Solar PV	Other Alternative Energy	Production	Transmission	Distribution	Commercialization	Consumption	Other
	20-Nov									
Decree 4413/2002	7-Oct	X	X					X		
Law 10433/2002	24-Apr	X	X					X		
Decree 4145/2002	25-Feb	X	X		X				X	
Decree No number/2002	9-Jan	X	X			X				
Law 10762/2003	11-Nov	X	X	X	X	X	X	X	X	
Provisional Measure 144/2003	11-Dec	X	X	X				X		
Decree 4873/2003	1-Nov	X	X		X	X	X	X	X	X
Provisional Measure 127/2003	4-Aug	X	X				X			X
Decree 4768/2003	27-Jun	X	X					X		X
Decree No number/2003	25-Jun	X	X			X				X
Decree 4758/2003	21-Jun	X	X	X	X			X		X
Decree 4713/2003	29-May	X	X			X	X	X		X
Decree 4667/2003	4-Apr	X	X		X	X	X	X	X	
Decree 4644/2003	24-Mar	X	X	X	X			X		
Decree 5025/2004	30-Mar	X		X	X	X	X	X	X	
Decree 5290/2004	29-Nov	X	X			X				
Decree 5287/2004	26-Nov	X	X					X		X
Decree 5271/2004	16-Nov	X	X		X			X		
Decree 5249/2004	20-Oct	X	X		X			X		
Decree 5198/2004	27-Aug	X	X			X				X
Decree 5175/2004	9-Aug	X	X							X
Decree 5163/2004	30-Jul	X		X	X			X	X	
Decree 5146/2004	20-Jul	X	X			X				
Decree 5070/2004	6-May	X	X			X				
Law 10848/2004	15-Mar	X	X	X	X	X	X	X	X	X
Law 10847/2004	15-Mar	X	X	X						X
Decree No number/2004	21-Jan	X	X			X				X
Law 11097/2005	13-Jan	X	X	X	X					X
Decree No number/2005	13-Dec			X	X					X
Law 11099/2005	14-Jan	X	X							X
Decree 5445/2005	12-May	X	X							X
Decree 5477/2005	20-Jun	X	X			X				
Decree 5499/2005	25-Jul	X	X		X			X		
Decree 5597/2005	28-Nov					X			X	
Decree No number/2005	13-May	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree No number/2005	4-Mar	X	X			X				
Decree No number/2005	4-Mar	X	X			X				
Decree 5571/2005	3-Nov									X

(*continued on next page*)

Table B1 (*continued*)

Policy [71,72].	Data	Wind	Solar PV	Other Alternative Energy	Production	Transmission	Distribution	Commercialization	Consumption	Other
Decree No number/2005	28-Dec	X	X			X				
Decree 5477/2005	24-Jun	X	X			X				
Decree No number/2005	4-Mar	X	X			X				
Decree No number/2005	2-Feb	X	X			X				
Decree 5793/2006	29-May									X
Decree 5702/2006	15-Feb	X	X			X				
Decree 5882/2006	31-Aug	X		X	X	X	X	X		X
Decree No number/2006	27-Mar	X	X			X				
Decree No number/2006	3-Apr	X	X			X				
Decree No number/2006	3-Apr	X	X			X				
Decree No number/2006	3-Apr	X	X			X				
Decree No number/2006	3-Apr	X	X			X				
Decree No number/2006	3-Apr	X	X			X				
Decree No number/2006	23-Jun	X	X							X
Decree 5823/2006	29-Jul	X	X			X				
Decree 5879/2006	22-Aug	X	X							X
Decree 5909/2006	27-Sep	X	X			X				
Decree 5911/2006	27-Sep				X					
Law 11488/2007	13-Aug	X	X		X	X	X	X		X
Decree 6267/2007	22-Nov	X	X			X				
Decree 6254/2007	13-Nov	X	X			X				
Decree No number/2007	18-Sep	X	X			X				
Decree 6210/2007	18-Sep				X			X		
Decree 6205/2007	14-Sep	X	X			X				
Decree 6167/2007	24-Jul	X	X		X	X				X
Decree 6161/2007	20-Jul	X	X			X				
Decree 6160/2007	20-Jul	X	X				X			X
Decree 6144/2007	3-Jul	X	X		X	X				X
Decree No number/2007	15-May	X	X			X				
Decree No number/2007	15-May	X	X			X				
Decree No number/2007	15-May	X	X			X				
Decree No number/2007	15-May	X	X			X				
Decree No number/2007	15-May	X	X			X				
Decree No number/2007	3-Apr	X	X			X				
Decree No number/2007	3-Apr	X	X			X				
Decree No number/2007	3-Apr	X	X			X				
Law 11454/2007	28-Mar	X	X	X	X	X				X
Decree 6048/2007	27-Feb	X	X	X	X			X		
Decree No number/2007	3-Apr	X	X			X				
Decree No number/2007	3-Apr	X	X			X				
Decree No number/2007	3-Apr	X	X			X				
Law 11465/2007	28-Mar	X	X				X			
Decree 6460/2008	19-May	X						X		
Decree 6608/2008	19-May	X	X			X				
Decree No number/2008	22-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				

(*continued on next page*)

Table B1 (*continued*)

Policy [71,72].	Data	Wind	Solar PV	Other Alternative Energy	Production	Transmission	Distribution	Commercialization	Consumption	Other
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree No number/2008	8-Oct	X	X			X				
Decree 6536/2008	11-Aug	X	X			X				
Decree 6535/2008	11-Aug	X	X			X				
Decree No number/2008	27-Feb	X	X			X				
Decree No number/2008	27-Feb	X	X			X				
Decree No number/2008	27-Feb	X	X			X				
Decree No number/2008	27-Feb	X	X			X				
Decree 6460/2008	19-May	X	X					X		
Decree 6423/2008	4-Apr	X	X			X				
Decree 6416/2008	28-Mar	X	X							X
Decree 6415/2008	28-Mar	X	X			X				
Decree 6402/2008	17-Mar	X	X			X				
Decree No number/2008	27-Feb	X	X			X				
Decree No number/2008	27-Feb	X	X			X				
Decree No number/2008	27-Feb	X	X			X				
Law 11943/2009	28-May	X	X							X
Decree No number/2009	18-Mar	X	X				X			
Law 12187/2009	29-Dec	X	X	X						X
Law 12111/2009	9-Dec	X	X	X	X	X	X	X	X	X
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Decree No number/2009	9-Nov	X	X			X				
Provisional Measure 466/2009	29-Jul	X	X	X			X	X		X
Decree No number/2009	22-Jul	X	X			X				
Decree No number/2009	22-Jul	X	X			X				
Law 11977/2009	7-Jul	X	X		X				X	X
Decree No number/2009	18-Mar	X	X			X				
Decree No number/2009	18-Mar	X	X			X				
Decree No number/2009	18-Mar	X	X			X				
Decree 6802/2009	18-Mar	X	X			X				
Decree No number/2009	26-Feb	X	X			X				
Decree No number/2009	26-Feb	X	X			X				
Decree No number/2009	26-Feb	X	X			X				
Decree No number/2009	26-Feb	X	X			X				
Decree No number/2009	26-Feb	X	X			X				

(continued on next page)

Table B1 (*continued*)

Policy [71,72].	Data	Wind	Solar PV	Other Alternative Energy	Production	Transmission	Distribution	Commercialization	Consumption	Other
Decree No number/2009	14-Jan	X	X			X				
Decree No number/2009	12-Jan	X	X			X				
Decree No number/2009	12-Jan	X	X			X				
Decree No number/2009	12-Jan	X	X			X				
Decree No number/2009	12-Jan	X	X			X				
Decree No number/2009	12-Jan	X	X			X				
Decree No number/2009	26-Feb	X	X			X				
Decree No number/2009	26-Feb	X	X			X				
Decree 6781/2009	18-Feb	X	X			X				
Decree 7377/2010	1-Dec	X	X	X						X
Decree 7378/2010	1-Dec	X	X	X	X					X
Decree 7390/2010	9-Dec	X			X					X
Decree 7204/2010	8-Jun	X	X	X						X
Decree 7224/2010	30-Jun	X	X	X	X				X	X
Law 12212/2010	20-Jan	X	X	X			X	X	X	
Law 12535/2011	8-Dec	X			X	X				X
Decree 7628/2011	30-Nov	X						X		X
Decree 7578/2011	11-Oct	X	X							X
Law 12424/2011	16-Jun		X							X
Decree No number/2011	28-Jan	X						X		X
Decree 7883/2012	28-Dec	X			X	X		X		X
Decree No number/2012	13-Dec		X		X	X		X		
Provisional Measure 579/2012	11-Sep	X	X		X	X	X	X		
Decree 7708/2012	2-Apr	X	X	X						X
Decree 7685/2012	1-Mar	X	X	X	X					X
Decree 7686/2012	1-Mar	X	X	X						X
Law 12783/2013	11-Jan	X	X	X	X	X	X	X		X
Decree No number/2013	23-Jan		X		X		X	X		X
Decree 8247/2014	23-May		X							X
Decree 8203/2014	7-Mar	X	X		X	X	X			X
Provisional Measure 641/2014	21-Mar	X	X					X		
Decree 8221/2014	1-Apr	X	X							X
Decree 8299/2014	15-Aug	X	X		X					
Decree No number/2014	28-Oct	X	X							X
Law 13043/2014	13-Nov	X	X							X
Decree 8379/2014	15-Dec	X	X					X		
Decree 8387/2014	30-Dec	X	X	X	X					X
Law 13242/2015	30-Dec		X		X			X		X
Law 13203/2015	8-Dec	X	X	X		X	X			X
Decree 8632/2015	30-Dec	X			X			X		X
Decree No number/2015	26-Feb	X			X					X
Law 13097/2015	19-Jan	X	X	X		X	X			X
Decree 8437/2015	22-Apr	X								X

(*continued on next page*)

Table B1 (*continued*)

Policy [71,72].	Data	Wind	Solar PV	Other Alternative Energy	Production	Transmission	Distribution	Commercialization	Consumption	Other
Decree 8461/2015	2-Jun	X	X				X			
Decree No number/2015	30-Sep	X	X							X
Law 13169/2015	6-Oct	X	X							X
Decree No number/2015	20-Aug	X	X			X				
Law 13360/2016	17-Nov	X	X			X	X			X
Decree 8874/2016	11-Oct	X	X	X						X
Law 13408/2016	26-Dec	X	X					X		X
Decree 8933/2016	16-Dec	X			X			X		X
Law 13386/2016	20-Dec	X			X					X
Law 13473/2017	8-Aug		X		X					X
Decree 9022/2017	31-Mar	x	X		X					X
Decree 9047/2017	10-May	X	X			X				X
Decree 9103/2017	24-Jul	X	X			X				
Decree 9143/2017	22-Aug	X	X	X	X		X	X		X
Decree 9192/2017	6-Nov	X	X			X	X			X
Law 13707/2018	14-Aug	X	X		X					X
Law 13759/2018	17-Dec		X		X			X		X
Decree 9611/2018	14-Dec	X			X					X
Decree 9383/2018	25-May	X	X			X				
Law 13941/2019	13-Dec		X		X					X
Law 13914/2019	25-Nov		X		X					X
Law 13898/2019	11-Nov		X		X					X
Law 13943/2019	13-Dec	X			X	X				X
Law 13942/2019	13-Dec	X			X					X
Decree 9675/2019	2-Jan	X	X	X	X					X
Decree 9914/2019	11-Jul	X	X			X				
Decree 10050/2019	9-Oct	X	X			X				X
Law 14.094/2020	17-Nov		X		X					X
Law 14.093/2020	17-Nov		X		X					X
Law 14.087/2020	17-Nov		X		X					X
Decree 10.387/2020	5-Jun	X	X	X	X					X
Decree 10.240/2020	12-Feb		X							X
Decree 10.560/2020	3-Dec	X			X					X
Law 14.095/2020	17-Nov	X	X			X				X
Decree 10.221/2020	5-Feb	X	X	X	X	X	X		X	X
Decree 10.387/2020	5-Jun	X	X	X	X					X
Law 14.093/2020	17-Nov	X	X		X	X				X
Decree 10.565/2020	8-Dec	X	X			X				

References

[1] Bento N, Borello M, Gianfrate G. Market-pull policies to promote renewable energy: a quantitative assessment of tendering implementation. J Clean Prod 2020; 248:119209. https://doi.org/10.1016/j.jclepro.2019.119209.

[2] Sovacool BK. The importance of comprehensiveness in renewable electricity and energy-efficiency policy. Energy Pol 2009;37:1529–41. https://doi.org/10.1016/j.enpol.2008.12.016.

[3] Xiao M, Junne T, Haas J, Klein M. Plummeting costs of renewables - are energy scenarios lagging? Energy Strategy Rev 2021;35:100636. https://doi.org/10.1016/j.esr.2021.100636.

[4] Neto DP, Domingues EG, Calixto WP, Alves AJ. Methodology of investment risk analysis for wind power plants in the Brazilian free market. Elec Power Compon Syst 2018;46:316–30. https://doi.org/10.1080/15325008.2018.1444686.

[5] Geels FW, Kern F, Fuchs G, Hinderer N, Kungl G, Mylan J, et al. The enactment of socio-technical transition pathways: a reformulated typology and a comparative multi-level analysis of the German and UK low-carbon electricity transitions

(1990–2014). Res Policy 2016;45:896–913. https://doi.org/10.1016/j.respol.2016.01.015.
[6] Bersalli G, Menanteau P, El-Methni J. Renewable energy policy effectiveness: a panel data analysis across Europe and Latin America. Renew Sustain Energy Rev 2020;133. https://doi.org/10.1016/j.rser.2020.110351.
[7] Aquila G, Pamplona E de O, Queiroz AR de, Rotela Junior P, Fonseca MN. An overview of incentive policies for the expansion of renewable energy generation in electricity power systems and the Brazilian experience. Renew Sustain Energy Rev 2017;70:1090–8. https://doi.org/10.1016/j.rser.2016.12.013.
[8] Empresa de Pesquisa Energética (Epe). Anuário Estatístico de Energia Elétrica 2020 - Ano base 2019 2020:256, Rio de Janeiro, https://www.epe.gov.br/pt%0Ahttp://www.epe.gov.br (accessed August 20, 2021).
[9] Empresa de Pesquisa Energética (Epe). Balanço Energético Nacional 2020. Empres Pesqui Energética 2020:7–295, Rio de Janeiro, https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-ben (accessed August 20, 2021).
[10] Hao F, Shao W. What really drives the deployment of renewable energy? A global assessment of 118 countries. Energy Res Social Sci 2021;72:101880. https://doi.org/10.1016/j.erss.2020.101880.
[11] Costa E, Seixas J, Baptista P, Costa G, Turrentine T. CO2 emissions and mitigation policies for urban road transportation: sao Paulo versus Shanghai. Urbe Rev Bras Gestão Urbana 2018;10:143–58. https://doi.org/10.1590/2175-3369.010.supl1.ao15.
[12] Costa E, Seixas J, Costa G, Turrentine T. Interplay between ethanol and electric vehicles as low carbon mobility options for passengers in the municipality of São Paulo. Int J Sustain Transp 2017;11:518–25. https://doi.org/10.1080/15568318.2016.1276651.
[13] Diógenes JRF, Claro J, Rodrigues JC. Barriers to onshore wind farm implementation in Brazil. Energy Pol 2019;128:253–66. https://doi.org/10.1016/j.enpol.2018.12.062.
[14] Frate CA, Brannstrom C. Stakeholder subjectivities regarding barriers and drivers to the introduction of utility-scale solar photovoltaic power in Brazil. Energy Pol 2017;111:346–52. https://doi.org/10.1016/j.enpol.2017.09.048.
[15] Empresa de Pesquisa Energética (EPE) e Ministério de Minas e Energia. Escassez hídrica e o fornecimento de energia elétrica no Brasil 2021, Rio de Janeiro, https://www.epe.gov.br/sites-pt/sala-de-imprensa/noticias/Documents/infogr%c3%a1fico.pdf (accessed June 25, 2021).
[16] Ferraz de Andrade Santos JA, de Jong P, Alves da Costa C, Torres EA. Combining wind and solar energy sources: potential for hybrid power generation in Brazil. Util Pol 2020;67:101084. https://doi.org/10.1016/j.jup.2020.101084.
[17] World Bank Group, ESMAP, Vortex D. Global Wind Atlas n.d, USA, https://globalwindatlas.info/area/Brazil (accessed June 30, 2021).
[18] World Bank Group, Esmap S. Global Solar Atlas n.d, USA, https://globalsolaratlas.info/map?c=-12.408413,-41.673889,3 (accessed June 30, 2021).
[19] de Faria H, Trigoso FBM, Cavalcanti JAM. Review of distributed generation with photovoltaic grid connected systems in Brazil: challenges and prospects. Renew Sustain Energy Rev 2017;75:469–75. https://doi.org/10.1016/j.rser.2016.10.076.
[20] Brazil Government. Law N° 10,438/2002 2002, Brasilia, http://www.planalto.gov.br/ccivil_03/leis/2002/l10438.htm. (accessed June 24, 2021).
[21] Brazil Government. Law Nº 10,762/2003 2003, Brasilia, http://www.planalto.gov.br/ccivil_03/leis/2003/l10.762.htm (accessed August 10, 2021).
[22] Kissel JM, Krauter SCW. Adaptations of renewable energy policies to unstable macroeconomic situations—case study: wind power in Brazil. Energy Pol 2006;34:3591–8. https://doi.org/10.1016/j.enpol.2005.07.013.
[23] do Valle Costa C, La Rovere E, Assmann D. Technological innovation policies to promote renewable energies: lessons from the European experience for the Brazilian case. Renew Sustain Energy Rev 2008;12:65–90. https://doi.org/10.1016/j.rser.2006.05.006.
[24] Brazil Government. Law No 10,848/2004 2004, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2004/lei/l10.848.htm (accessed June 25, 2021).
[25] Brazil Government. Decree N° 10,087/2019 2019, Brasilia, http://www.planalto.gov.br/CCIVIL_03/_Ato2019-2022/2019/Decreto/D10087.htm#art1 (accessed June 30, 2019).
[26] Brazil Government. Decree N° 4,873/2003 2003, Brasilia, http://www.planalto.gov.br/ccivil_03/decreto/2003/d4873.htm (accessed June 30, 2021).
[27] Pottmaier D, Melo CR, Sartor MN, Kuester S, Amadio TM, Fernandes CAH, et al. The Brazilian energy matrix: from a materials science and engineering perspective. Renew Sustain Energy Rev 2013;19:678–91. https://doi.org/10.1016/j.rser.2012.11.063.
[28] Brazil Government. Decree Nº 6,442/2008 2008, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2008/decreto/d6442.htm (accessed July 6, 2021).
[29] Brazil Government. Decree Nº 7,324/2010 2010, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/decreto/D7324.htm (accessed July 6, 2021).
[30] Brazil Government. Decree Nº 7,520/2011 2011, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2011/decreto/d7520.htm (accessed July 6, 2021).
[31] Brazil Government. Decree Nº 7,656/2011 2011, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2011/decreto/D7656.htm (accessed July 6, 2021).
[32] Brazil Government. Decree Nº 8,387/2014 2014, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2014/decreto/D8387.htm (accessed July 6, 2021).
[33] Brazil Government. Decree Nº 9,357/2018 2018, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2018/decreto/D9357.htm (accessed July 6, 2021).
[34] Eletrobras Programa Luz Para Todos - Resultados e Metas 2020, Rio de Janeiro, https://eletrobras.com/pt/Paginas/Luz-para-Todos.aspx (accessed July 5, 2021).
[35] Aquila G, de Queiroz AR, Balestrassi PP, Rotella Junior P, Rocha LCS, Pamplona EO, Nakamura WT. Wind energy investments facing uncertainties in the Brazilian electricity spot market: a real options approach. Sustain Energy Technol Assessments 2020;42:100876. https://doi.org/10.1016/j.seta.2020.100876.
[36] Fraundorfer M, Rabitz F. The Brazilian renewable energy policy framework: instrument design and coherence. Clim Pol 2020;20:652–60. https://doi.org/10.1080/14693062.2020.1754157.
[37] Azuela Elizondo G, Barroso L, Khanna A, Wang X, Wu Y, Cunha G. Performance of Renewable Energy Auctions: Experience in Brazil, China and India 2014:1–39. World Bank Policy Research Working Paper 7062. https://openknowledge.worldbank.org/bitstream/handle/10986/20498/WPS7062.pdf;sequence=1 (accessed August 20, 2021).
[38] Porrua F, Bezerra B, Barroso LA, Lino P, Ralston F, Pereira M. Wind power insertion through energy auctions in Brazil. IEEE PES Gen. Meet., IEEE; 2010. p. 1–8. https://doi.org/10.1109/PES.2010.5589751.
[39] Bayer B. Experience with auctions for wind power in Brazil. Renew Sustain Energy Rev 2018;81:2644–58. https://doi.org/10.1016/j.rser.2017.06.070.
[40] Carstens DD doss, Cunha SK da. Challenges and opportunities for the growth of solar photovoltaic energy in Brazil. Energy Pol 2019;125:396–404. https://doi.org/10.1016/j.enpol.2018.10.063.
[41] Agencia Nacional de Energia Eletrica. Normative Resolution Nº 482/2012 2012, Brasilia, http://www2.aneel.gov.br/cedoc/ren2012482.pdf (accessed August 20, 2021).
[42] Agencia Nacional de Energia Eletrica. Normative Resolution Nº 687/2015 2015, Brasilia, http://www2.aneel.gov.br/cedoc/ren2015687.pdf (accessed July 4, 2021).
[43] Vazquez M, Hallack M. The role of regulatory learning in energy transition: the case of solar PV in Brazil. Energy Pol 2018;114:465–81. https://doi.org/10.1016/j.enpol.2017.11.066.
[44] Hansen LA, Zambra DAB. An overview about the Brazilian photovoltaic market development. J Power Energy Eng 2020;8:73–84. https://doi.org/10.4236/jpee.2020.88006. 0.
[45] Caixa Economica Federal. Construcard 2021, Brasilia, https://www.caixa.gov.br/voce/cartoes/casa/construcard/Paginas/default.aspx (accessed July 6, 2021).
[46] Santander. CDC (Crédito Direto ao Consumidor) 2021, São Paulo, https://www.santander.com.br/creditos-e-financiamentos-para-empresas/expansao-de-negocios/cdc (accessed August 20, 2021).
[47] Banco do Nordeste. FNE Sol - Energia Renovável 2021, Ceara, https://www.bnb.gov.br/fne-sol (accessed July 6, 2021).
[48] Banco Nacional do Desenvolvimento (BNDES). Plano Inova Energia 2021, Rio de Janeiro, https://www.bndes.gov.br/wps/portal/site/home/financiamento/plano-inova-empresa/plano-inova-energia (accessed July 6, 2021).
[49] Ministry of Economy Brazil. Confaz - Convênio ICMS 101/97 n.d, Brasilia, https://www.confaz.fazenda.gov.br/legislacao/convenios/1997/CV101_97 (accessed July 5, 2021).
[50] Agencia Nacional de Energia Elétrica. Normative Resolution Nº 77/2004 n.d, Brasilia, http://www2.aneel.gov.br/cedoc/bren2004077.pdf (accessed July 6, 2021).
[51] Brazil Government. Law Nº 9,427/1996 1996, Brasilia, http://www.planalto.gov.br/ccivil_03/leis/l9427cons.htm (accessed July 7, 2021).
[52] Brazil Government. Law Nº 14,120/2021 2021, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2021/lei/L14120.htm (accessed July 6, 2021).
[53] Ministry of Economy Brazil. Confaz - CONVÊNIO ICMS 16/2015 2015, Brasilia, https://www.confaz.fazenda.gov.br/legislacao/convenios/2015/CV016_15 (accessed July 7, 2021).
[54] Empresa de Pesquisa Energética (Epe). Plano Decenal de Expansão de Energia (PDE 2030) 2021, Rio de Janeiro, https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/plano-decenal-de-expansao-de-energia-2030.
[55] Sohrabi C, Alsafi Z, O'Neill N, Khan M, Kerwan A, Al-Jabir A, et al. World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19). Int J Surg 2020;76:71–6. https://doi.org/10.1016/j.ijsu.2020.02.034.
[56] Ritchie Hannah, Mathieu Edouard, Rodés-Guirao Lucas, Appel Cameron, Giattino Charlie, Ortiz-Ospina Esteban, et al. Coronavirus pandemic (COVID-19). OurWorldInDataOrg 2020. https://ourworldindata.org/coronavirus; 2020. [Accessed 19 February 2022].
[57] Emenike SN, Falcone G. A review on energy supply chain resilience through optimization. Renew Sustain Energy Rev 2020;134:110088. https://doi.org/10.1016/j.rser.2020.110088.
[58] The World Bank. Covid-19 in Brazil: Impacts and Policy Responses. World Bank 2020, USA, https://openknowledge.worldbank.org/handle/10986/34223 License: CC BY 3.0 IGO, (accessed February 19, 2022).
[59] Adams WC. Conducting semi-structured interviews. Handb Pract Progr Eval 2015;4:492–505. 978-0-470-52247-9third ed.
[60] Costa E, Paiva A, Seixas J, Costa G, Baptista P, Gallachóir BÓ. Spatial planning of electric vehicle infrastructure for belo horizonte, Brazil. J Adv Transport 2018;2018. https://doi.org/10.1155/2018/8923245.
[61] Hansen M, Hauge B. Scripting, control, and privacy in domestic smart grid technologies: insights from a Danish pilot study. Energy Res Social Sci 2017;25:112–23. https://doi.org/10.1016/j.erss.2017.01.005.
[62] Hardman S, Shiu E, Steinberger-Wilckens R, Turrentine T. Barriers to the adoption of fuel cell vehicles: a qualitative investigation into early adopters attitudes. Transp

Res Part A Policy Pract 2017;95:166–82. https://doi.org/10.1016/j.tra.2016.11.012.
[63] Caperello N, Kurani KS, TyreeHageman J. Do you mind if I plug-in my car? How etiquette shapes PEV drivers' vehicle charging behavior. Transp Res Part A Policy Pract 2013;54:155–63. https://doi.org/10.1016/j.tra.2013.07.016.
[64] Graham-Rowe E, Gardner B, Abraham C, Skippon S, Dittmar H, Hutchins R, et al. Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: a qualitative analysis of responses and evaluations. Transp Res Part A Policy Pract 2012;46:140–53. https://doi.org/10.1016/j.tra.2011.09.008.
[65] Kurani KS, Turrentine T, Sperling D. Testing electric vehicle demand in 'hybrid households' using a reflexive survey. Transport Res Transport Environ 1996;1:131–50. https://doi.org/10.1016/S1361-9209(96)00007-7.
[66] Glaser B, Strauss A. The discovery of grounded theory: strategies for qualitative research. EE. UU; 1967. https://doi.org/10.4324/9780203793206.
[67] Corbin J, Strauss A. Basics of qualitative research: Techniques and procedures for developing grounded theory. UK: Sage publications; 2014, ISBN 978-1-4129-9746-1.
[68] Zhang W, Zhang M, Zhang W, Zhou Q, Zhang X. What influences the effectiveness of green logistics policies? A grounded theory analysis. Sci Total Environ 2020;714:136731. https://doi.org/10.1016/j.scitotenv.2020.136731.
[69] Bryant ST, Straker K, Wrigley C. Designing our sustainable energy future: a shock doctrine for energy. Energy Pol 2020;147:111914. https://doi.org/10.1016/j.enpol.2020.111914.
[70] Brazil Government. Provisional Measure N^o 579/2012 2012, Brasilia, http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/mpv/579.htm (accessed August 10, 2021).
[71] Agencia Nacional de Energia Elétrica. Sistema de Informações de Geração da ANEEL 2020, Brasilia, https://www.aneel.gov.br/siga (accessed August 10, 2021).
[72] Brazil Government. Legislation 2020, Brasilia, http://www4.planalto.gov.br/legislacao (accessed March 10, 2021).