

Review

# Bigger Is Not Always Better: Review of Small Wind in Brazil

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**Abstract:** This century registers a significant expansion in the wind power market. However, the vast majority of these investments are concentrated in large wind turbines. The century begins with an installed capacity of about 20 GW, which reaches 650 GW in 2019. On the other hand, it is important to highlight that small wind turbines have not followed this virtuous path, a fact that is evident in Brazil's reality. In this context, the article aims at evaluating the current situation of the wind energy market for Small Wind Turbines in Brazil (SWT) and its future perspectives, identifying the main characteristics of the sector, its challenges, and opportunities. It is an exploratory–explanatory research study that investigates the theme, generating knowledge that turns to practical application, as it seeks answers to solve local interests. This methodological approach provides objective evidence that the production of knowledge about the use of SWT in Brazil still remains embryonic, shaded by the impressive progress registered by the major wind farms in the country, despite all the potential and socioeconomic and environmental attractions. This fact credits the revision research with an innovative role in the apprehension of knowledge related to the development of SWT in Brazil.

**Keywords:** renewable energy; energy planning; Brazilian small wind market



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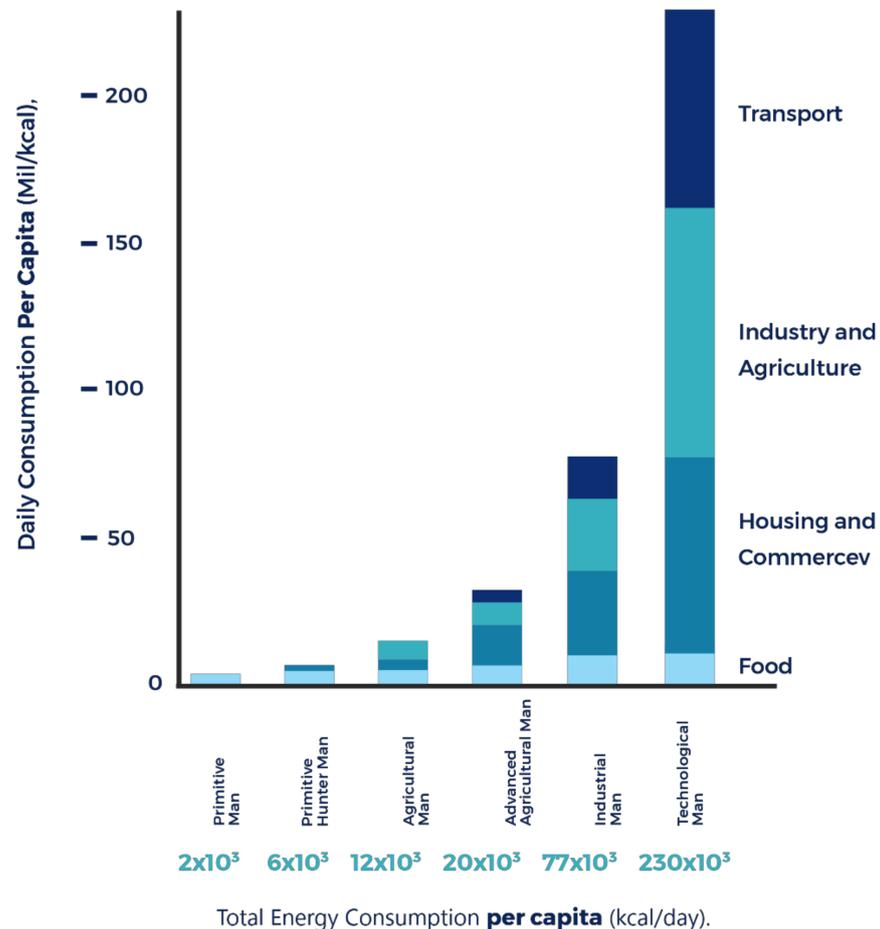


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## 1. Introduction

The technological development conducted in the field of energy generation and distribution has led to major changes in the way of life of humanity, and many of these changes are related to the use of energy. In the 18th century, the improvement of the efficiency of the thermal machine led to an intensification of the pace of industrial production, making consumer goods more accessible. This same machine would start, in the following century, the use of motorized transport, with the advent of steam-powered ships and locomotives. The discovery, in the 19th century, of the phenomenon of electromagnetic induction enabled, from the following century, the generation of electrical energy on a large scale. At the end of the 19th century, the development of the internal combustion engine culminated in the invention of the automobile, which transformed the scene of urban centers. These same engines are currently responsible for the propulsion of ships and aircraft, facilitating the transport of goods and people between continents. In the last century, the invention of the transistor made the microelectronics revolution possible, increasingly present in our daily lives, and the design of the nuclear reactor gave rise to a new way of obtaining electricity, currently responsible for about 11% of the worldwide electricity matrix [1].

The technological innovations mentioned above have provided profound changes in the human way of life, contributing to an increase in their well-being. However, they significantly impacted humanity's energetic demand, as shown in the graph represented by Figure 1.



**Figure 1.** Evolution of daily energy consumption per capita in periods of human history. Source: Based on Goldemberg and Lucon (2012) [2].

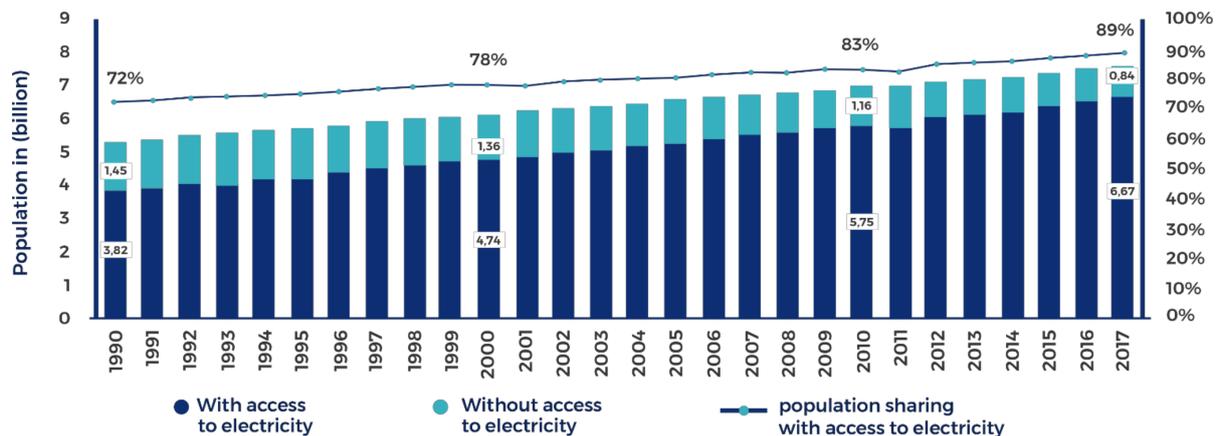
However, this expansion of energy consumption took place in a quite uneven way in different regions of our planet, creating a greater gap between the standard of living of the inhabitants of the regions with the highest and purchasing power and those ones with the lowest.

According to Hinrichs [3], there is a great disparity between the per capita use of energy between developed and developing countries. Developing countries concentrate almost three-quarters of the world population but consume only a quarter of the energy. An American consumes 1.87 times more electricity than a Frenchman, 3.3 times more than a Chinese, 5.95 times more than a Brazilian, 16.14 times more than an Indian, and 79 times more than a Kenyan inhabitant [4].

Studies conducted by the International Energy Agency (IEA) [5] showed that the Asian Continent had the most progress in the reduction of the deficit in access to electricity. In that continent, between the years 2000 and 2016, 870 million people started using electricity in their homes, 500 million of which are registered in India. Sub-Saharan Africa has also made progress. However, the electrification rate did not exceed the population growth rate, causing this region to have a greater number of people without access to electricity than in 2000.

Despite the significant number of people still without access to electricity, it appears that the effects resulting from global actions aimed at reducing the demands for access to

electricity in recent years have proved to be satisfactory in the most different regions of the planet. More recent data, published by the IEA [5], as shown in Figure 2, show the improvement of access to electricity worldwide (see Figure 2). In a 2019 report, it is shown, that in 2010, there were about 1.2 billion people who did not have access to electricity, while in 2016 that number was reduced to approximately 1 billion, and at the end of 2017, that number had decreased to 840 million people, being most of those who have no access to electricity concentrated in sub-Saharan Africa.



**Figure 2.** Evolution of the population over the years with and without access to electricity. Source: Based on IEA [5].

According to Balza [6], providing people with access to electricity impacts positively a wide range of development issues, including education, income, and health, among many others. For example, electric light increases the number of hours of study, providing students with better school performance, which in turn helps to increase, in the future, their insertion in the labor market.

The consequence of the lack of access to electricity goes beyond the imposition of a more discreet lifestyle, molded to more primitive habits, also reflecting on the capacity to produce wealth and basic health care for the population. For this reason, universalizing access to electricity is a challenge to be faced by developing countries, especially in rural areas that have always presented lower indicators of access to electricity distribution networks.

Electricity is, therefore, a vitally important source. Therefore, its arrival in the rural environment favors the emergence of economic activities that would not be feasible without this input, contributing in this way to the reduction of poverty levels.

In Brazil, according to Oliveira [7], since the beginning of the implementation of electricity distribution networks, energy distributors—of private origin—have favored the installation of their networks in large urban centers due to the low attractiveness of rural electrification in view of the unfavorable cost–benefit ratio. Table 1 shows how small the share of rural electrification (6.1%), if compared to residential (29.0%), and the number of other consumption classes that are, except the rural class, all located in urban areas. It is worthwhile to point out that in the years shown in Table 1, there was considerable growth in rural electrification, being the class that grew the most between 2014 and 2018, while general consumption in the country practically stopped in the same period.

Regarding the universalization of electric energy, renewable sources of energy through the use of technologies for their use, associated with a number of legal instruments aimed at their expansion in the world market for electricity production, have made themselves prominent actors regarding public electrification policies. In terms of internal electricity supply in Brazil, data from the Energy Research Office (EPE) [8] show that renewable energies show an average annual growth of 2.9%, with wind and solar sources mainly having average growth. Even higher, in the order of 7%. In this way, it is estimated that the percentage of renewable energies in the Brazilian energy matrix will reach the level of 48% in 2029. The same source also reports that in 2018, in Brazil, around 400 MW of Micro and

Distributed Mini Generation were installed—the Micro and Distributed Mini Generation (MMGD), which, for comparative purposes, “represented the same capacity added to natural gas thermal plants, twice what was installed in sugarcane bagasse thermal plants or, still, three times the installed capacity of Small Hydro Power (SHPs) in the same year” [9].

**Table 1.** Electricity consumption by consumer class—2014 to 2018.

BRAZIL	2014	2015	2016	2017	2018	$\Delta\%$	$\Delta\%$	Total (%)
						(2018/2017)	(2018/2014)	2018
Consumption (GWh)	474,824	465,709	461,780	467,162	474,821	1.6	0.0	100.0
Residential	132,302	131,190	132,872	134,368	137,615	2.4	4.0	29.0
Rural	25,671	25,899	27,266	28,136	29,168	3.7	13.6	6.1
Industrial	179,106	169,289	165,314	167,398	169,625	1.3	−5.3	35.7
Commercial	89,840	90,768	87,873	88,292	88,631	0.4	−13	18.7
Public Authorities	15,355	15,196	15,096	15,052	15,076	0.2	−1.8	3.2
Street Lighting	14,043	15,333	15,035	15,443	15,690	1.6	11.7	3.3
Public Services	15,242	14,730	14,969	15,196	15,778	3.8	3.5	3.3
Individual Consumption	3265	3304	3355	3277	3238	−1.2	−0.8	0.7

Source: Based on EPE (2019)—statistical yearbook of electricity [1].

Large wind turbines have a significant role in the Brazilian wind market. In this market, small wind turbines hold limited participation, thus lacking the support of different orders: economic-financial, scientific, marketing, regulatory, and research and development. In this context, the article innovates by contributing to the debate, supported by the scientific literature concerning the diffusion and improvement of technology. The article also reports the Brazilian truth about competitive conditions and considers the political, social, economic, and environmental aspects.

Renewable sources of energy are stimulated by governmental programs aimed at allowing their greater diffusion as an option for generating energy in a distributed manner, thus stimulating the structuring of their production chains, enabling the generation of jobs and income. In this context, this article aims at accessing the current situation of the wind energy market for small wind turbines in Brazil and its future, perspectives, identifying the main characteristics of the sector, its challenges, and opportunities. This article also recommends the creation of public policies to promote the development of small wind farms and their association with other technologies in Brazil, in addition to assessing perspectives on market trends for this technology.

It is important to highlight that the diffusion of wind energy in Brazil occurs mainly through large wind farms connected to electric energy networks, being Small Wind Turbines (SWT) recent and little stimulated. This way, the article is divided into five sections. It starts with the introduction in Section 1. Section 2 presents a context of small wind energy in Brazil, referring to the global market of this technology. Section 3 presents the methodological path followed in the research study. Section 4, Result and Discussions, evaluates its supply chain, barriers, and strategies, in addition to incentive mechanisms in Brazil and the potential market and its evolution projections. Lastly, Section 5 presents recommendations and final considerations.

## 2. Context

In the context of the so-called “energy transition” in progress, the challenge is not limited to choosing between one source and another, but how to organize the energy system around this “new” source. Therefore, it is essential to understand the opportunities placed on wind energy within a conceptual environment, including, also, social and economic issues, in addition to those of a technical nature—associated with its construction and operation—seeking to reveal its complex relationships, observing that social and economic aspects interact and shape technological issues, and vice versa, not being watertight compartments.

The market orientation for the energy sector in the world, including the wind industry, moderates in “growing or perishing”, which is a usual statement of the neoclassical school of economic thinking. According to Mészáros [10], the expansion of capital and its appropriation is legitimized by this statement. Together, criticism is only viable if it leads to a historically sustainable alternative. Thus, it is not enough to reject the global decision-making process.

Supported by high governmental incentives, the winning business model of the wind market has consolidated itself in a structure guided by the continuous search for gains in scope and scale that can be maximized by the use of increasingly powerful wind turbines, based on the concepts of large parks and parks wind farms connected to national centralized transmission and distribution systems. This model enabled a significant increase in installed capacity in the world when, in 2019, a total of 662 GW were registered, of which 210 in China, 103 in the USA, 196 GW in Europe, and to a lesser extent in Latin America and the Caribe 23 and 6 GW in Africa and in the Middle East [11].

Despite the attractive use of renewable resources in peripheral regions, in terms of contributing to sustainable development, the energy sector remains inseparable from monopoly capital. In these terms, the development model remains controversial, as it motivates the National States and the market to continue shaping their industrialization process based on the wasteful exploitation of natural resources.

In Brazil, the rapid and expressive progress of wind energy, recorded since the beginning of this century, is credited to the existence of extraordinary winds, of high technical quality and regularity in its direction and speed, distributed over a large part of the national territory, especially on the coast of the northeast region. These favorable conditions have led operating wind farms to record load factors in numbers that exceed the world average, 42.7% in 2019, reaching its maximum value of 59.1% in August, against a global average of 34% in that same year [12].

Brazilian onshore wind potential is estimated at 143.5 GW when average annual winds equal to or greater than 7.0 m/s is accounted for. Such potential has the capacity to offer an annual generation of 272.2 TWh/year, which would require the use of 0.8% of the entire national territory—an area of about 71,735 km<sup>2</sup>, based on an average density of land occupation 2 MW/km<sup>2</sup> and the performance curves of turbines at a height of 50m. Studies to update the Brazilian onshore wind potential, used in the projection of turbines installed at 100 m, expand the national potential to values of around 880 GW [13,14].

Chagas et al. [15] state that small wind power is embryonic in Brazil, still requiring public policies for its promotion, seeking to reduce the technological gap and the reduction of costs, and indicate as a strategy for directing the industry when they propose the goal of 1 GW of installed capacity in 15 years.

Small-scale wind energy is an alternative. It is an option to generate social wealth, distancing itself from the classic concentration, promoting the generation of electricity in a decentralized and more accessible way in view of the large investments required in large traditional plants, enabling the reduction of the concentration of income, specifically observed in developing countries like Brazil. According to Robespierre, extreme poverty and extreme wealth are obstacles to pure democracy. Moreover, in the reading of Atkinson [16], the greatest danger in the world (in Europe and the United States) refers to inequality.

This technology can be oriented to expand the supply of electric energy in the grid, as well as being an alternative for regions outside the grid. In developing countries, considering the low quality of the energy offered and difficulties in the universalization of its access, it creates opportunities for decentralized generation from small wind energy, with the backdrop of promoting renewable energy sources and their consequences in environmental issues and those linked to climate changes, fostering a low-carbon economy, in addition to generating local income and employment. Kamp and Vanheule [17] point to this alternative as an opportunity to face energetic poverty in Kenya, replacing diesel generators.

Leary, Schaubé, and Clementi [18] highlight that 1.1 billion people are not yet connected to the grid, being the decentralized generation, based on renewable energy, an

important instrument to overcome this challenge and, in this case, small wind power is inserted. The authors reinforce that in the last decades there has been a rapid growth of the wind industry, in addition to the environmental concern arising from the use of fossil fuel, prompting the revival of small wind technology. However, this converter still has several challenges permeating the social, economic, organizational, political, and technical spheres. Kamp and Vanheule [17] emphasize that among the challenges present in Kenya, which are associated with the promotion of technology, it can be mentioned: “Dependency Syndrome” (passive behavior), resistance to new technology, lack of qualified labor, high level of poverty in the rural area, lack of interaction with other agents of the production chain, fragmented experiences thus reducing the possibility of gains from the “learning effect”.

Lema et al. [19] bring to the debate the importance of the development of local capacities together with the promotion of renewable energy sources. In this environment, SWT gains relevance due to the demand for a local supply and labor chain, as well as the complexity of its operation in terms of electromechanical knowledge.

According to the author, the levels and types of pre-existing capacities at the site are important for the success of investments in renewable sources. However, new opportunities for additional capacity building that arise with the ventures are of greater importance, since they can leverage local economies, including new opportunities of learning that come from the information flows established between the developing/offering economies and receiving technologies.

It is important in this context that public authorities play an active role in the regulation and support to the SWT sector, structuring training, education, and capacity building programs so that the adopted technologies can be effectively well adapted to the needs of their economies.

Pereira et al. [20] reinforce that the Northeast region of Brazil stands out for being mostly supported by renewable energy sources, with emphasis on the solar and wind potential. The current challenge is to take advantage of it in a truly decentralized way, aiming at promoting local development. In this sense, incentives are needed to overcome the logic of the so-called “great gains” that are limited to promoting gains in scale and scope.

Energy sources are diverse and abundant in Brazil, although poorly geographically distributed. However, the central issue to be discussed is not limited to the use of energy resources, but also for whom this energy is being produced and what is its purpose? Although energy planning seeks to offer energy solutions at minimal cost, including social and environmental costs, there is still room to consider how to move from the discussion of technical efficiency to social efficiency. Is energy planning nowadays also a mechanism for promoting social effectiveness?

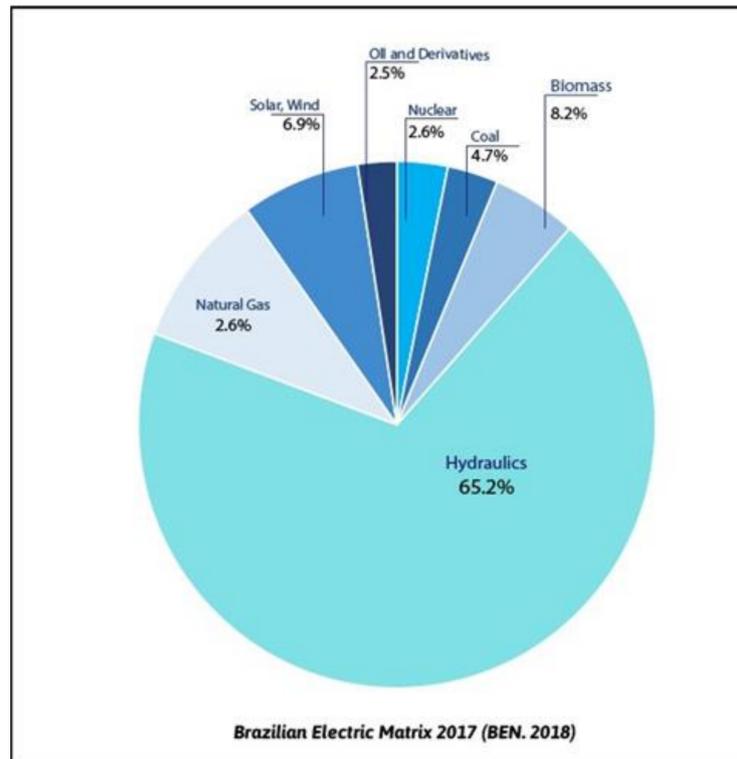
Celso Furtado sought to discover a way to create the conditions that lead to overcoming underdevelopment. According to Furtado [21]: “Development, endogenously generated, requires creativity in the political level, and this manifests itself when a strong ingredient of collective will is added to the perception of obstacles to be overcome”.

The collective will ideally and obstinately seek the reduction of inequalities. In the point of view of Atkinson (2015), reducing inequality should be a priority for everyone. In this context, Stiglitz [22] states: “The price of inequality is the deterioration of the economy, that becomes less stable and less efficient, with less growth, and with the subversion of democracy. The large and growing division between the richest 1% and ‘the other 99%’ is not just one of many concerns, but the defining characteristic of a completely sick economy”.

John Rawls [23], in his formulation about “Theory of Justice”, seeks to argue that the idea of benefiting the least favored the view according to which inequality matters in terms of the distance between the rich and the poor, and can be a reason to act, even when there is no gain for the poorest. John Rawls (1981) started a wide debate among moral philosophers about the nature of social justice. Anthony B. Atkinson [16] reinforces that it is wrong to see today’s high inequality as a product of forces over which we have no control. In this

sense, it is possible to promote technological development, in particular small wind energy, and its positive economic and social results.

Comparing the Brazilian electric matrix with the global one, it is noticed that the main difference lies in the fact that in Brazil there is predominant participation of renewable sources, especially hydraulic energy, as can be seen in Figure 3. The great participation from this source in the Brazilian electric matrix places over the system the concern about the occurrence of droughts since the scarcity of rain will strongly reflect on the capacity to generate electricity and, consequently, on the security of supply.



**Figure 3.** Brazilian and world electrical matrix. Source: adapted from EPE (2019) [9].

In the search for low tariffs, greater diversification of the Brazilian electric matrix, and environmental gains, the new renewable sources of energy have gained greater attention from public management and society. This is driven by the attractiveness of these sources being clean and inexhaustible, in addition to being easily modulated to the localized demands, as well as adjusted to the interconnected market. However, wind farm utilization has been taking place through large parks that make use of wind turbines of great power, according to the Brazilian electricity generation structure that is supported by large load blocks, predominantly hydroelectric, away from consumption centers and interconnected in a national system through long transmission lines. Because of the model, the option for small wind turbines loses competitiveness and its market proves to be incipient.

In Brazil, small decentralized projects are mainly located in isolated systems, not representing a considerable volume in the national electricity supply structure, since the total generation units and the volume generated are still small when compared to the flow total load made available in the system by the large generation units. This means that, in Brazil, the degree of penetration of the small load Distributed Generation is small and with limited incentives.

On one hand, historically, Brazil has adopted the strategy of combining renewable sources and its energy security policies, developing and supporting initiatives aimed at increasing the renewable energy supply of the country and promoting a low-carbon economy, as well as of encouraging scientific and technological advances linked to innovation. On the

other hand, measures are needed to consolidate and expand the renewable energy market, mainly for small wind farms, since the participation of the Country in the international market is still insignificant despite its great potential.

Despite the current consolidation of the large installed power wind market—wind farms—in Brazil, small wind power is still in its early stages, with little experience, unlike China and the USA that have 732,000 and 160,995 units installed, respectively. At the end of 2015, there were approximately 991,000 small wind turbines installed worldwide [24].

Even in the face of the timid growth in relation to China and the USA, it cannot be said that there was no increase in the Micro and Distributed Mini Generation (MMGD) modality in Brazil. According to EPE (2019), in June 2019, the Country reached the milestone of 1 GW in installed capacity in MMGD was reached [9]. Brazilian data, extracted from National Electric Energy Agency (ANEEL) [25], point to a greater demand for the photovoltaic source, when the subject refers to distributed micro or mini generation, as shown in Table 2 below.

**Table 2.** Consumer units with distributed generation until February 2020—Brazil.

Type	Number of Plants	Quantity of CUs That Receive the Credits	Installed Power (kW)
Hydroelectric	101	8473	97,681.80
Eolic	61	105	10,401.86
Photovoltaic	183,780	231,045	2,129,009.25
Thermoelectric	213	4527	63,158.04
Total	184,155	244,150	2,300,250.95

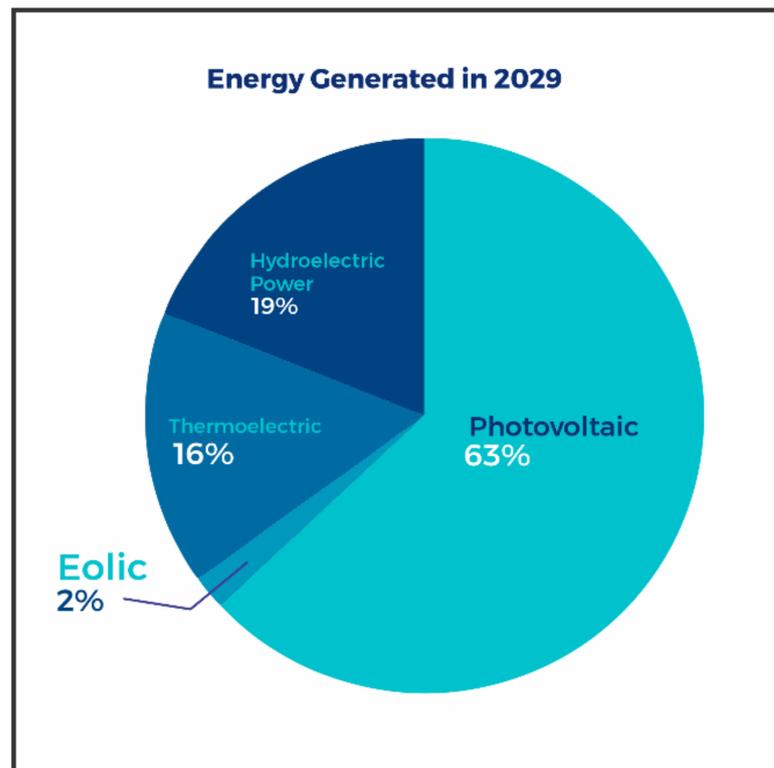
Source: Adapted from ANEEL (2020) [25].

Data made available by EPE [8], extracted from the ten-year electricity plan 2019–2029, also indicate a significant growth of this MMGD modality, mainly due to the high potential of renewable sources, the quality of national energy resources, and the high value practiced in tariffs. The expectation, according to applied modeling, is that in 2029 about 1.3 million users will adopt the distributed micro and mini generation system, which should mean a generation of 2300 average MW, representing 2.3% of the total national load, with approximately R\$ 50 billion in private investments.

The study also demonstrates that photovoltaic solar energy should continue to represent the largest share of the modality. It should be noted that there is a great potential for the participation of wind energy considering its competitiveness in a basket of technological options of renewable basis. Figure 4 shows the expectation of electricity generation by MMGD source, at the end of 2029, as presented by EPE [8].

In order to have a greater advance of wind energy in the form of distributed micro and mini generation, the technology applied will be a decisive factor for its increase. Currently, commercial models of large wind turbines use the orientation of the horizontal axis, making small wind turbines more versatile, as they are marketed with a horizontal or vertical axis, being the horizontal design significantly more common according to World Wind Energy Association (WWEA) [24]. Despite the considerable number of models above 10 kW, most commercial models available are below 5 kW. Only 25 manufacturers worldwide have the capacity to manufacture turbines between 50 kW and 100 kW.

The generation of electrical energy through small wind turbines is close to the daily lives of people, as its technology does not require large areas or transmission lines. In addition, they are suitable for smart grids in the context of distributed power generation, and the maintenance of the turbine is stable, with little vibration and noise. Its electromechanical performance is improved when it is combined with other sources to compose a hybrid system [25].



**Figure 4.** The expectation of generation of electric energy by the Micro and Distributed Mini Generation (MMGD) source, at the end of 2029. Source: Adapted from EPE (2019) [8].

The technological development of small wind turbines has been significant, which is proven by the different types, sizes, and techniques of the control devices. However, these devices are little widespread. The two main small wind technologies are horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). HAWTs are better known for having better performance in addition to the best cost-efficiency ratio, favoring their integration into the built environment. VAWTs, on the other hand, are less efficient at converting wind kinetic energy into electrical energy. However, they are more resistant and their integration is better accepted by developers and users. They are safer due to less vibration and, finally, they take better advantage of the typical turbulent wind on the roof of built environments [26].

The International Electrotechnical Commission (IEC) defines, in the IEC 61400-2, the standard SWT as the one that has a swept area of the rotor smaller than 200 m<sup>2</sup>, a value that is equivalent to a maximum rated power of about 50 kW [27].

Several countries establish a local standard for SWT. This difference in standard places the SWT classification among the countries with the largest markets at the extreme limits of 15 kW to 100 kW. The standard that limits the SWT to 100 kW is more recurrent and it reflects the standard imposed by the leading North American and European markets.

In Brazil, differently from the world trend that classifies the SWT based on its dimensional aspects: geometry or nominal power, ANEEL defines micro generation as the one that uses wind turbines with nominal power less than or equal to 75 kW. For the distributed mini generation, the installed power must be greater than 75 kW and less than or equal to 3 MW hydroelectric generation, or less than or equal to 5 MW for other renewable sources. Different classification standards are shown in Table 3 below.

**Table 3.** Small wind turbine classification standards.

SWT Classification Location	Rating Institution	Classification	Maximum Rated Power kW
International	IEC—International Electrotechnical Commission	SWT	≈50 Rotor < 200 m <sup>2</sup>
EUA	AWEA—American Wind Energy Association	SWT	<200
Canada	NRCan/CanWEA	Min Wind	0.3–1
Germany	BWE—Bundesverband WindEnergie	SWT	<75
United Kingdom	RenewableUK	Micro Wind	0–1.5
		SWT	1.5–15
		Small-medium Wind	15–100
China	REEP—Renewable Energy and Energy Efficiency Partnership	SWT	<100
Brazil	National Electric Energy Agency—ANEEL	SWT	<500
		Medium wind	≥500 < 1000
		Large wind	≥1000
		Micro generation	<75
		Mini generation	≥75 ≤ 5000

Source: Own elaboration based on References [24,25,28].

According to ANEEL [29], small wind turbines are below 500 kW, medium wind turbines between 500 kW to 1000 kW, and large wind turbines above 1 MW. In general, small wind power is used up to 30 m and the production of electricity depends on the capacity factor of the location.

The use of renewable energy sources has been increasingly encouraged in the world, especially in the USA and in many European countries. The inclusion of small wind turbines in the electricity grid has been encouraged by government agencies to contribute to the fulfillment of the goals established to reduce air pollution and greenhouse gases. The adoption of distributed generation means that the consumers are no longer passive elements of the electricity grid: they become an active part and a "silent revolution" that makes generation planned beyond the paradigm that supports the generation of electricity by "large blocks of energy". In this environment, the growth of the small wind turbine market can also be attributed to the search for decentralized solutions for electricity generation, due to the increase in fossil fuel prices and environmental issues that are involved in the conventional energy generation process.

### 3. Materials and Methods

The followed methodological path is based on the hypothetical-deductive method of Popper [30], so-called for dialoguing with the deductive and inductive methods. Thus, it seeks to bring together aspects that are explored in different formulations related to the object of study in order to structure hypotheses to be investigated. Its objective, therefore, is to generate knowledge aimed at practical application, as it seeks answers to solve local interests. Regarding study objectives, it has a scope of explanatory research work since it seeks to explain the reasons for the study and to identify aspects that favor the occurrence of the phenomena [31].

The technical procedures used bibliographic search for making use of published material, consisting mainly of books, publications in journals and scientific articles, dissertations, theses, and material obtained through the internet. Finally, the way of approaching the problem is characteristic of qualitative research, in which the data collected allow to portray elements that lead to the examination of the studied reality [31].

The usual bibliography of the authors was started by (re)visiting and consulting digital information banks, in which articles and other documents were searched by keywords

or by all of them, namely, Small Wind Turbine, Wind Power and Wind farm; associated with Brazil: productive arrangement, action Strategies, incentive mechanisms, and market potential. In this first stage, it was already possible to confirm an assumption that gave impetus to the construction of the object of research despite the recognition of the significant wind potential in Brazilian territory, whose use is guided by public policies that encourage large undertakings, leaving small wind turbines a marginal presence, which puts this market at an early stage, far behind in relation to what occurs in countries that develop concurrently their production parks with large and small wind turbines. This statement is corroborated by the National Bank for Economic and Social Development (BNDES) [32], accounting for only 9 companies operating in the small wind turbine market in the country.

Following the methodological path adopted, the selection of publications that are relevant to the research area was conducted, as well as the inclusion of studies, documents, reports, and official data with links to the small wind turbines object in Brazil, and, thus, the analysis between the conceptual basis, data, and the research problem was formulated.

When evaluating the publication metrics of a theme/research area, the use of “exploratory research” is recurrent, particularly in the most well-known services and available in the world network-WWW. Such tools define a small set of scientific journals that are monitored. Therefore, only articles published in these journals are monitored. As the criteria for a journal to be included in indexing are sufficiently rigorous, the very fact of a journal is indexed already means an endorsement of its quality.

When searching for the term “small Wind Turbine” in the Google Scholar Service [33] considering the period from 2010 to 2019, 38,500 documents in English were observed, while in Portuguese there were only 134 references,

In searching for “Small Wind” in the Science Direct Database, the publication of 2445 articles was obtained for the same period, only 113 (4.6%) of which had “Small Wind” in its title, and of this total only 28 deal effectively with aspects linked to the planning of the expansion of the SWT, as well as to social, economic, and environmental impacts of this technology. In this same search, the remaining 2310 articles deal with technical, aerodynamic aspects and the survey of wind potential, renewable energy, and related topics, without focusing directly on SWT. It is noteworthy that this search did not indicate the publication of a single article regarding research on SWT in Brazil [34].

On this same path, when searching for “Wind Energy” or “Wind Power”, in the Science Base [34], the total number of publications reaches about 22,000 articles, whose studies concentrate on great improvements in their aerodynamic aspects, gains efficiency, and wind potential.

On the MDPI Basis, the search for “Small Wind”, between 2010 and 2019, shows 59 published articles, 13 articles on “small Wind” in their titles, but only 7 of them focus on the planning and expansion of SWT, as well as on social, economic, and environmental problems. There are not also, in such a period, articles on SWT in Brazil. However, searching for “Wind Energy” or “Wind Power”, there are, in the same period, about 900 published articles, also directed to great investments, aerodynamic studies, improvement of performance and efficiency, as well as on wind potential [35].

This methodological approach provides us with objective evidence according to which knowledge production about the improvement of STW in Brazil is still embryonic despite all impressive advance that has been registered by the large wind enterprises in the country and also in spite of all attractive, social, economic, and environmental potential of SWT. This provides revision research studies with an innovator role in the development of knowledge regarding the SWT improvement in Brazil.

## 4. Discussion and Results

### 4.1. Productive Arrangement

Wind turbine manufacturers can be integrated or not and produce one or more components. In this market, components are often subcontracted and used by nacelle manufacturers, that assemble the equipment. Nacelle manufacturers have the technology

associated with the production of wind energy and are, therefore, responsible for the performance of the turbine and for the choice of blades and towers when these components are subcontracted. Technological variations related to the different internal devices of the wind turbines are mainly associated with the existence or not of a gearbox and power control systems.

An analysis of the market for small wind farms in Brazil shows that a small number of companies stand out: Enersud, WEG Electrical Equipment, Wind Canoas, ZM Bombas, and Suma Engenharia—Installer/Designer. They are still in the embryonic process of consolidating their products and processes and require efforts to achieve solidification in the medium term. It is important to mention that, unlike the sector of great wind power, in which the supply chain is very segmented, small wind energy manufacturers need to offer services and products together with the sale of small wind turbines, distancing them from specialization and reducing their production costs. Some supply chain activities are design, component production, assembly, prospecting, and execution of projects.

It should be noted that the rapid growth of wind energy in the world is also directly associated with the development of composite materials (MC), the most common being resin [36]. When looking at the small wind energy production chain in the country, this requires a better structuring in terms of its suppliers, in this context the supplier of resins (composite material) for the manufacture of the blades is inserted, considering cost and guarantee of supply. Another challenge associated with technology in the country is the structuring of manufacturers of towers for SWT, in addition to reliable and competitive generators. Such factors may limit the maturation of this market in the country, giving space for the import of equipment (off-the-shelf X components manufactured in-house) [37], and reducing its positive developments in the generation of jobs and local income and regional.

A research study conducted by Pereira et al. [20] shows that the capacity of most models manufactured in Brazil varies between 1 kW and 6 kW, similar to 80% of the small wind turbines commercially available in the world [25].

Most small wind turbine models have a horizontal axis, with only one model using a vertical axis (1.5 kW model). Unlike large wind turbines, with more than 8,000 components, small wind turbines are characterized by less industrial complexity with vertical integration, and most components are produced in the country. It is worthwhile to mention that the inverter is still imported, representing up to 30% of the final price and, therefore, a barrier to the industrial process.

Profitability is essential for a company to continue operating. Therefore, it is necessary to identify ways to maintain it, considering a long-term perspective. In addition, the relative position of the company in the sector will determine its behavior in relation to other companies, mainly foreign competitors due to imports.

When analyzing the reality of the Brazilian sector, it is observed that the manufacturing companies have not yet taken measures to increase their competitive advantages, nor to conduct strategic activities with the objective of improving the productive arrangement and reducing costs. Some specific measures were observed in the companies, but they were more directed to individual efforts, not being part of a clear and planned strategic action.

#### *4.2. Barriers and Action Strategies*

The lack of an appropriate legal framework to support the development of renewable sources is one of the aspects mostly mentioned in the literature. Guaranteed access to the distribution network is discussed because logistical and connection costs are higher for small independent manufacturers. This reality also applies to the small wind industry in Brazil, where financing is a strong barrier, as an initial investment by the final consumer is necessary. Another issue is the misperception about renewable sources since the reduction of greenhouse gas emissions is still not considered one of its benefits (not priced). Therefore, some countries such as the UK, Australia, Canada, among others are implementing taxes on carbon emissions.

Research studies on the technological development of small wind turbines in Brazil are not coordinated between institutions and research groups. For this reason, developers, research centers, and universities need to work together to reduce technological backwardness and increase productivity.

The current regulatory framework refers to the federal scope, under the responsibility of ANEEL. Municipalities have no role in matters pertaining to the electricity sector. However, municipal authorities believe in the potential contribution of policies at the municipal level in improving the regulatory arrangement and local incentives.

A study by CEPEL [38] pointed actions aimed at expanding and consolidating possible strategies to stimulate the small wind energy sector, as shown through Table 4.

**Table 4.** Action strategies.

	Actions			
<b>Short-Term</b>	Develop a discussion forum among market agents, facilitating the organization of the sector and decreasing information asymmetry. This activity can be led by a research institution, a university, or even the Brazilian Wind Power Association.	Development or enhancement of database on small and medium wind system installations. This database is partially developed by CEPEL and ANEEL, but complementary information is still needed.	Taxes are essential for the expansion of the sector. States like Minas Gerais have already stopped charging the ICMS tax on electric power microgeneration. We recommend that all states work together to remove this barrier.	Outreach strategies for other society sectors, without restricting it to niches that are essentially technological. This outreach should be expanded to areas related to sustainability.
<b>Medium and Long-Term</b>	Financing lines specific for manufacturing companies and subsidies for possible final consumers, decreasing the impact of the initial investment on the consumer and expanding the scale effect in production.	Development of certifying market is a fundamental issue for the expansion of the sector, giving it more credibility in the eyes of the final consumer.	Development of the Small Wind Potential Map	More diversity of incentives and technology promotion, particularly for tax final consumer.

Source: Elaborated by the author based on Reference [38].

To achieve economies of scale in production, it is necessary to leverage new markets, particularly by encouraging exports. In this context, public policies aimed at foreign trade take greater importance, as well as the interaction with producing companies to reduce the technological gap, accelerating the learning effect.

In order to attract stakeholders to leverage national production, fiscal and financial incentives are still not enough. An institutional framework is also needed to remove some barriers [39]. In Brazil, the Tax on Consumption of Goods and Services-ICMS is calculated over the amount of electricity produced and made available on the grid in almost all states, which is a central issue for small wind power.

Another relevant barrier for the expansion of the energy distributed in the country refers to the need to define taxes for the produced energy. Although ANEEL Resolutions numbers 482/2012 and 687/2015 state that the relationship between the energy injected by microgeneration into the distribution network is “compensatory”, renewable generators of up to 5 MW of capacity are allowed when interconnected to low and medium networks tension, “selling” a surplus of electricity back to the national grid, in exchange for the kWh credit to be recovered in 60 months.

Small wind turbines need more investments in research and development, mainly for their use in low-speed wind regions, as well as in urban and rural areas. NREL [40] has been studying small wind and pumping applications in rural areas for a long time. Moreover, in the early 2000s, it considered small wind power as a more promising technology for pumping water. Small wind turbines are more efficient than traditional windmills and have

fewer moving parts. They are competitive in terms of cost with diesel and photovoltaic systems, presenting low costs of maintenance. Albiero et al. [41] show some technological innovations for low wind speeds in a rural area in the state of Ceará, Brazil. In this research, the authors developed an innovative turbine suitable for irrigation of small properties. It is important to mention that agricultural practice in the semiarid region of Brazil is highly dependent on irrigation and, with the introduction of technological innovations, such as small wind turbines associated with pumping water, it is possible to increase the harvest, in addition to producing electricity, saving financial resources of the farmers.

Together, the development of research associated with the use of small wind energy diffusers is relevant because it can maximize the kinetic energy extracted from the wind. In isolated regions, diffuser turbines are necessary due to the typically low wind speeds. Regions like this are commonly found in the Amazon and are characterized by difficulty in accessing electricity and the application of diffusers. This mechanism provides improvements in turbine performance [42].

Training and the reach of technology are also necessary to allow the technology to be accepted beyond certain niches. Governmental agencies can promote the technology, including a goal of energy consumption generated by small wind turbines in their strategic planning, showing the importance of the sector to society and contributing to generate economies of scale.

Like Europe, Brazil could also adopt a target for the consumption of electricity from renewable sources offered by the sector of small wind farms in the next 15 years. The objective of reaching 0.5 GW of installed capacity in the country with small wind turbines is feasible in the long run, which would allow to consolidate the supply chain and directly contribute to the diversification of the electricity supply in Brazil, strengthening the role of the country as a world leader, regarding renewable energy.

It is worth noting that the State has a great capacity to leverage the demand for a service or product, supporting its technological development, and promoting routes according to its strategic interest. This action is known in the economic literature as “Market Transformation” [43] and, in this context, the goal established in the past of promoting large wind power through Program of Incentive to Alternative Electric Energy Sources (PROINFA) is inserted.

#### 4.3. Incentive Mechanisms

As previously stated, Brazilian regulation on incentives for small wind power plant technologies is discussed in ANEEL, through Resolution 482, of 17 April 2002, with improvement by ANEEL Resolution 687, of 24 November 2015, which define the general conditions for access to distributed generation from micro and mini generation to electricity distribution systems.

Distributed generation is understood as a form of electricity generation, in which this generation happens together with or close to consumers, individually or in partnership, directly connected to the electrical distribution system of the local concessionaire. It can be said that the incentive to distributed generation through renewable sources is a way to stimulate social and environmental awareness, in addition to making the consumption of electrical energy cheaper and self-sustainable and, consequently, allowing it to be made more accessible to all.

In this context, ANEEL, created through Law 9.427/96, has been making efforts to regulate and make distributed generation more attractive [44]. Its resolutions established the general conditions for the access of the micro and mini generation distributed to the electricity distribution systems, also creating the corresponding electric energy compensation system, with the objective of reducing barriers for the connection of these small generating plants (micro and mini generation) to the distribution network. Furthermore, according to what is provided for in these regulations, micro and distributed mini generation consist of the production of electrical energy by means of small generating plants that

use hydraulic, solar, wind, and biomass sources or qualified cogeneration, connected to the grid distribution through the installation of consumer units.

What differentiates distributed micro generation from the mini generation is that in the former there is an electric power generating plant, with installed power less than or equal to 75 kW, while in the mini generation distributed, the generating plants have an installed power greater than 75 kW and less or equal to 3 MW for the water source and above 75 kW up to 5 MW for the other sources: wind, solar, biomass, and qualified cogeneration.

In this context, the resolutions by ANEEL break paradigms since they promote energy compensation—kWh instead of financial compensation, in which the entrepreneur receives a price based on the cost of renewable electricity, similarly to the power system. The power system, adopted by many European countries, has led to the rapid growth of many renewable energy sources at a cost that was often questioned, especially the price that is paid.

As determined by ANEEL Resolution 687, access to the electricity distribution system occurs in accordance with the Energy Distribution Procedures in the National Electric System—PRODIST. This set of guidelines aims at standardizing the procedures for accessing the distribution networks, in which each distributor generally defines its specificities.

To facilitate access to the distribution network, it is not necessary a contract for the use and connection of the generating unit in which it participates in the distributor's power compensation system. An Operational Agreement between the participants, mini generator and/or micro generator and distributor, is sufficient. The signing of the Operating Agreement provides greater flexibility in sending energy by the renewable energy generator that participates in the compensation system. No contract between the generator and the concessionaire determines the amount of energy generated and dispatched. Therefore, the generator is responsible only for the operation in its plant and for the quality of the energy generated by it. The person responsible for the generation unit is also responsible for the connection costs and the energy meter to operate within the compensation system.

The energy compensation system establishes rules to calculate the balance between the offered electricity and that demanded by the generating unit, being this balance the basis for calculating the economic viability of a project in the context of distributed generation, as defined in ANEEL, Resolution 687. Unlike the power system in which a premium rate is obtained through the generation of renewable energy, energy compensation depends on the relationship between the energy generated and the energy consumed, based on the electric bill paid by the consumer. Electricity tariffs are not low for consumers in Brazil—US \$ 0.21/kWh despite the fact that the main source of generation of the national electrical system, hydroelectric, is of low cost. The comparative use of this same cost basis can enable small wind generation in some areas of the country in the short and long terms, depending on the availability of resources.

In general, the energy compensation system is characterized by:

- If the energy generated is higher than the energy consumed in the generation unit, the electricity bill will be determined by the difference between consumption and generation.
- If the energy generated is less than the energy consumed in the generation unit, the excess will be discounted from consumption in the following months.
- If the amount of energy generated was not sufficient to offset the consumption of the generation unit itself, other units that are within the same concession area can be used to offset this consumption.
- The credit for the excess generated in the cleared system expires 60 months after invoicing.

Normative Resolution 687/2015 sought to respond to the call for a new profile of the consumer market, seeking to encourage the growth of photovoltaic technology and of the small wind generation in the Distributed Generation mode. The reclassification of micro and mini generators with new energy limits and the possibility of a shared generation tend to lead the market to create new businesses. The implementation of these new systems and their integration into the constituted environment are notable advances related to meeting

the demands of a new energetic paradigm, inserting MMGD as a tool to be considered in urban planning [45]. In another way, it must be emphasized that many challenges need to be overcome when the expansion of small wind generation in rural areas is projected, as for example, project financing, commercialization of surplus energy generated, training and qualification of specialized labor, and cultural aspects.

#### 4.4. Potential Market

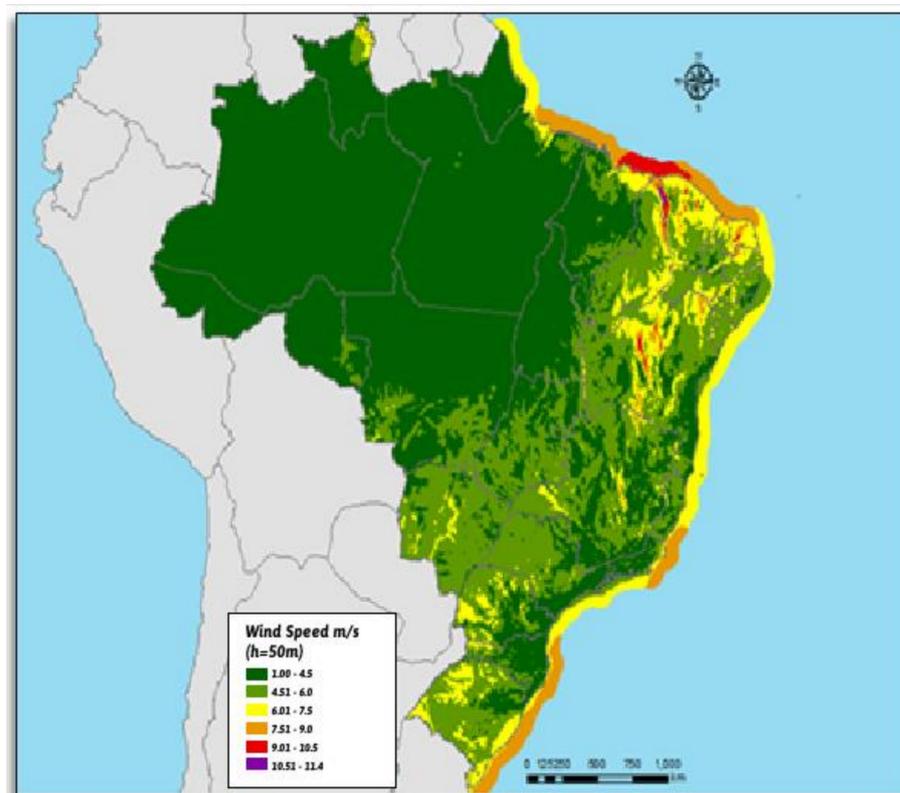
The development of wind energy in Brazil began in 2002. The first wind farms were contracted by the Program for the Stimulation of Alternative Electricity Sources—PROINFA [46]. The objective of the program was to diversify the electrical energy mix in the country, increasing the use of new alternative energy sources. The total wind energy capacity contracted under PROINFA was 1429 MW. According to the MME, it is expected that 39.5 GW of wind energy will be installed in the Brazilian electrical matrix in 2029 [8]. This optimistic estimate is because Brazil has used an intelligent combination of strategies to allow the use of renewable sources and to structure their own production chains. These strategies include guaranteed energy purchase contracts—PPAs and auctions of energy contracts to boost the market for renewable sources, as well as the use of indirect local supply requirements, not imposed by the commercial system, but indirectly by the financing mechanism, operated by the National Bank for Economic and Social Development—BNDES [47].

The distributed generation projects in Brazil, especially those related to small wind power, are still in their early stages, despite the considerable potential of this type of energy in the country. In the 2000s, the government promoted only the large wind industry and this trend is still being maintained, despite some advances in distributed micro and mini generation. Nowadays, the projects of small generation plants distributed in the country can be analyzed by using information from the Generation Information Bank—BIG of ANEEL. According to data from ANEEL [25], until February 2020, as shown in Table 2, only 61 small wind farms, a total of 10,401 kW, were registered in the category of distributed micro generation or mini generation. Likewise, at the end of the same period, 183,129 solar photovoltaic projects, a total of 2129 MW, had already been registered in the same category [9]. The country has not yet made significant use of its full potential of renewable sources for application in the distributed generation. The current scenario also arises from the high costs related to equipment, and lack of knowledge about available technologies, in addition to the absence of public policies aimed at the promotion and effective stimulus to small-scale distributed generation.

It is important to note that Brazil stands out for its great wind potential and, according to estimates produced by CEPTEL [48], it can reach 143.5 GW when its potential at a height of 50m is counted and wind speeds of up to 7 m/s.

It should be noted that the new Atlas of the Brazilian Wind Potential [14] shows the wind potential of small turbines, at 50 m high in rural and urban areas—Figure 5. Considering the information from the new Atlas, there is no doubt that the Northeast of Brazil has the best wind regimes for the application of small wind turbines, with many areas above 5 m/s speed, average of the year. Undeniably, towers with 50 m in height increase productivity and offer better project performance when compared with those ones with 20 or 30 m [49].

The Brazilian wind atlas allows inferring that the regions with the greatest potential are in the entire coastal region with the highest incidence of quality winds (speed and direction) on the coast of the Northeast Region, where the states of Ceará and Rio Grande do Norte. Other areas of attraction are observed in higher altitude territories (mountains and plateaus) with emphasis on the central regions of the Northeast or South-Southeast.



**Figure 5.** Wind Energy Potential—Brazil (50 m). Source: Elaborated by the author based on CRE-SESB (2018) [14].

When assessing the wind potential for height, initially at 50m, and more recently at 100 m, it is evident that the conceptual basis provided by public management and adopted in the construction of the Wind Atlas is preferably oriented to large wind farms. This is because the SWT makes use of towers of heights less than 50 m [13,14,50].

The map shown in Figure 5 shows Brazilian wind atlas wind speeds at 50 m. For use at a height of less than 50 m, which is the case for small wind turbines, it is possible to make use of the wind data shown in Figure 5 and, using Equation 1, it is possible to extrapolate these speed values and obtain the speed at the height desired.

$$V(h) = V(50) \frac{\ln\left(\frac{h}{z_0}\right)}{\ln\left(\frac{h_{50}}{z_0}\right)} \quad (1)$$

where:

$V(h)$  = wind speed to be determined at height  $h$ ;

$V(50)$  = the known wind speed at height  $h$  50 m;

$h$  = the height where the wind speed is unknown;

$h_{50}$  = the height for which the wind speed is known; and

$z_0$  = terrain roughness in the study area.

In addition to the rural application, there is enormous potential in urban areas. Unlike vast rural areas, urban locations offer many locations for mounting small wind turbines. These existing urban structures replace dedicated posts which, on average, represent 40% of the total cost of small wind systems. This is an interesting area of research and development and, with a partnership between universities and research centers, it is possible to accelerate technological innovations and reduce costs.

The civil construction codes for different built environments must be reviewed and recommendations must be made considering the operation of small wind turbines in urban environments. Therefore, more studies should be conducted to clarify all the legal

structures necessary to increase this application. In Brazil, municipal governments continue to disregard energy planning, losing space for interaction with agents, and do not promote actions that are more focused on local demands. This behavior discourages private actions in this type of enterprise: legal barriers increase risk and create uncertainty, increasing the rate of return required by the entrepreneur.

In fact, the use of small wind turbines in urban areas faces many challenges. There are several bottlenecks regarding the development and installation of wind turbines in urban spaces. The bottlenecks were grouped around some important aspects, namely, technologies, projects, costs, attitudes, and turbine licenses. In contrast, according to CACE [51], these technologies are suitable for small-scale power generation in places where there is no room for large turbines. In addition, small wind turbines should not be seen as technology competing with large turbines, but as a complementary technology. The electricity generated can be used at the installation site and the building owner can use it as a message to the public in support of more sustainable technologies. In the Netherlands and the United Kingdom, small wind generators in urban areas are also present as a complement to solar photovoltaic energy.

The potential for expanding small wind turbine applications in homes and small businesses is considerable. However, many challenges related to the market remain: such as lack of incentive policies and the need for technological development.

In these terms, Table 5 shows the number of households in Brazil, both in urban and rural areas, with access to electrical energy. The data for the year 2010 are absolute figures available in the 2010 census [51]. The figures for 2018 result from the values computed by the National Household Sample Survey [52]. When projecting the year 2029, for simplification, the same percentage of the number of households with electricity obtained from 2018 was used. However, the total households projected for that year 2029 was extracted from the simulation of the 10-year Energy—PDE 2029 [8].

**Table 5.** Evolution and projection of the number of residences in Brazil.

Scenario for Use of Small Wind Turbines in Residences	Base Year: 2010		Evolution: 2018		Projection: 2029	
	Total (Million)	%	Total (Million)	%	Total (Million)	%
<b>Potential Market</b>						
Total Number of Residences	62.8	100.0	71.0	100.0	86.7	100.0
Residences with electric power	61.4	97.8	70.8	99.7	86.4	99.7
Occupied private residences (base)	57.4	91.4	64.7	91.4	79.0	91.4
>Urban Residences	49.3	85.9	55.6	85.9	67.8	85.9
>Rural Residences	8.1	14.1	9.1	14.1	11.1	14.1

Source: Elaborated by authors, based on References [5,8,52,53].

Table 6, in turn, shows a scenario of the potential of the residential market in the country capable of making use of small wind turbines to produce electricity. These estimates were based on the indication of the World Bank [5], according to which 35% of the rural population and only 4% of the urban population use alternative energy solutions outside the conventional grid. For the number of existing households, data from the Brazilian Institute of Geography and Statistics-IBGE [52,53] were used. However, as already explained in the previous paragraph, because there are not more updated data, we used information from 2010 and 2018 as premises for a possible scenario in 2029. Moreover, the year 2029 as a projection is based on PDE 2029.

**Table 6.** The potential residential market for small wind turbines in Brazil.

Residences—2029	Total (Million)	%	Overall Penetration Rate	Total Households (Millions)	Penetration Rate for Wind Energy	Potential Wind Energy Household
Occupied private residences (base)	79.0	100.0	—	—	—	—
>Urban Residences	67.8	85.9	4%	2.7	5%	135,670
>Rural Residences	11.1	14.1	35%	3.9	5%	194,857
Estimate of residences for the use of SWT						<b>330,527</b>

Source: Elaborated by authors, based on References [5,8,52,53].

The number of occupied private households was used as the basis for the projections, as there is more probability that the owners of these properties, when encouraged, may be interested in investing in new electricity generation technologies. It seems that the same interest may not occur in residences that are not occupied.

Therefore, based on the 2029 projection and using the general penetration rate indicated by the World Bank [5], there is a possibility that a total of 2.7 million urban households and 3.9 rural households acquire new technologies for their own electrical generation, regardless of whether it is used in isolation from the conventional grid or even as distributed generation. Considering, however, that part of this group will obtain other generation technologies or simply will not have enough reasons to have their own source of energy generation, a penetration rate was used for the acquisition of small wind generators, of modest 5%. With this penetration rate of small wind generators over the general penetration rate, it is still possible, in the horizon until 2029, to reach 330,527 houses in Brazil with potential for the use of small wind turbines that, projecting the use of a turbine of 1.5 kW, the estimated total installed capacity would be approximately 0.5 GW, corresponding to about 0.2% of the installed capacity of the Brazilian electricity sector projected for 2029 which, according to EPE [8], should reach 251 GW.

The number of 330,527 households that could use small wind turbines by 2029 is attainable and even conservative, mainly when we consider that it represents the exploration of a potential market that represents less than 5% of the total market.

It should be noted that this estimate is not intended to exhaust the subject. This study seeks to obtain space to reinforce the need to elaborate a more detailed and exhaustive model, considering the production of wind energy at different heights, different turbine power curves, as well as the capacity factor and wind profile, to evaluate, through multi-criteria analysis, how to better explore the wind potential for small wind turbines in Brazil and their economic impacts. The structuring of a detailed model can assist future public policies in the sector, aiming at the implementation of best practices to increase competitiveness, in addition to measures to stimulate the market for small wind turbines in Brazil.

It is the obligation of the concessionaire to connect to the residential segment, in accordance with ANEEL Resolution 482/2012. Other actions are performed by the contractor. Daytime fluctuations are compensated by the grid in the compensation system. The focus of the work is based on the current economic reality in Brazil, in the current regulatory framework, opening space for discussions and indication of complementary studies.

Given the importance of companies to the economic system of countries, ensuring their maintenance in the economy becomes a matter of public interest, becoming a real governmental challenge. Thus, there are demands for public policies aimed at strengthening and developing the business basis. Therefore, this search led, in some countries, to the adoption of public policies that propose the use of goals to promote certain technology.

Brazil has been working with renewable sources for energy production for over 70 years. However, its programs must be continually updated and revised for future needs [54]. This strategy is recurrent in the Brazilian energy sector, such as PROALCOOL, which stimulated the production of alcohol for the needs of the national automotive fuel

market, PROINFA, which encouraged the development of alternative renewable energies, the National Program for the Production and Use of Biodiesel (PNPB) aimed at introducing biodiesel into the Brazilian energy matrix with focus on social inclusion and regional development. Moreover, more recently, RENOVABIO, whose objective is to expand the production of biofuels in Brazil, is based on predictability, environmental, economic, and social sustainability, and compatible with the growth of the market. Such strategies can also be applied to small wind turbines in order to further promote low carbon technologies in Brazil. In the context of market transformations, this is a political objective of encouraging or inducing social, technological, and economic changes in the direction of greater energy efficiency, promoting, in this case, new renewable energy technologies for decentralized use.

#### 4.5. Social Acceptance

Social acceptance is a concept built with the attempt to capture and evaluate the degree of importance that a given situation or fact has on a set of social actors [55]. The analysis and knowledge of this behavior can provide useful elements in reducing barriers to the consent of the social groups involved, as well as increasing the interest for its consolidation and expansion.

The first challenges regarding social acceptance concerning the implementation of energy projects are motivated by the socio-environmental impacts resulting from the use of conventional energy sources—with an emphasis on those derived from fossil resources, as well as the exhaustible nature of these sources.

The conflicts generated by the location of nuclear power plants and the disposal of nuclear waste generated, as well as the wide-ranging impacts arising from large hydroelectric dams have enabled renewable energy technologies to enjoy a high level of support in society in general, thus allowing the neglect of the approach regarding Social acceptance of such technologies until the 1990s.

This creates an environmental thought in which energy sources and their technologies were classified as: (i) “appropriate” (renewable solar, wind and biomass, and hydroelectric with restrictions); (ii) cyclically acceptable (small scale fossil fuel plants); (iii) inadequate—Centralized plant grids, with an emphasis on nuclear power plants [56,57].

The concept of Social Acceptance is diverse in the literature. Authors, such as Chataigner and Jobert [58], point out that the use of the term Acceptance is a disguised way of scanning the real object of the research, that is, what is wanted to know for sure is the level of rejection of technology by the different actors, but the correct use of the term Social Unacceptability would be in advance recognizing the existence of incompatibilities of the project with the interests of the social group involved.

From the set of possible and usual definitions of the concept of Social Acceptance [59,60], it points out that the same is revealed in a favorable behavior or in attitudes and positives towards the technology in question, or even the arrival of the enterprise, by the different actors that make up the territory, as well as the structured social unit and/or its representative entities. This approach is adherent to the three dimensions recurrently addressed in studies of social acceptance of renewable energy technologies, as seen in References [55,57,59,61,62], which are: (i) market acceptance; (ii) socio-political acceptance; (iii) community acceptance. This reflects the acceptance of specific siting decisions and energy projects, particularly by residents and local authorities.

As far as wind energy is concerned, this technology enjoyed a high level of acceptance when operating on a smaller scale of wind turbine power. However, with the increasing use of large wind turbines and in greater density—consolidating the concept of wind farms—in the areas of its location, the initial attraction that gives it socio-environmental prestige shows signs of wear.

Its reduced power density, compared to conventional sources, results in high demands for land, resulting in a smaller scale of energy supply per generation center. In this way, to expand its market, its presence in the territories is expanded, approaching the consumption

center, giving greater visibility to its operation, and with this, it increases its dependence on environmental socio-political decisions.

On the other hand, the operation with small wind turbines in the configuration of mini and micro generation and the demand for land is limited to private spaces, without compromising other actors located in the vicinity. On the contrary, it conforms to an intramural decision, limiting the choice to a small number of users or investors, which considerably restricted possible conflicts in the tripod of social acceptance.

In Brazil, the wind energy market is driven by public policies exclusively focused on large developments on the technical concept of “wind farms” interconnected to the interconnected network. In this environment, STW remained at the margin of the government support process, followed at a stage outside the discussion linked to social acceptance, given its reduced market penetration, as well as the nature of the individual choice of technology.

Wind energy also enjoys a high level of acceptance in Brazil, when operating on a smaller scale of power per wind generator. However, with the increasing use of wind turbines with greater power and greater density in the areas of its location, the initial attraction that gives it socio-environmental prestige shows signs of wear.

Its reduced power density, compared to conventional sources, results in high demands for land, resulting in a smaller scale of energy supply per generation center, which, in order to expand its market, expands its presence in the territories, approximates from the consumption center, giving greater visibility to its operation, and thereby increasing its dependence on environmental socio-political decisions [56]. On the other hand, for the operation with small wind turbines, in the format of mini and micro generation, the demand for land is limited to private spaces, of individual choices, where the decision of its location does not affect a large portion of interested parties; on the contrary, it depends on reduced numbers of customers, often unitary, or investors.

The establishment of standards for access to energy distribution systems through distributed micro generation and mini generation, from renewable sources, through Normative Resolutions No. 482 of 2012 (ANEEL, 2012) and No. 687, of 2015 (ANEEL, 2015) has the potential to demand attention to the issue of social acceptance for SWT. This is because these resolutions establish a compensation system for electric energy generated by the consumer unit, with micro generation or mini generation distributed with or renewable sources of electric energy [44].

To the American market, the Distributed Wind Energy Association (DWEA) [63] evaluates that the distributed generation, from the wind power utilization through small aerogenerators, presents potential to create 150.000 jobs throughout the whole country and contributes with the addition of 30 GW of installed capacity widespread throughout the whole territory by 2030. Thus, advocating that this way of generation may become the most indicated option to make North-Americans become prosumers, namely, people who also produce their own electricity, in a clean way, fostering national economy through the use of equipment produced in their own country.

To reach this goal, the support of public management to SWT is necessary, just like it has already happened with other renewable energy technologies. Public policy pointed by DWEA encompasses: (i) Provision of Tax Credit with extended terms; (ii) Budget increase of the Energy Department to Research and development (RD&D) in distributed wind energy; (iii) Encourage states and public companies to promote the use of distributed wind energy.

The introduction of the “prosumer” figure in the distribution system, understood as that consumer who also produces electricity and can supply the distributor’s network [64] has already counted in Brazil the entry of countless residential and commercial consumers, where it stands out if the photovoltaic solar technology with the increase of 867.81 MWp installed in 82,380 units, accounting for 86% of the units connected in the system and until June 2019. The decentralized wind units in this period totaled only 57 units, totaling 10.31 MW [65]. With the regulatory attractions of the distributed generation, the SWT has the potential for expansion, which puts on the screen the necessary attention to social

acceptance, hitherto shadowed by the dedication given to the large wind farms, as well as the maintenance of the high level of acceptance that STW stands for keeps enjoying [13].

## 5. Conclusions

This review article reaffirms the need to make efforts so that small wind power can gain space as an object of research and development in Brazil so that this technology can establish itself as a growing alternative in the electricity supply matrix in the country.

It is important to emphasize that there is still little interest in this technology, which reflects and is reflected in the markedly modest production focused on this object. In this context, the article ratifies the assessments according to which SWT is embryonic in the country. Moreover, it demands, so that its expansion occurs on a rational basis, from a socioeconomic and environmental point of view, that public management plays a prominent role in the proposition and in the implementation of public policies aimed at structuring a regulatory framework that can enhance its development and benefits. Supporting SWT in the establishment of its production chain with national content and structuring training, education, and capacity-building programs, the government will be promoting the expansion of MMGD, adapted to the socioeconomic and environmental demands underway. Thus, the regulatory framework for the adoption of micro and distributed mini generation, which is in formation, emphasized in the research study, can be shaped into an effective public policy in the search for this objective.

It was also found in the research that, for a greater expansion of the small wind turbine industry, in order to make its participation as an alternative for micro and mini-generation, such an expansion will be dependent on the reduction of its technological costs. To that end, it is necessary, in addition to the incentive policy, the interest of investors, the incentive to the improvement of the perception of society regarding the economic and environmental gains of technology, certification, and consumer safety, as well as instruments and models that allow evaluating better the potential for energy generation in the localities.

Public policies and specific financial incentives will determine how quickly the SWT market will develop. In addition, the mechanisms designed should not be limited to net metering or feed in tariffs [37]. Many measures can be adopted to promote the market of small wind turbines, creating a favorable business environment, considering the approximation between companies and research centers-universities, in addition to the possibility of using tax credits, and capital subsidies, among others.

In these terms, it can be evaluated that if technological improvements, certification, and the introduction of financial incentives, such as the feed-in tariff, are implemented in Brazil, its small wind turbine industry can grow substantially, creating jobs and adding value to its low carbon economy.

On the plaintiffs' side, it is necessary to persuade consumers, guaranteeing that the technology is safe and reliable and that there will be a market structure that allows easy access to the maintenance and the purchase of spare parts after the acquisition. It is a fact that, due to the lack of incentives for producers, the low level of sales, and the still high cost of certain imported parts, these market agents end up closing their ventures even before the guarantee of their products is over. Thus, investment alternatives can be compared, using not only their financial results but also their technological and technical attractions and their commercial and after-sales advantages. These elements still need to be better articulated among society, the government and companies, so that greater development of the small wind generation in Brazil occurs. The adoption of a target plan by the public management regarding the demand for energy generated by small wind turbines has additional potential for the development of the sector, as well as for society, since it contributes to generate economies of scale and, with it, socioeconomic and environmental benefits.

The projection analyzed in the survey, based on the World Bank [7], to promote efforts to reach the target of around 0.5 GW, in 2029, of installed capacity in small wind turbines, that is, to reach close to 135 thousand small wind systems installed in urban homes and 195,000 rural homes, is an attainable and even a conservative goal. This is because in the

projection it is being considered only a potential market that represents less than 5% of the total market. On the other hand, considering only the increase in new homes to be built in the projected period, it would be necessary to reach about 10% of these new residential units in the countryside and just over 1% in the urban areas to reach the goal 0.5 GW.

Finally, it is noteworthy that the bibliographic research and the methodology used, present in their results the indication of the insufficiency of technical–scientific information on the subject, reinforcing the need for actions of both public policy and regulation for its dissemination and support, otherwise the industry will remain without relevance. It is also worth mentioning that the results allow visualizing a broad field of growth of this technology in Brazil, such as its application in distributed generation.

It has been concluded through the conducted revision that the possibilities of using small wind turbines to increase the capacity of electric power generation in Brazil are perfectly achievable in the long term, requiring for that an energetic planning with this specific destination and governmental incentives to stimulate entrepreneurs and consumers. Moreover, in this way, it could contribute directly to the diversification of the energy supply of country, further strengthening the role of Brazilian leadership in the global renewable energy scenario.

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