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An overview of incentive policies for the expansion of renewable energy generation in electricity power systems and the Brazilian experience

Giancarlo Aquila[a], Edson de Oliveira Pamplona[a], Anderson Rodrigo de Queiroz[b], Paulo Rotela Junior[c,*], Marcelo Nunes Fonseca[a]

[a] Institute of Production Engineering and Management, Federal University of Itajuba, Itajuba, MG, Brazil
[b] CCEE Department at North Carolina State University, Raleigh, NC, USA
[c] Department of Production Engineering, Federal University of Paraíba, João Pessoa, PB, Brazil

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ABSTRACT

Energy production from renewable sources is already a reality in many countries, and with that, different strategies for incentivizing investments in renewable energy generation have been proposed and used over the years. In this study, long-term policies that have been applied in several countries, such as feed-in tariffs, shares with commercialization of certificates, auctions, and net metering, are overviewed and discussed. The main advantages and disadvantages of these incentive strategies are emphasized, focusing on applications. Some of these strategies that have already been applied in Brazil are analyzed in greater depth, emphasizing the potentialities and fragilities of these mechanisms observed within the country. Even though it is a country that stands out in relation to other Latin American countries regarding electricity generation from non-hydro renewable sources, Brazil still faces barriers that prevent a utilization compatible with its potential. Moreover, the trend for renewable sources, such as wind and solar power, is to represent an energy capacity reserve to cover hydrological risks and also to contribute to a distributed generation spread through electricity distribution networks.

1. Introduction

The limits of the world's oil reserves became a cause for concern in the 1960s and 1970s, especially with the Oil Crisis. It was precisely during this period that the renewable energy sector started to attract investments and increased effort in the development of new technologies in order to become an attractive and viable alternative to replace conventional fossil fuel systems [1,2]. The catastrophic nuclear power plant accident, in Chernobyl, Ukraine, in 1986 also contributed to the change in the planning direction of electrical power generation systems. This accident contributed to the notion that nuclear energy is to be distrusted and considered dangerous, given the seriousness and widespread impact on human health associated with this tragedy. Lipp [3] points out that after the Chernobyl accident, opposition to nuclear power generation increased by approximately 70% in Germany, stimulating a new enthusiasm for renewable energy sources (RES) in the country.

According to Wüstenhagen and Bilharz [4], the accidents that might occur in nuclear power plants were one of the reasons for renewable energy to gain attention, and the interest in accelerating their development continued to increase. After the nuclear power plant disaster in Fukushima in 2011, this issue returned to Japan, with the Japanese government having an urgent interest in finding alternatives to nuclear energy sources through RES [5,6].

Regarding RES utilization, one of the benefits that can be provided is the reduction of society's dependence on fossil fuels, which consequently also reduces carbon dioxide (CO_2) emissions in the environment [7]. Ramli and Twaha [8] add that fossil fuels are getting close to being exhausted and, at the same time, are causing devastating consequences worldwide. Besides this, Bertoldi et al. [9] affirm that renewable energy is intimately related with environmental preservation and climate change mitigation.

In this context, initiatives were observed in recent decades in many countries, including Brazil, to promote a sustainable model of energy generation, mainly related to electricity. In Brazil, the existence of several rivers within its territory favors the predominance of hydroelectric sources for power generation. Hydropower plants contribute to approximately 80% of the country's total electricity production.

* Correspondence to: Cidade Universitária s/n, João Pessoa, PB 58051-900, Brazil.
E-mail addresses: giancarlo.aquila@yahoo.com (G. Aquila), pamplona@unifei.edu.br (E.d.O. Pamplona), arqueiroz@ncsu.edu (A.R.d. Queiroz), paulo.rotela@gmail.com (P. Rotela Junior), marcelonunes21@yahoo.com.br (M.N. Fonseca).

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However, large hydropower dams and their associated facilities have significant socio-environmental impacts, including the widespread blackouts of 2001 and 2002. Since the 2000s, the country has been focusing greater attention on renewable energy sources that differ from large-scale hydropower [1].

Schmidt et al. [10] point out that in the years 2014 and 2015, drought resulted in low levels of hydro plant reservoirs. This event was a determining factor in the increase in electricity prices in the market and raised concerns regarding the ability of the system to ensure that the supply could meet the electricity demand.

Some initiatives have been taken to encourage the sector's development, the most relevant being the Alternative Sources Incentive Program (PROINFA) considered the primary initiative in terms of incentive policy for renewable energy in Brazil [11,12]. Following the PROINFA initiative, other enterprises were developed to encourage RES [13–15] for generating clean energy without the use of large-scale hydropower, which will be discussed in this work.

Thus, this paper discusses the main long-term incentive policies, emphasizing their advantages and disadvantages, with a focus on their relevance and compatibility with the Brazilian renewable energy market.

Section 2 presents the main perspectives for the future development of renewable power generation. Section 3 discusses the main incentive policies used in several countries to attract investments in renewable energy. Section 4 describes the Brazilian experience with incentive policies related to the expansion of renewable energy generation with the PROINFA program and long-term auctions. Section 5 concludes this paper.

2. Perspectives for development of renewable energy generation

According to the warning by Nalan et al. [16], the main barrier for penetration of RES in electric power systems are the high technological costs and the disadvantages regarding cost-benefit in comparison to conventional sources. The economic point of view is fundamental if RES are to supersede technological progress and dissemination of its utilization. Abolhosseini and Heshmati [17] explain that without an economic advantage, renewable energy generation technologies will not be able to compete with conventional sources.

Shum and Watanabe [18] emphasize that efficiency gains regarding a certain product increase along with the user's network. This is no different in the case of technologies for renewable energy generation. The larger the number of users of a certain technology, such as solar panels for example, the more likely the occurrence of knowledge gains is (*spillovers*) and there is consequently a cost reduction for the manufacturers. Besides this, along with the growth of consumers, other potential users tend to feel more secure in using this new type of technology.

Stoke [19] considers this very important to implementing strategies that favor the reduction of technology costs related to the use of RES. The costs in the RES sector are still significant when compared to energy production costs from technologies that use fossil fuels, characterizing a competitive disadvantage for renewable energy without the support of appropriate programs. Incentive policies for RES development are strategies used in many locations, and international treaties, regulatory mechanisms, and incentives for investment are among their attributes [20]. Within this scenario, governments of several countries have been adopting incentive mechanisms for the sector over the last 10 years. Thus, there was a significant increase of investments in RES, mainly in developing countries, according to the data shown in Fig. 1, of which the values are presented in billions of US $.

According to Jacobs et al. [22], several Latin American countries are gradually implementing measures in order to insert a larger proportion of renewable energy into their respective electricity grids, trying to avoid too much dependence on fossil fuels. The REN 21 [23] report about future worldwide scenarios for renewable energy indicates that RES will present a growth in installed capacity until 2035. It is possible to observe in Fig. 2 the evolution of the representative proportion of the three sources of electricity generation in the world.

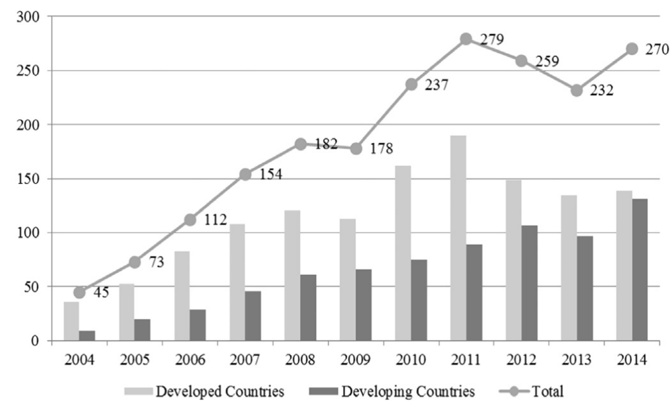

Fig. 1. Investments in renewable energy generation per year. Source: Adjusted from REN 21 [21].

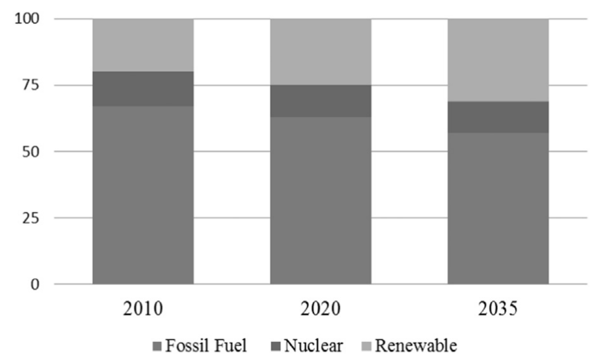

Fig. 2. Proportion of each source in global electricity generation. Source: REN 21 [23].

The study by Islam et al. [24] reveals that the investment cost in wind power generation is an example of renewable generation that presented accentuated reductions over the years. Nielsen et al. [25] affirm that the reduction in costs for Denmark was also significant: by 2003 costs were reduced by 55% of those of the 1980s. During this period, technological innovations have been allowing the development of more efficient turbines at lower costs.

Economies of scale are obtained from the increase of project size and the manufacturing process. More specifically, innovations regarding the material, design, manufacturing processes, and logistics help to reduce system and component costs necessary for wind power generation. Islam et al. [24] affirm that the US, Denmark, Spain, and other European countries had significant cost reductions until the mid-2000s, during which these countries adopted policies to leverage the renewable energy sector. It is worth mentioning that after 2004 until the period between 2007 and 2009, the associated technology costs became unaffordable, mainly due to the increase of energy prices and commodities.

3. Designs of policies and well succeeded applications

Governments may intervene using different strategies to leverage the renewable energy market. Such strategies can be short or long-term. The difference is that short-term strategy investments run out when the strategies are finished, while long-term strategy investments continue even after the policies have been implemented, the latter results are due to the creation of a market.

The most popular types of short-term strategies for the renewable

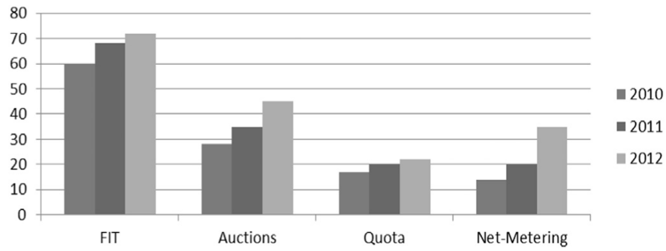

Fig. 3. Number of countries that have policies for promoting RES. Source: Adjusted from REN 21 [23].

energy sector are: direct subsidies, tax cuts for projects that use RES, and charging taxes for a certain amount of CO_2 emissions. As a matter of fact, almost all governmental policies for the promotion of RES involve a mix between short and long-term strategies [5]. However, long-term strategies have greater relevance and end up being fundamental in constructing a new model of production and energy consumption. Among these strategies, the most important and known mechanisms for promoting renewable energy in the long-term are divided into three categories: feed-in tariffs (FITs), auctions, and the quota system.

As observed in Fig. 3, there was an increase in the number of applications of policies supported by these three mechanisms, and also for applications of the net metering system at either a national or state level between 2010 and 2012. The main advantages and disadvantages of these four mechanisms and their potential for inserting RES into the electricity grid will be reviewed in this section, with a special focus on developing countries.

3.1. Feed-in tariffs

Several authors in the literature clarify that a good policy is necessary to develop and utilize RES, and in this sense, FITs present higher efficiency in promoting these sources, providing stability, and ensuring financial security for energy producers [8,26–31]. Due to these reasons, FITs have been applied in countries that have been employing strategies to promote RES use, mainly in developing countries, as it can be seen on Fig. 4.

Couture and Gagnon [33] emphasize that among the main properties of policies based on FITs, there are: the guarantee of access to the electric power grid, contracts that establish the energy supply in the long-term, and calculated prices based on levelized costs of energy generation compatible with each source. Table 1 shows the most advantageous characteristics that can be incorporated into a policy supported by a FIT.

An interesting approach that can be incorporated into FIT-based policy is one that Germany uses and has been serving as the reference

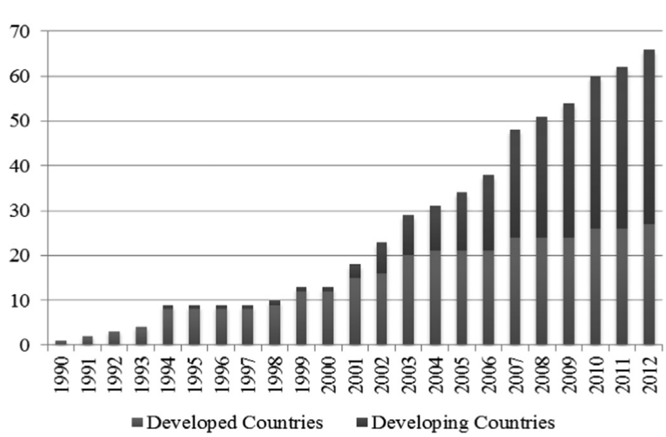

Fig. 4. Amount of developed and developing countries that use FIT. Source: Glemarec et al. [32].

for FIT applications the world over: the periodic reduction of prices or digression. This property can be decisive in determining the efficiency of a FIT application. According to Lipp [3], the reduction of the remuneration paid to the producer throughout time assigns higher competitiveness to the technology manufacturers, and moreover, it also makes the FIT program less financially onerous to the final consumer.

Regarding policies with FIT utilization, Germany offers a successful example in this application. Mabee et al. [37] and Büschen and Dürrschmidt [38] emphasize that with a simple and basic structure offering minimum remuneration taxes as prizes for generation of green electricity, the *Erneuerbare-Energien-Gesetz* (EEG) was consolidated as the most successful program for promotion of renewable energies, on a national and worldwide level. Fig. 5 shows the increase in growth of RES in Germany, during the period between 1990 and 2012. While not specifically shown here, it is an interesting note that only tidal energy and geothermal sources did not reach 100 GWh until 2012.

Lehr et al. [40] mention that the German FIT program significantly contributed to job generation derived from the sector's growth, mainly those related to civil construction, technology, and also public jobs. According to Sovacool [41], Enercon, one of the main producers of wind power generation technology in Germany, expects that the number of jobs created in the renewable energy sector will reach a baseline of 710,000 jobs by 2030, which is equivalent to the number of jobs created by the German automotive industry.

The German FIT program was very successful in promoting RES use, which was evident by the fact that the contribution of renewable energy to the electricity grid increased more rapidly than what was predicted. Büschen and Dürrschmidt [38] emphasize that in 2007, RES contributed 14% of German electricity generation, surpassing the predicted goal of 12.5% until 2010, a significantly higher contribution.

However, it is necessary to highlight that another determinant factored into the success of the German strategy through FIT, and that was the stability and the continuous improvement of the program. A study by Jacobs et al. [22] presents examples of countries from Latin America and the Caribbean not obtaining the same efficiency as Germany, due to the formulation of inadequate strategies, in addition to regulatory instability and politics that impair the strategies. Therefore, it is worth mentioning that poorly designed policies can turn FITs into expensive options for the final consumer, in addition to not producing the desired results.

3.2. Quotas with commercialization of certificates

A quota-based approach requires a certain amount of energy be generated through RES. In this mechanism, the producers of clean energy receive a marketable certificate for each unit of energy generated. Abolhosseini and Heshmati [17] explain that instead of what occurs in FIT and auction arrangements, RES policies based in a quota system do not have a guarantee of energy purchase by the government and instead trusts in the private market to absorb the energy generated.

The *Renewable Portfolio Standard* (RPS) is highlighted as the main category among the mechanisms related to the quota system [5]. The RPS is characterized as an approach based on the market and is administratively efficient. Keeping this in mind, RPS depends on private investment but also relies on government support to establish quotas to promote RES growth [34].

One of the most known variants related to the quota system is the commercialization of green certificates. In this mechanism, the green electricity produced is measured and certified by a certification authority generally controlled by a government agency. The process is similar to a bank account in which the energy produced is saved as a credit [2]. It is worth mentioning that commercialization of certificates has been applied in international scenarios, for example, the Clean Development Mechanism (CDM) established through the Kyoto Protocol. The CDM is designed with the objective of channeling foreign

Table 1
Main producer advantages that can be incorporated into a FIT program.

Characteristic	Description
Guarantee of connection to the electricity power grid	Energy producers are guaranteed a connection to the electricity power grid. Generally, standard and transparent rules are already established for the connection process.
Priority in the connection and distribution	The process to insert new projects in the transmission system is generally long. FIT projects, however are given priority connection and distribution rights.
Guarantee of purchase for produced energy	Generator agents are guaranteed a 100% purchase rate of the energy they produce. This may be accompanied by rules to avoid cuts and interruptions in the contracted energy supply.
Duration of long-term contracts	Long-term contracts avoid exposure of revenues from renewable energy projects, considering the volatility of electrical energy prices. Generally, the contracts last according to the lifetime of the project's technology, thus avoiding the need for contract renovations when the deadline of the current policy is terminated.

Source: Jacobs et al. [22], Abdomouleh et al. [34], Del Río [35] and Jenner et al. [36].

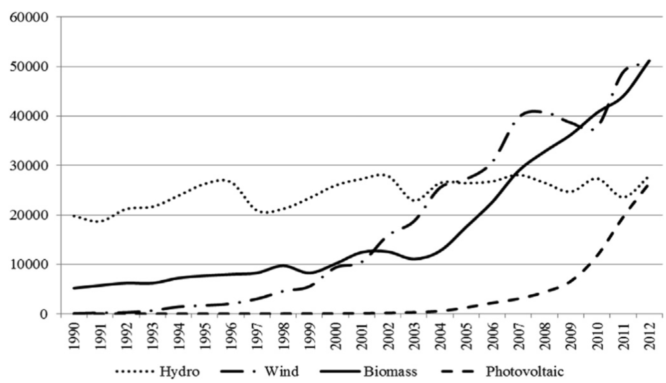

Fig. 5. Growth of gross electricity generated by certain RES in Germany. Source: Adjusted from IEA [39].

investment into non-Annex I countries as designated per the Kyoto Protocol.

Watts, Albornoz, and Watson [42] clarify that the CDM established in the Kyoto Protocol in the mid-2000s, reached it peaked in 2010. However, the authors observe that the geographic distribution of hired projects has been unequal, with most projects found in Asia and the Pacific (86%), followed by Latin America (11%). The main necessary change in the mechanism is to improve the clarity and regulation of the requirements for registering with the CDM.

The quota system establishes a general volume for renewable energy generation, however it does not provide a guarantee that all energy will be purchased through the market. Therefore, in this last system, an energy plant can sell off all of the energy it produced at the beginning, and later on it can be replaced by a less expensive energy generation [43]. Besides this, not having standardized contracts creates high transaction costs and the bureaucratic bidding process makes this mechanism more difficult, which is why it is generally not recommended to leverage RES in developing countries [44,45].

Due to the paperwork process and several uncertainties that the quota system provides to producers of renewable energy, this mechanism is not considered the most recommended as an insertion policy for RES in developing countries. Mainly because the political and economic scenarios in these countries are unstable, it is necessary to have strategies that eliminate as many uncertainties as possible for any producer introducing new energy to the market.

3.3. Auctions

Mir-Artigues and Del Río [46] explain that in an auction tendering system, the government invites the renewable energy producers to compete within a certain budget basis or a generation capacity. Several sources can be involved in the same event or it can be configured for only some sources, in which the cheapest biddings per kWh are hired and provided with a subsidy.

This system can be supported for development of technology connected to different sources, and according to Abdomouleh et al. [34], this is due to the fact that, often times, auctions motivate competition among different sources. This can result in cost reductions from suppliers for many sources and allow them then to also reduce their energy prices: this occurred in Brazil with wind power generation.

The main characteristics that can vary among auctions organized in different jurisdictions are shown on Table 2.

In one study by Becker and Fischer [47], they clarify that in countries, such as India and South Africa, auctions have been a viable alternative due difficulty that these countries face in keeping FIT-based mechanisms around long-term. Among the obstacles are maintenance of a reasonable tariff level in the long-term, lack of stability in the formulated policies, and judicial and regulatory scenarios that make FIT implementation more difficult.

Del Rio [48] adds that auctions share some advantages present in a FIT system, such as the guarantee of long-term revenue for renewable energy producers, and regulators are permitted to know the support

Table 2
Main auction characteristics.

Characteristic	Description
Scope	The bidding process can be adopted to define the level of support offered or concede rights for project implementation, with the tariff support defined later on.
Event organization	The remuneration baseline can be defined in different manners: – Uniform price (the lowest bid given to attend the quota is given to everybody at the number of shares they requested). – Pay-per-bid (the price in exercise defines a support roof, but the winners receive their bid); – Vickrey auctions (the winner receives the second best price, the second winner receives the third best price, etc.). – By average of biddings (the average offer price defines the tariff value).
Penalty for non-fulfillment of the norms	Penalties can be applied with a fixed fee, modulated based on delay time, defined by MW or kWh, and also by a percentage of investment done.
Discrimination by source	This can include all types of energy sources in the same bidding event or can be done only for certain sources.
Duration of contracts	Contracts are differentiated, being configured in the most appropriate manner for each source and project scale, in order to guarantee low risk and profitability to the producer.

Source: Adjusted from Del Río [48].

offered beforehand. Besides this, auctions also deal better with the problem of asymmetric information in comparison to FITs, regarding trends in technology costs connected to each RES. This advantage brings certain efficiency to the mechanism, as it prevents the renewable energy producers being paid with excessive revenues.

However, auctions offer fewer guarantees to the producer in comparison to FITs, since a delay can occur in the organization of new auctions to purchase renewable energy [34]. There is also a risk of having proposals with very low prices that do not reflect technology costs, which sends a negative signal to the industry. Brazil had an occurrence of this type regarding wind power generation at the end of 2012.

3.4. Net metering

Net metering partially or totally compensates the user of RES electricity with the distributed generated system. This occurs through the utilization of a meter that is able to show the liquid consumption balance, as well as the energy generation balance. The balance of energy consumption or generation is verified at the end of each cycle (e.g. monthly, bi-monthly), regarding the energy produced by the system [49–51].

The problem, however, with net metering is that it won't provide a sufficient insertion of RES into the electricity grid for a significant penetration in the market and, therefore, can only be considered as a transition step for the integral price system. However, Watts et al. [49] explain that this policy promotes a distributed generation with the fee paid to the generation system owner in the retail being higher than would be received by a conventional generator producing the same energy. The value paid to the owner encompasses the payment of the distribution system, becoming an implicit subsidy for generation of distributed green electricity.

According to Zahedi [52], Australia is an example where there was application of the net metering system in six states (Victoria, Western Australia, South Australia, Northern Territory, Queensland, and Tasmania) to leverage the use of photovoltaics to produce solar energy. However, it was concluded that adopting net metering as the main strategy was not the most appropriate system in these locations, given that it did not offer enough economic attraction for installation of the technology. Another risk highlighted by the author regarding the net metering system, is that it could stimulate the reduction of electric energy consumption throughout the day, alternating the consumption to the night period, and putting a higher pressure over the day period, where there is a peak demand.

Even though net metering is not the most adequate strategy to lead the promotion of RES technologies, it is an interesting way to motivate the production of renewable energy on a small scale. Several countries have utilized this approach, especially since decentralized technologies and their installations, as well as wind and solar energy generation on small scales are changing the characteristics of energy supply structures [53].

According to Bayod-Rújula [54], some noteworthy benefits associated with energy micro-generation include: avoidance of transmission jams, the perspective of replacing an infrastructure of expensive capital with resources focused on micro-generation, and the fact that on-site production reduces loss during transmission.

4. Applications of strategies to promote RES in Brazil

In this section, we present the Brazilian experiences using policies discussed in Section 3. Except by the quota system, the country has adopted policies based on FIT, auctions and net metering. However, despite not having been adopted a relevant policy share in Brazil, many power generation projects from RES in the country are part of the CDM, which is based on the trading of carbon credits (a closely related strategy to quota system). Initially, a brief contextualization of the Brazilian electricity market and the share of renewable energy sources in the country are showed and discussed; then, the Brazilian experience regarding to FIT is discussed along with energy auctions and the participation in the CDM; later, we address the net metering mechanism adopted by Brazil in 2012, and finally we analyze the prospect of electricity production from RES in Brazil with respect to other Latin American countries.

4.1. PROINFA, auctions and participation in the CDM

Historically, the Brazilian energy sector has been subject to significant state intervention, and it was only in 1996 when the sector was privatized, nevertheless, most of the major generation companies/assets remained under government control. Among the main public agencies, the Brazilian Electricity Regulatory Agency (ANEEL) is the regulatory body responsible for setting electricity tariffs and ensuring fair prices. The National System Operator (ONS) acts as the independent system operator (ISO) and is responsible for operating the electricity grid, including coordination and control of generation and transmission.[55]. And the Electricity Commercialization Chamber (CCEE) operates in energy trading contracts, registering and verifying the generation compliance signed in agreement by the producers [14].

Since 2004, a new energy-trading model has been established, with two markets for trading and buying power contracts: the regulated market characterized by auctions and the free market [14].

State intervention has also been playing a role in the promotion of new energy alternatives throughout the country. Since the 2000s, there has been the introduction of different policies to encourage new energy alternatives [11,14].

In addition to the energy-rationing crisis that Brazil faced in 2001, other reasons have motivated the government to promote the use of new sources of renewable energy, such as the growth of industrial activities, urban growth, and agricultural expansion that pollutes and degrades the environment [56].

Through PROINFA, the obligation of electricity energy providers was established in order to promote their participation in the universalization of the access to this program. Until 2001, there were no favorable incentives within the country and therefore it was hard for the entrepreneurs of small renewable energy projects to become established. It was only with the creation of PROINFA that Brazil really started to notice the execution of a policy directed toward the renewable energy sector that contained greater amplitude and international repercussions.

PROINFA was divided in two phases. In the first phase, FITs were used to insert 3300 MW produced by the contemplated renewable sources. The second phase (which was also initially supposed to be based on FITs, but was reformulated in 2003) was based in tendering through auctions [57]. Dutra and Szklo [58] add that the program still includes special financing systems through the National Development Bank (BNDES) and a minimum requirement for participation of utilization of national equipment in the hired projects.

Even though PROINFA was a strategic plan for the sector, with goals and objectives defined for the long-term, in addition to the FIT application being similar to those found one in Europe, the program was designed to contemplate only three sources (wind power, biomass, and small hydro plants (SHPs)). Solar energy, for example, was not part of the program, and initiatives to motivate tendering of large-scale projects from this source started to appear in some auctions only in 2014. Moreover, BNDES is the only bank that offers advantageous financing lines for power generation projects from RES, and there is still a lack of lines that support the growth of the sector within the country.

Regarding the second PROINFA phase, an insertion goal for RES was established (not considering the large hydroelectric power plants) in the Brazilian power system, considered ambitious and corresponding to 10% of the total power generation installed capacity until the end

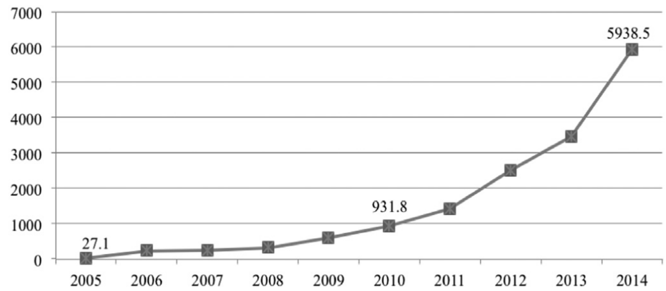

Fig. 6. Evolution of the wind power energy installed capacity in Brazil (MW). Source: ABEEOLICA [59].

of 2022. In the period in which the application of the project tendering strategy through auctions was confirmed, Dutra and Szklo [58] claimed that the wind power source could be the most damaged with the application of auctions. Their cited reasons included the cost of this technology being elevated in comparison to other sources competing in the auction events. However, it has been verified following the first specific auction for this source in 2009, its utilization has significantly grown.

The good performance of wind energy in long-term auctions showed the source' recent potential to compete with other sources without subsidies, what it was unlikely before PROINFA. This fact motivated the adoption of auctions as a means of wind power projects hiring, as well as other RES participating in the PROINFA. In the end of the last decade, the choice of the lowest price auctions instead of a FIT-based strategy aimed to provide a fair rate (necessary to offset the cost of technology) to remunerate the power producers and therefore, prevent unbalances in electricity prices to the customers [47,48].

In addition, wind farms have displayed a substantial increase in their capacity factor and have thus been highlighted in several auctions. Fig. 6 displays the evolution of the installed capacity for wind power generation in Brazil.

The tendering of renewable energy generation projects in Brazilian auctions occurs through regular auctions or through energy reserves, these being carried out every three or five years (A3 and A5 auctions, respectively) before the date of initial delivery of electricity [14]. In regular auctions, such as those for new energy or alternative sources, the government has been organizing events for exclusive tendering of generation projects from certain sources. Reserve Energy Auction (LER) purchases the extra energy to increase the reserve margin of the national grid (SIN). Mastropietro et al. [60] explain that since 2009, the LER has been oriented toward tendering non-conventional energy sources, mainly wind.

Some sources in particular, i.e., wind and solar power more recently, have served as complementary alternatives for power generation of some Brazilian regions that are deficient in energy production for the grid, such as the Northeast [14,61–63]. The wind potential in this region is greater during the dry season (winter), while the potential for solar energy is greater in the summer;the latter of which is the time of year when energy demand increases [61].

Therefore, a noticeable trend in Brazil is that wind and solar farms have been contracted for energy reserve capacity, in order to reinstate the balance between physical guarantees attributed to the generation power plants and the total physical guarantee of the system. This last one corresponds to the maximum amount that the system is capable of supplying given a specific supply criterion [64]. However, since wind and solar generation are intermittent sources, the contracted plants of this type are run many times during periods in which the generation capacity is low.

Other studies have highlighted cases where other countries benefited from the use of solar and wind energy sources for power generation as a complementary form to hydropower [65–67].

Two other reasons that show alternative energy sources, i.e., wind, solar, biomass, and SHPs are favored: there are limited resources to produce electricity using fossil fuels; and there is resistance nuclear energy.

Coal and natural gas, for example, represent around 40–60% of primary energy imports to Brazil, in addition, the existing coal reserves in the country are considered of low quality [68]. Therefore, supporting a strategy to supplement the power supply with coal and natural gas requires imported energy acquisitions [69], increasing the country's exposure to macroeconomic uncertainty with exchange variations.

Considered a clean form of energy production by many, nuclear power generation is considered an option in Brazil [69]. Currently there are only two nuclear power plants in Brazil, however like in other countries there is resistance on expanding the use of nuclear energy [70], especially after the Fukushima accident on March 11, 2011. The main obstacles to the growth of nuclear power in Brazil include: higher costs due to increased security requirements, shortening of the nuclear reactors' lifecycles, reducing the lifetime of nuclear reactors, slow development of technologies that provide greater safety for use of the source, and difficulty in removing and recycling the spent fuel [71].

This scenario, as well as the policies created for alternative RES, has favored wind power growth. In 2012, recognizing the right time to strengthen internal production technology related to wind power generation, BNDES started requiring that in order for candidate businesses to be considered for receiving funds, at least 60% of their technology must be manufactured in the country [1]. Such an initiative has the objective of leveraging technology production in Brazil. Other measures, such as exemptions from some taxes along the production chain of the components' manufacturing for wind power generation, were also implemented in order to encourage the development of wind farms.

Besides an increase in the installed capacity for wind power generation, prices for energy generated from this source are considerably decreasing since the creation of PROINFA, as can be observed in Fig. 7. Until 2012, the price for energy produced by wind farms decreased, reaching its smallest baseline in the country. After 2013, however, electricity prices from these sources increased due to the rise in worldwide technological costs and commodity prices.

Solar photovoltaic (PV) technology began to participate in long-term auctions in Brazil in 2014, where solar farms started to compete with other renewable and conventional power generation sources. Since then, the country is experiencing a steady decrease in investment/installation costs associated with this electricity generation source. This is a consequence of a worldwide reduction in technology costs over the past decades, a trend that is expected to continue in the near future [57]. However, it is important to mention that solar PV equipment costs varies considerably from one country to another [57]. In some countries such as China, German and USA, technology prices have been even lower than in Brazil [15] because there are specific policies directed to this generation source, such as subsidies, taxes incentives and special rates to power producers (as in the German FIT program [37,38]). Based on the result of the last auction for wind and

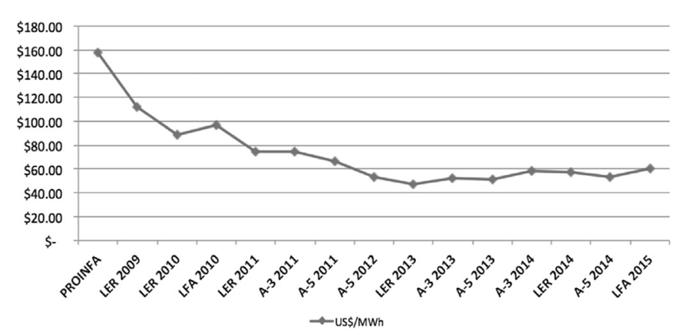

Fig. 7. Evolution of wind energy prices in Brazil. Source: Adjusted from ABEEOLICA [59].

solar farms in Brazil, investment costs for these types of projects would be approximately 1170 US$/kW and 1240 US$/kW respectively [72], showing cheaper results than what was expected.

However, job creation statistics connected to the wind power sector reveal that it is the construction of wind farms that contributes the largest number of new jobs [73]. The authors still reinforce that this scenario is different than what occurs in countries that export this technology. Even though there are initiatives to stimulate wind power technology production in the country, Brazil still remains distant from the list of countries with intensive manufacturing of wind power generation equipment,

Considering that the main manufacturers in the country are multinational companies, it is possible to notice throughout the years a variation in electricity prices and in values for wind power generation investments. This is due to the country's dependence on technology developed abroad, the consequent variation to exchange rates and economic instability (a frequent event in developing countries), which also contributes to the instability of technology costs.

The participation of the government creating tax incentive mechanisms are important to support the growth of the wind industry in the country [1]. Especially the reduction of high import taxes, since much of the technology used in Brazil are manufactured by foreign companies. Recent reductions in import taxes were applied for the solar PV technology used in distributed generation projects with the purpose to help the microgeneration growth in the country [57].

Regarding Brazil's participation in the CDM, the country represents 2% of the program's low carbon portfolio, and has the greatest participation within Latin America and the fourth largest CDM participant with certified emission reductions (CERs) [49]. Other forms of RES, such as SHPs, [74] may be financially interesting for participation in the CDM in Brazil, especially for generation units that are not connected to the national interconnected power system. However, the CDM registration process is bureaucratic and complex, requiring patience and persistence from the applicants. Besides this, there is also a delay for release of green certificates.

4.2. Net metering for distributed generation

Similarly to the application of net metering in Brazil, Holdermann et al. [50] describe the ANEEL introduced in April 2012, a net metering mechanism that is applied to renewable energy generation systems on a small scale. The objective of this strategy is to remove the barriers for the generation distributed through the RES in the country and it applies to generators with an installed capacity of up to 1 MW, for micro-generators producing power smaller or equal to 100 kW connected to the low voltage distribution networks, as well as to power generators with an installed capacity between 100 kW and 1 MW, that can be connected to the distribution network of low or medium voltage levels.

However, even though the initiative is valid, mainly within the context of liberalization of the Brazilian electricity power sector, adequate financing lines are still missing. Financial instruments that can offer support to attract and leverage investments in distributed renewable generation are key to disseminating power generation at residential levels.

4.3. RES generation in Brazil compared with other Latin American countries

Brazil is currently applauded as Latin America's main producer of renewable energy when excluding hydropower. Until 2012, the country was responsible for more than half of all green electricity generated in South America. Table 3 shows that until 2012, the four largest producers of renewable energy (excluding hydropower) are Brazil, Mexico, Chile, and Argentina. The total produced by those four countries is equivalent to approximately 60 TWh.

Table 3
Main Latin American countries producing energy from RES.

Countries	TWh	(%)
Argentina	2.75	4.5%
Brazil	40.287	66.4%
Chile	5.263	8.8%
Mexico	12.321	20.3%

Source: Adjusted from EIA [75].

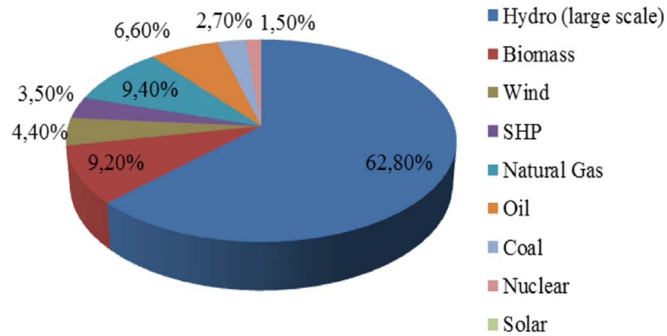

Fig. 8. Composition of the Brazilian power generation installed capacity until the end of 2014. Source: ABEEÓLICA [59].

Following Brazil, the countries that have a larger amount of electricity from non-hydro RES are Mexico, Chile, and Argentina, even though the total sum of the three countries reaches only a little more than half the energy produced in Brazil. However, as it can be observed in Fig. 8, even though Brazil is the country using more electricity from non-hydro RES among Latin American countries, a large portion of the total generation installed capacity is from large hydroelectric power plants. Brazil has an abundance of hydro resources and smaller production and investment costs from this source can be observed when comparing with other RES.

In addition to SHPs, wind, solar, and biomass energy sources have large growth potential within the country and are still underused in comparison to what they could contribute to electricity generation. Discussions around RES utilization have grown since 2014, when Brazil faced a serious drought resulting in low water levels in the hydro plant reservoirs consequently threatening the country's energy supply. Moreover, the construction of large hydroelectric power plants has been suffering opposition from some parties due to environmental impacts to the interior regions with implications for their natural reserves and cultural heritage.

Alemán-Nava et al. [76] show how Mexico is an example of a country with an elevated RES potential, but also its underutilization of these resources. Mexico is falling short of its RES capacity due to a lack of long-term strategies and policies well-aligned for the sector, mainly tax and financial incentives. Furthermore, the country has abandoned its focus of promoting technology that can contribute to the Mexican power generation system in the long-term, as for example, low-enthalpy geothermal energy.

5. Conclusions

Unlike what was discussed in studies performed over a decade ago, the utilization of RES is not seen as just a necessity anymore, but also a reality. For this reason, many countries have adopted long-term policies to encourage RES. Even though FIT strategies have been successful and therefore preferred by many countries, it is necessary to exercise caution, as they are not always the best strategy to promote the use of RES. Each country's particular history, politics, economics, and culture need to be considered in the design of FIT policies in order to ensure the program's adequacy in inserting RES into the energy system.

This study examined the main long-term incentive policies along with a discussion about their advantages and disadvantages. This paper aimed to present incentive initiatives introduced in the Brazilian power system that helped to promote RES in the country. Since the first relevant policy for the sector was created through PROINFA, Brazil has been experiencing long-term incentive strategies. The initiatives that stand out include FITs through PROINFA, and later, long-term auctions for RES contracting supported by BNDES credit lines. Basically, these two policies leveraged RES for electricity generation in the country. Auctions have played an important role to place larger amounts of RES at a price that reflects a fair amount to recover the technology costs with a fair profit margin. Brazil has not seen yet any initiative with respect to quotas with carbon credit transactions, although the country is a CDM participant and therefore renewable energy producers can benefit from carbon credit transactions. However, delays and bureaucracy for the approval of CDM projects is an ongoing obstacle discouraging new producers from participating in this mechanism.

With the analysis carried out in this paper it is possible to notice that wind power is one RES that stood out since the creation of PROINFA. Incentive policies also provided financial stability and were responsible to reduce the uncertainty in the market for wind power producers. Such policies are key for solar PV as well because the source still cannot compete on its on with conventional energy sources in the market. More recently, the net metering mechanism stated to support the growth of distributed generation. Net metering has been applied since 2012 in a context where the country intends to develop its electricity spot market. In this context, the goal is to allow consumers to commercialize its electricity production with other utilities, traders and consumers of the interconnected power system.

RES projects in Brazil highly depends on the technology developed in foreign countries, even though the BNDES initiative requires that 60% of technology used in its financed projects must be manufactured in the country. Also, in many cases the manufacturing process depends on specific equipment produced by multinationals, what exposes investors to variations in technology costs and exchange rates. In this sense, it is also important the government's participation by enhancing existing initiatives with short-term policies, such as tax exemption and reduction, especially import-related taxes.

Even though Brazil is the largest producer of electricity using RES in Latin America, excluding hydropower, it still faces barriers that delay the growth of the sector. Many projects hired in auctions have difficulty being connected to the power grid with their entry into operation ending up delayed. In addition, BNDES is the only agency that finances clean energy enterprises. Finally, but not less importantly, it is worth mentioning that the Brazilian electric sector, similarly to neighboring countries, also presents several regulatory uncertainties making the environment unstable for investors of renewable power generation projects.

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References

[1] Juárez AA, Araujo AM, Rohatgi JS, Oliveira Filho ODQ. Development of wind power in Brazil: political, social and technical issues. Renew Sustain Energy Rev 2014;39:828–34.
[2] Ringel M. Fostering the use of renewable energies in the European Union: the race between feed-in tariffs and green certificates. Renew Energy 2006;31:1–17.
[3] Lipp J. Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom. Energy Policy 2007;35:5481–95.
[4] Wustenhägen R, Bilharz M. Green energy market development in Germany: effective public policy and emerging customer demand. Energy Policy 2006;34:1681–96.
[5] Ayoub N, Yuji N. Governmental intervention approaches to promote renewable energies – special emphasis on Japanese feed-in tariff. Energy Policy 2012;43:191–201.
[6] Lim XL, Lam WH, Hasim R. Feasibility of marine renewable energy to the feed-in tariff system in Malaysia. Renew Sustain Energy Rev 2015;49:708–19, [Sep.].
[7] Faggiani R, Barquín J, Hakvoort R. Risk based assessment of the cost efficiency and the effectivity of renewable energy support schemes: certificate markets versus feed-in tariffs. Energy Policy 2013;55:648–61.
[8] Ramli MAM, Twaha S. Analysis of renewable energy feed-in tariffs in selected regions of the globe: lessons for Saudi Arabia. Renew Sustain Energy Rev 2015;45:649–61.
[9] Bertoldi P, Rezessy S, Oikomonou V. Rewarding energy savings rather than energy efficiency: exploring the concept of a feed-in tariff for energy savings. Energy Policy 2013;56:526–35.
[10] Schmidt J, Cancella R, Pereira A. Jr, An optimal mix of solar PV, wind and hydro power for a low-carbon electricity supply in Brazil. Renew Energy 2016(85):137–47.
[11] Costa C, 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):69–90.
[12] Grisi E, Yusta J, Dufo-López R. Opportunity costs for bioelectricity sales in Brazilian sucro-energetic industries. Appl Energy 2012(92):860–7.
[13] Anaya K, Pollitt M. The role of distribution network operators in promoting cost-effective distributed generation: lessons from the United States of America for Europe. Renew Sustain Energy Rev 2015(51):484–96.
[14] Silva R, Marchi Neto I, Seifert SS. Electricity supply security and the future role of renewable energy sources in Brazil. Renew Sustain Energy Rev 2016(59):328–41.
[15] Rodrigues S, Torabikalaki R, Faria F, Cafôfo N, Chen X, Ivaki AR, Mata-Lima H, Morgado-Dias F. Economic feasibility analysis of small scale PV systems in different countries. Sol Energy 2016(131):81–95.
[16] Nalan ÇB, Murat Ö, Nuri Ö. Renewable energy market conditions and barriers in Turkey. Renew Sustain Energy Rev 2009;13(6–7):1428–36.
[17] Abolhosseini S, Heshmati A. The main support mechanisms to finance renewable energy development. Renew Sustain Energy Rev 2014;40:876–85.
[18] Shum KL, Watanbe CNetwork externality perspective of feed-in tariffs (FIT) instruments – some observations and suggestions. Energy policy. v. 38. p. 3266–69.
[19] Stoke LC. The politics of renewable energy policies: the case of feed-in tariffs in Ontario, Canada. Energy Policy 2013;56:490–500.
[20] Solangi KH, Islum MR, Saidur R, Rahim NA, Fayaz H. A review on global energy policy. Renew Sustain Energy Rev 2011;15:2149–63.
[21] REN 21. Global status report-key findings, Available at: ⟨http://www.ren21.net/ren21activities/globalstatusreport.aspx⟩; 2015 [accessed 25.03.15].
[22] Jacobs D, Marzolf N, Paredes JR, Rickerson W, Becker-Birck C, Solano- Peralta M. Analysis of renewable energy incentives in the Latin America and Caribbean region: the feed in tariff case. Energy Policy 2013;60:601–10.
[23] REN 21. Global status report, Available at: ⟨http://www.ren21.net/ren21activities/globalstatusreport.aspx⟩; 2013 [accessed 18.03.15].
[24] Islam MR, Mekhlief S, Saidur R. Progress and recent trends of wind energy technology. Renew Sustain Energy Rev 2013;21:456–68.
[25] Nielsen S, Sorknaes P, Ostergaard PA. Electricity market auction in settings in a future Danish system with a high penetration of renewable energy sources – a comparison of marginal pricing and pay-as-bid. Energy 2011;36:4434–44.
[26] Huenteler J. International support for feed-in tariffs for developing countries – A review and analysis of proposed mechanisms. Renew Sustain Energy Rev 2014;39:857–73.
[27] Tongsopit S, Graecen C. An assessment of Thailand feed-in tariffs program. Renew Energy 2013;60:439–45.
[28] Couture TD, Becker-Birck C. Energy policy design for low and middle income countries: from best practices to "next" practices. In: Colombo E, Bologna S, Masera D, editors. Renewable energy for unleashing sustainable development. Geneva: Springer International Publishing; 2013. p. 239–54.
[29] Lesser JA, Su X. Design of economically efficient feed-in-tariff structure for renewable energy development. Energy Policy 2008;36:981–90.
[30] Del Río P, Gual MA. An integrated of the feed-in tariff system in Spain. Energy Policy, 2007;35:994–1012.
[31] Sgroi F, Tudisca S, Di Trapani AM, Testa R, Squatrito R. Efficacy and efficiency of Italian energy policy:: the case of PV systems in greenhouse farms. Energies 2014;7(6).
[32] Glemarec Y, Rickerson W, Waissben O. Transforming on-grid renewable energy markets. New York: United Nations Development Programme (UNDP); 2012.
[33] Couture TD, Gagnon Y. An analysis of feed-in tariff remunerations models: implications for renewable energy investment. Energy Policy 2010;38, [p. 955-065].
[34] Abdomouleh Z, Alammari RAM, Gastli A. Review of policies encouraging energy integration & best practices. Renew Sustain Energy Rev 2015;45:246–62.
[35] DEL RÍO P. The dynamic efficiency of feed-in tariffs: the impact of different design elements. Energy Policy 2012;41:139–51.
[36] Jenner S, Groba F, Indvik J. Assessing the strength and effectiveness of renewable electricity in feed-in tariffs in European Union countries. Energy Policy 2013;52:385–401.
[37] Mabee WE, Mannion J, Carpenter T. Comparing the feed-in tariff incentive for renewable electricity in Ontario and Germany. Energy Policy 2012;40:480–9.
[38] Büsgen U, Dürrschmidt W. The expansion of electricity generation from renewable energies in Germany: a review based on the renewable energy sources act progress report 2007 and the new Germany feed-in legislation. Energy Policy 2009;37:2536–45.

[39] IEA. Statistics: Germany renewable and waste, Available at: ⟨http://www.iea.org/statistics/statisticssearch/report/?country=GERMANY= & product=renewablesandwaste & year=Select⟩; 2015 [accessed 19.01.15].
[40] Lehr U, Nitsch J, Kratzat M, Lutz C, Edler D. Renewable energy and employment in Germany. Energy Policy 2008;36:108–17.
[41] Sovacool BK. The importance of comprehensiveness in renewable electricity and energy-efficiency policy. Energy Policy 2009;37:1529–41.
[42] Watts D, Albornoz C, Watson A. Clean development mechanism (CDM) after the first commitment period: assessment of the world's portfolio and the role of Latin America. Renew Sustain Energy Rev 2015;41:1176–89.
[43] Mitchell C, Bauknecht D, Connor PM. Effectiveness though risk reduction: a comparison of the renewable obligation in England and Wales and the feed-in system in Germany. Energy Policy 2006;34:297–305.
[44] Holm D. Renewable energy for the developing world. Int Sol Energy Soc 2005.
[45] Fouquet D, Johansson TB. European renewable energy policy at crossroads – Focus on electricity support mechanisms. Energy Policy 2008;36:4079–92.
[46] Mir-Artigues P, Del Río P. Combining tariffs, investment subsidies and soft loans in a electricity deployment support. Energy Policy 2014;69:430–42.
[47] Becker B, Fischer D. Promoting renewable electricity generation in emerging economies. Energy Policy 2013;56:446–55.
[48] Del Río P. Back to the future? Rethinking auctions for renewable electricity support. Renew Sustain Energy Rev 2014;35:42–56.
[49] Watts D, Valdés MF, Jara D, Watson A. Potential residential PV development in Chile: the effect of net metering and net billing schemes for grid-connected PV systems. Renew Sustain Energy Rev 2015;41:1037–51.
[50] Holdermann C, Kissel J, Beigel J. Distributed photovoltaic generation in Brazil: an economic viability analysis of small-scale photovoltaic systems in the residential and commercial sectors. Energy Policy 2014;67:612–7.
[51] Squatrito R, Sgroi F, Tudisca S, Di Trapani AM, Testa R. Post feed-in scheme photovoltaic system feasibility evaluation in Italy: Sicilian case studies. Energies 2014;7(11):7147–65.
[52] Zahedi A. A review on feed-in tariff in Australia, what is now and what it should be. Renew Sustain Energy Rev 2010;14:3252–5.
[53] Arnold U, Yildiz Ö. Economic risk analysis of decentralized renewable energy infrastructures e A Monte Carlo simulation approach. Renew Energy 2015;77:227–39.
[54] Bayod-Rújula AA. Future development of the electricity systems with distributed generation. Energy 2009;37:377–83.
[55] Tovar B, Ramos-Real FJ, Almeida EF. Firm size and productivity. Evidence from the electricity distribution industry in Brazil. Energy Policy 2011;39(2):826–33.
[56] Pereira Junior AO, Pereira AS, La Rovere E, Barata MM, Villar SC, Pires SH. Strategies to promote renewable energy in Brazil. Renew Sustain Energy Rev 2011;15(1):681–8.
[57] Pereira MG, Camacho CF, Freitas MAV, Da Silva NF. The renewable energy in Brazil: current status and potential. Renew Sustain Energy Rev 2012;16:3786–802.
[58] Dutra RM, Szklo AS. incentive policies for promoting wind power production in Brazil: scenarios for the alternative energy sources incentive program (PROINFA) under the new Brazilian electric power sector regulation. Renew Energy 2008;33:65–76.
[59] ABEEÓLICA – Associação brasileira de energia eólica. Boletim de dados – Janeiro, Available at: ⟨http://www.portalabeeolica.org.br/index.php/dados.html⟩; 2015 [accessed 16.06.15].
[60] Mastropietro P, Batle C, Barroso LA, Rodilla P. Electricity auctions in South America: towards convergence of system adequacy on RES-E support. Renew Sustain Energy Rev 2014;40:375–85.
[61] Jong P, Sanchez A, Esquerre K, Kalid R, Torres E. Solar and wind energy production in relation to the electricity load curve and hydroelectricity in the northeast region of Brazil. Renew Sustain Energy Rev 2013(23):526–35.
[62] ONS – Balanço de Energia GWh – 2013, Available at: ⟨http://www.ons.org.br/download/biblioteca_virtual/publicacoes/dados_relevantes_2013/html/04-02-Balanco-de-Energia-GWh.html?expanddiv=04,05sub01⟩; 2013 [accessed on: 04. 01.16].
[63] ONS – Relatório Final BEN 2015, Available at: ⟨https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2015.pdf⟩; 2015 [accessed 04.01.16].
[64] EPE – EMPRESA DE PESQUISA ENERGÉTICA. Nota técnica – Metodologia de Cálculo da Garantia Física das Usinas; 2008.
[65] Murage M, Anderson C. Contribution of pumped hydro storage to integration of wind power in Kenya: an optimal control approach. Renew Energy 2014(63):698–707.
[66] Francois B, Borga M, Creutin J, Hingray B, Raynaud D, Sauterleute J. Complementarity between solar and hydro power: sensitivity study to climate characteristics in Northern-Italy. Renew Energy 2016(86):543–53.
[67] Silva SR, Queiroz AR, Lima LMM, Lima JWM. Effects of wind penetration in the scheduling of a hydro-dominant power system. In: Proceedings of the IEEE general meeting; 2014
[68] Lima F, Pereira JP, de Lucena AFP, Rochedo P, Cunha J, Nunes ML, Szklo AS. Analysis of energy security and sustainability in future low carbon scenarios for Brazil. Nat Resour Forum 2015;39(3–4):175–90.
[69] Santos RLP, Rosa LP, Arouca MC, Ribeiro ED. The importance of nuclear energy for the expansion of Brazil's electricity grid. Energy Policy 2013;60:284–9.
[70] Moreira JML, Cesaretti MA, Carajilescov P, Maiorino JR. Sustainability deterioration of electricity generation in Brazil. Energy Policy 2015;85:334–46.
[71] Goldemberg J. News and views: perspectives for nuclear energy in Brazil After Fukushima. Braz J Phys 2011;41(2):103–6.
[72] CCEE. O que fazemos?-leilões, Available at: ⟨http://www.ccee.org.br/portal/faces/oquefazemos_menu_lateral/leiloes?_afrLoop=2871576345300101#%40%3F_afrLoop%3D2871576345300101%26_adf.ctrl-state%3Ducbx91pyy_49⟩; 2015 [accessed 04.01.16.
[73] Simas M, Pacca S. Assessing employment in renewable energy technologies: a case study for wind power in Brazil. Renew Sustain Energy Rev 2014;31:83–90.
[74] Martins DEC, Seiffert MEB, Dziedzic M. The importance of clean development mechanism for small hydro power plants. Renew Energy 2013;60:643–7.
[75] EIA – Energy information administration, International energy statistics, Available at: ⟨http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=6 & pid=29 & aid=12⟩; 2015 [accessed 10.07.15].
[76] Alemán-Nava GS, Casiano-Flores VH, Cárdenas-Chavez DL, Díaz-Chavez R, Scarlat N, Mahlknecht J, Dallemand JF, Parra R. Renewable energy research progress in Mexico: a review. Renew Sustain Energy Rev 2014;32:140–53.