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Assessment of the potential of small hydropower development in Brazil

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ABSTRACT

This paper aims to show the current context of Small Hydro Power Plants (SHPs) in Brazil, presenting and discussing the institutional acts, regulations for growth of the SHP, public and private policies for the sector and growth prospects. After the restructuring of the Brazilian electricity sector, a series of laws, decrees and resolutions were developed with the purpose of regulating the sector in favor of SHPs. In 2001, the number of SHPs in Brazil was 303 with an installed capacity of 855 MW. Over the years, with the changes in the sector and, in 2010, the number of buildings has reached 387, with an installed capacity of 3428 MW. Today, they are 475 SHPs in operation with the generation capacity in the country, around 4799 MW, representing 3.49% of all Brazilian energy matrix. It is estimated that in 2020 the installed capacity will be approximately 6500 MW, but there is more potential available in the country for SHPs, that has great technical and environmental characteristics. It is concluded that more attention must be given by the government policies of the electricity sector to reach in the future the full the potential of SHPs available in Brazil.

Contents

1. Introduction

Energy is considered to be a key factor in the generation of wealth, social development and improved quality of life in all developed and developing countries in the world. Therefore, produced and consumed energy resources and especially renewable energy sources have a very important value [1].

The use of renewable source is the most valuable solution to reduce the environmental problems associated with fossil fuels based energy generation and achieves clean and sustainable energy development. Hydro, wind, biomass, solar and geothermal are among the most important renewable sources for energy generation. All nations of the world are shifting the focus to extract energy from renewable sources [2]. Table 1 shows the list of top 10 renewable electricity producer nations of the world.

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Table 1
World's top renewable electricity producer nations (units in TW h).
Source: Energy Information Administration [3].

Rank Country		1 China	2 United States	3 Brazil	4 Canada	5 Russia	6 India	7 Norway	8 Germany	9 Japan	10 Venezuela
Hydropower	2010	713.8	260.2	399.3	347.8	164	113.3	115.6	20.22	81.39	76.01
	2011	690.6	319.4	424.1	371.9	164.2	129.4	119.6	17.1	82.36	82.83
	2012	856.4	276.2	411.2	376.2	161.6	114.5	140.4	21.2	76.9	80.9
Wind power	2010	44.6	94.7	2.2	9.6	0.004	19.9	0.9	37.8	4.0	–
	2011	73.2	120.2	3.0	19.7	0.0	26.0	1.3	46.5	4.3	–
	2012	–	141	–	23	–	–	2	46	5	–
Solar	2010	0.94	1.21	–	0.16	–	0.02	0.02	11.68	3.80	–
	2011	3.00	1.80	–	0.40	–	1.00	0.02	19.00	3.80	–
	2012	–	4.33	–	0.507	–	–	0.03	28.0	4.19	–
Biomass	2010	11.41	68.94	31.5	8.710	2.77	2.06	0.45	39.87	23.45	–
	2011	34	70.8	32	6.4	2.8	4.0	0.48	43.6	23.15	–
	2012	43.56	71.41	34.0	6.38	2.8	4.13	0.48	44.25	23.15	–
Geothermal	2010	0.16	15.22	–	–	0.51	–	–	0.03	2.63	–
	2011	0.16	15.3	–	–	0.51	–	–	0.02	2.65	–
	2012	0.16	15.56	–	–	0.51	–	–	0.02	2.92	–
Other sources	2010	–	–	–	0.03	–	–	–	–	–	–
	2011	–	–	–	0.03	–	–	–	–	–	–
	2012	–	–	–	0.03	–	–	–	–	–	–
Total	2010	770.9	440.2	432.9	366.3	167.3	135.3	116.9	109.6	115.2	76.0
	2011	801.0	527.5	459.1	398.4	167.5	160.4	121.4	126.2	33.9	82.8
	2012	900.1	508.4	445.2	406.2	164.9	118.6	142.6	139.5	112.0	80.9

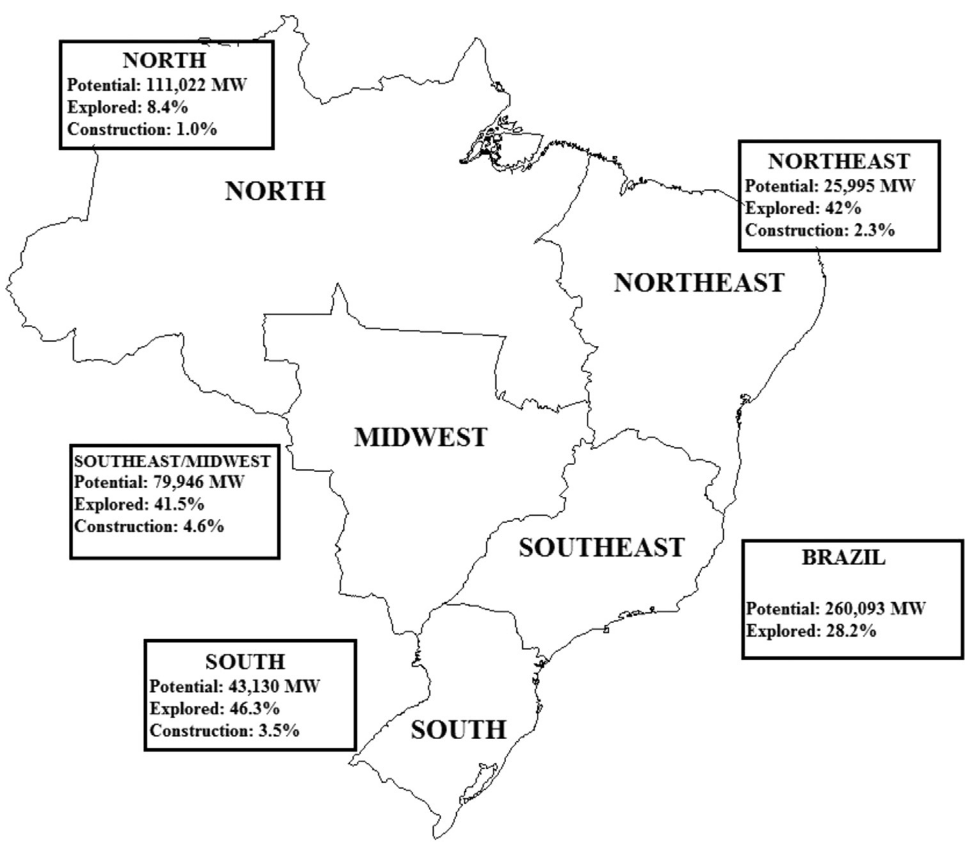

Fig. 1. Brazilian hydropower potential by region.
Source: Adapted from Ministry of Mines and Energy [6].

The Brazil belongs to the group of countries where electricity production is massively from hydroelectric plants. These plants account for 67.5% of the installed capacity in the country [4].

The importance of hydroelectricity is based on vast hydropower potential in Brazil and it has resulted in a strategic option since made in the 50s of last century, despite the increased competitiveness that petroleum represented as a primary energy source [5].

However, only about 30% of the national hydroelectric potential has been exploited, proportionally less than the amount observed in industrialized countries (Fig. 1). The low utilization of hydroelectric potential in northern Brazil is due to the predominant topography of the region (plains), to its great biological diversity and the distance of the main centers of energy consumers. But the country's internalization process and the fast depletion of hydroelectric energy potential of South and Southeast has demanded an increase in hydroelectric projects in remote and economically less developed areas [5].

In this context, many argue that the basis of the expansion of electricity supply in Brazil is, even in a long term perspective, hydroelectricity [5].

Due to the dimensions of the Brazilian hydroelectric potential, especially since the utilization rate of the potential is relatively small compared to other industrialized nations (Germany, Japan, United States, and Norway), and for the indications of the utilization rate of the potential that can be utilized is lawful to admit the expansion of the supply of electricity in Brazil can be based in the hydroelectricity [5].

However, this expansion will be subject to certain conditions, among which stand out [5]:

- Increase the portfolio of projects in the medium term: this aspect is related to the level of knowledge of the potential advantage.
- Growth of the consumer market: the growth of the consumer market is naturally another important constant, in which the national electricity demand in 2012 increased 3.5% compared to 2011 (Fig. 2).
- Transmission: the available hydroelectric potential is concentrated in regions far from large consumer centers.
- Environment: the location, the dimension and level of knowledge of the hydroelectric potential refer, naturally, to the discussion of social and environmental aspects.
- Competitive: another factor for the hydroelectric expansion is competitivity, synthesized in the average generation cost. The cost of hydroelectric generation is strongly influenced by the cost of investment and the discount rate. The cost of installing hydropower plants varies from place to place. It depends on the existing infrastructures (civil, electro-mechanical equipment and power transmission lines, for example) and the installation capacity [7]. The investments in generation change according to the source used and the expansion strategy adopted. The investment costs are parameterized according to the level of marginal investments in Table 2.

In this scenario, the small hydropower plants, an alternative way to produce energy, has been exerting prominence in the Brazilian energy matrix because of the large Brazilian hydroelectric potential, and from the commercial and technical point of view, places are already in scarce number for exploration of its potential, so it is needed to seek small exploitations. Table 2 above shows clearly that energy from biomass and energy from natural gas compete with lower cost than the energy of SHPs. This being therefore a heavy competition that SHPs have in Brazil regarding the investment return rate.

And, above all, because of the its advantages and benefits, with low environmental impact [1,2,7,9–12], its concept characterizes

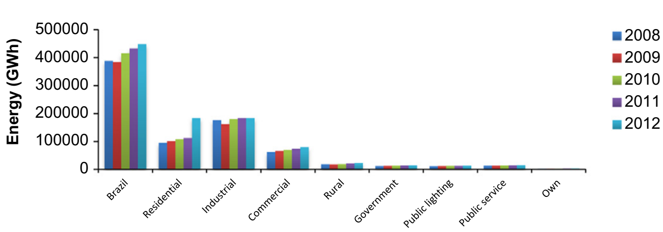

Fig. 2. Energy consumption by sector in Brazil in 2012.
Source: Energy Research Enterprise [8].

Table 2
Investment costs in the generation of electricity (US$/kW).
Source: Energy Research Enterprise [5].

Generation source	US$/kW
Hydropower	1330
Potential until 60,900 MW	1100
Potential between 60,900 and 70,900 MW	1450
Potential between 70,900 and 80,900 MW	1800
Potential above 80,900 MW	2500
Small hydropower	1200
Wind power	1200
Biomass (sugar cane)	900
Waste	1250
Nuclear	2200
Thermal coal	1600
Thermal natural gas	750

small area occupation and buildings with low environmental impacts these plants can be located closer to consumer centers, reducing energy losses in transmission, reduce costs for consumers and takes higher level jobs to regions with low index of human development.

Therefore, this paper aims to show the current context of small hydropower plants in Brazil, presenting and discussing the institutional acts, regulations for growth of the SHP in the Brazilian electric sector, public and private policies for the sector and growth perspectives.

2. Small hydropower as a choice

Amongst the renewable energy technologies, small hydropower is one of the most attractive and probably the oldest environmental friendly energy technology. Small hydro potential is available on small rivers, canal heads and canal drops. Of all the nonconventional renewable energy sources, small hydropower represents the highest density resource and stands in first place in the generation of electricity from renewable sources throughout the world [9].

Hydropower plants are of three types [7]:

- Impoundment: this is a large hydropower system which uses a dam to store river water in reservoir. Water stored in the reservoir is then used to generate electricity.
- Diversion: a diversion facility channels a portion of a river through a canal or penstock. This system may not require the use of a dam.
- Run-of-river: the system uses water within the natural flow range and it requires little or no impoundment.

Small-scale hydro is mainly ‘run-of-river’, so it involves construction of a quite small dam or barrage, usually just a weir, and generally little or no water is stored.

A small scale hydropower facility generates power through the kinetic energy of moving water as it passes through a turbine. Most small scale hydropower facilities are ‘run-of-river,’ meaning that the natural flow of the river is maintained, and that a dammed reservoir is not created in order to generate power. Without a permanent dam to block river flow, nor a large reservoir to flood arable land and disrupt river temperature and composition levels, many of the negative riverine effects of traditional hydropower are avoided with a small scale hydropower plant [13].

SHP projects can be installed in rivers, small streams, dams and canals with negligible apparent environmental effects. In order to minimize the environmental effects and maximize water conservation, prominence has been given to the development and integration of SHP projects into river systems during last few years [2].

Small hydropower is a key element for sustainable development due to the following reasons [2]:

- Proper utilization of water resources: various streams and rivers can safely provide energy to run a small hydroelectric plant. No big water storage is required in such projects which prevents resettlement and rehabilitation of the population.
- Small hydro power is a renewable source of energy: small hydropower meets the definition of renewable because it uses the energy of flowing water repeatedly and generates electricity without fear of depletion also.
- Small hydro is a cost effective and sustainable source of energy: simple and less expensive construction work and inexpensive equipment are required to establish and operate small hydropower projects. The cost of electricity generation is inflation free. Also, the gestation period is short and the schemes give financial returns quickly.
- Small hydro aids in conserving scarce fossils fuels: no fossil fuels or other petroleum products are required in small hydroelectric projects. SHP replaces the fossil – fired generation of electricity.
- Low polluting: SHP projects are known for low carbon energy production. Several authors [14–17], have evaluated Small hydropower (SHP) projects as candidates for the reduction in GHG emissions. Renewable energy technologies, which include SHP, contribute to global sustainability through GHG mitigation, and these technologies lead to building capacity and infrastructure sites. Small hydropower projects directly displace emissions of GHG and contribute to sustainable rural development [12]. The development of small hydro has low effect on the environment. In small hydro, no big storage is formed and rehabilitation of population is not required as in case of large hydropower projects.
- Development of rural and remote areas: In remote and hilly areas, sources for development of Small Hydro Power Plants are found in abundance. Small hydro development provides electricity, transportation, communication links and economy to such rural areas.
- Other uses: Small hydropower also gives additional benefits along with power generation such as irrigation, water supply, flood prevention, fisheries and tourism.

During the development of the project and operation of SHP, and any hydroelectric plant, the Brazilian environmental legislation operates for the production of sustainable energy.

The legislative developments in the power and environmental management sectors (such as the creation of ANEEL(Brazilian Electricity Regulatory Agency), Law no. 9427 [18], the implementation of the National Water Resources Plan and of the National Water Resources Management System, Law no. 9433 [19], and creation of the National Water Agency, Law no. 9984 [20], among others) led to the revision the Hydropower Inventory Studies Manual. The hydropower inventory aims at select the best alternative based on a cost-benefit analysis, taking in to account energy and economic studies of hydropower undertakings, and preliminary environmental impacts assessments in the Integrated Environment Assessment (IEA) of the river basin [21].

The IEA's objectives and strategies are defined as follows: analyze the cumulative effect that comes from increased incidence of localized impacts generated by other similar projects in the same river basin, intensifying them and the synergistic effect, that go beyond the physical limits of the river basin and interact with impacts from other projects, producing an affect distinct from those that originated it, of hydropower sets on natural resources and human populations; assess the current and potential uses of water resources for current and future planning, taking into account the need to balance energy generation with biodiversity conservation and maintaining gene flow of aquatic species; consider social diversity and economic development of the basin, in light of the national legislation and the international commitments undertaken by the Federal Government [21].

To comply with the law, SHPs need to develop social and environmental programs during construction and operation, associated with sustainability and environmental preservation.

These programs occur when the SHPs establish, by law and contract, around the perimeter of its reservoir, and develop conservation, maintenance and constant surveillance activities. Thus, areas and riparian vegetation, which are normally degraded by irregular occupation of riverbanks, are necessarily recomposed by enterprises, as operating conditions, subject to inspection, in its entire reservoir.

Therefore, to provide a solution for the energy problems in a sustainable way and follow the law, some SHPs in Brazil develop environmental actions. The main ones are [22]:

- Margin Protection Program and Recovery of Degraded Areas – processes to recover the affected areas by the implementation of PCH, in order to protect the soil and water sources against the erosion and siltation through monitoring and tracking of planting seedlings is done.
- Monitoring Program of Water Quality – characterization of water in the area of interest in terms of its physical, chemical, bacteriological and ecological characteristics, identification of trends and risk assessment for water quality and suggest actions for the control and prevention of pollution.
- Fauna Monitoring Program – this program aims to verify the diversity of species pertaining to different taxonomic groups in the area of direct and indirect influence of PCH, assessing the changes occurring in the composition and dynamics of fauna.
- Monitoring Project Groundwater – to manage groundwater resources, to monitor changes in groundwater level, to assess and monitor the risk of instability of foundations and buildings; with the formation of the lake, to propose mitigation and compensation measures for the impacts that may be caused.
- Communication with society – convey to the communities knowledge about the environment of the region, obtained through EIA – Environmental Impact Assessment and RIMA – Environmental Impact Report, to inform the new relations introduced in the daily life of the population with the implementation of SHP, encouraging positive changes in the way we relate to the environment and awareness of environmental values and local cultural tradition.

3. Small hydropower in Brazil

There is no internationally agreed definition and its classification is based only on a country's level of hydropower development [23]. In Brazil, the small hydropower plants are defined as hydropower developments with power above 1 MW and below 30 MW, and with a maximum flooded area of 3 km^2, as per Law no. 9648/98.7 on December 9, 2003, with Resolution no. 652, the flooded area was authorized to reach 13 km^2, provided it met the equation $A \geq (14.3 \times P)/\text{Hb}$, where P is the power of the venture, given in Megawatts (MW) and Hb is the venture's available gross head, given in meters; or when the reservoir has been designed based on other uses which are not for power generation [24].

Table 3 shows the definition in Brazil compared to other countries and it is possible to see that in some countries, such as China, France and New Zealand, the classification of the installed capacity of a SHP is higher than in Brazil, with installed capacities up to 50 MW.

In 2001, the number of SHP in Brazil was 303 and with an installed capacity of 855 MW. With the changes in the sector and over the years, in 2013, the number of SHP has reached 480, with an installed capacity of 4656 MW. As shown in Fig. 3, the amount of power inserted in the installed capacity per year for SHPS and that there was an increase until 2008, when 658 MW of power were inserted in this year, and then a decrease occurred with amount of power inserted in the installed capacity per year [4].

Table 3
SHP definition and classification in some selected countries.
Source: Ohunakin et al. [23]; Masera et al. [25]; Capik et al. [1].

Country/organization	Micro (kw)	Mini (kw)	Small (kw)
Brazil	< 100	101–1000	1001–30,000
China	≤ 100	≤ 2000	≤ 50,000
Philippines	–	51–500	< 15,000
Sweden	–	–	101–15,000
USA	< 500	501–2000	< 15,000
India	< 100	< 2000	–
Japan	–	–	< 10,000
Nigeria	≤ 500	501–2000	–
France	< 500	501– 2000	< 50,000
New Zealand	–	< 10,000	< 50,000
United Kingdom	< 1000	–	–
Canada	–	< 1000	1001–1500
Russia	–	–	< 30,000
Norway	< 100	101–1000	1000–10,000
Germany	< 500	501–2000	< 12,000
Turkey	< 100	101–2000	< 10,000

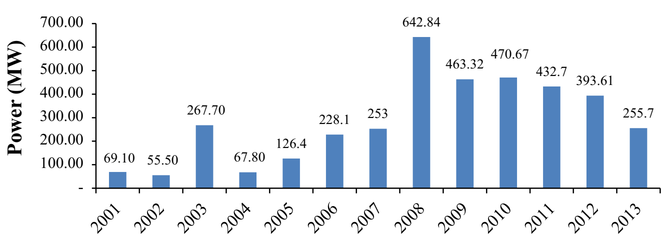

Fig. 3. Power inserted in the installed capacity per year for SHPs.
Source: ANEEL [4].

According to ANEEL, federal organ with the purpose of regulating and supervising the production, transmission and sale of electricity in Brazil, in July 2015, the number of SHPs in operation was 475 and influenced the generation capacity in the country to around 4.799 MW, representing 3.49% of the all Brazilian energy matrix. Despite the growth in the last 15 years, the power generation of this segment is small compared the available potential [4].

Currently, there are 37 plants, with characteristics of SHP, under construction, which will insert another 428 MW of power, and 128 stations granted, which could add more 1818 MW in power generation through this alternative source of energy in the next years [4].

The South and Southeast/Midwest regions have the highest concentration of SHP in Brazil in operation, construction and granted (Fig. 4). Also, they have the plants with higher power generation capacity (Table 4).

However, the hydropower potential for SHP is vast in Brazil, and only 18% of the known potential is used to generate electricity, low number compared to other countries which use much of their small hydro potential. The main problem is the non-viability of the implementation of projects for different reasons: bureaucratic or economic [22]. According to the data shown in Table 5, some countries want to evolve their SHP installed capacity, taking advantage, in full, of their SHP potential. Brazil, with a SHP potential of 22,500 MW, intends to evolve its potential to about 6700 MW of its SHP installed capacity.

4. Brazil regulatory environment for SHPs

After the restructuring of the Brazilian electricity sector, which started in 1995, a series of laws, decrees and resolutions were developed with the purpose of regulating the sector and create mechanisms to attract investments. [28].

Among these regulations, there are those that deal with investments and the organization of the electricity sector, the

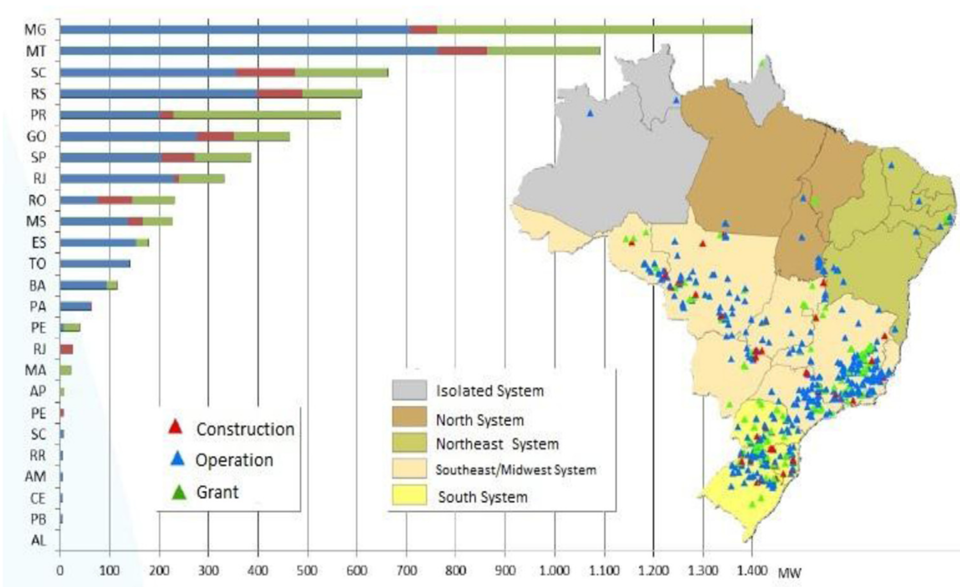

Fig. 4. SHP in operation, construction and granted in Brazil in 2013 (Isolated System: AM, MA, RR; North System: PA, TO, MA; Northeast System: PI, CE, RN, PB, PE, AL, SE, BA; Southeast/Midwest System: MG, MT, SC, RS, GO, SP, RJ, MS; South System: PR, SC, RS).
Source: ABRAGEL [26].

Table 4
Brazil's 25 largest SHPs.
Source: ANEEL [27].

Name	Granted power (kw)	Supervised power (kw)	State	River	NA_MONT (m)	NA_JUS (m)	Drainage area (km^2)	Reservoir area (km^2)
Bocaiúva	30,000	30,000	MT	Cravari	311	275	2543	2.73
Buriti	30,000	30,000	MS	Sucuriú	415.5	382.11	6742	0.5
Irara	30,000	30,000	GO	Doce	657	604.2	2006	2.58
Jataí	30,000	30,000	GO	Claro	600	556	754	0.425
Lavrinha	30,000	30,000	SP	Paraíba do Sul	491.2	484.5	12,633	0.76
Ludesa	30,000	30,000	SC	Chapecó	635	589	2290	8.17
Mosquitão	30,000	30,000	GO	Caiapó	400	354.84	6240	2.8
Passo do Meio	30,000	30,000	RS	Rio das Antas	535	492	3457	1.77
Pery	30,000	30,000	SC	Canoas	823	780	5750	5.2
Porto Franco	30,000	30,000	TO	Palmeiras	446	396.3	1727	5.92
Queixada	30,000	30,000	GO	Corrente	530	490	3923	6.16
Queluz	30,000	30,000	SP	Paraíba do Sul	484.5	471.5	12,732	1.27
Sacre 2	30,000	30,000	MT	Sacre	382.5	337	6397	0
Salto Curuá	30,000	30,000	PA	Curuá	394	253.6	1150	0.3
Santa Fé I	30,000	30,000	RJ/MG	Paraibuna	296	261	8576	2.05
Santa Rosa II	30,000	30,000	RJ	Grande	489.5	354.9	979	0.62
Santo Antônio do Caiapó	30,000	30,000	GO	Caiapó	450	419	0	6.59
São Pedro	30,000	30,000	ES	Jucu	420	228.72	210	0.11
Telegráfica	30,000	30,000	MT	Juruena	289.5	269.81	5945.69	1.14
Garganta da Jararaca	29,300	29,300	MT	Sangue	410	373	2591	1.76
Nova Maurício	29,232	29,232	MG	Novo	281.8	1888	0	3.12
São Lourenço	29,100	29,100	MT	São Lourenço	222	200.51	5775	12.9
Júlio de Mesquita Filho	29,072	29,072	PR	Chopim	348.1	325.5	7470	0.42
Serra dos Cavalinhos II	29,025	29,000	RS	Das Antas	450	4188	3809	0.48
Paranatinga II	29,020	29,020	MT	Culuene	345	330	8469	12.9

Table 5
Small hydropower: current potential and prospects for the future.
Source: Masera et al. [25]; ANEEL [4]; Capik et al. [1].

Country	SHP installed capacity (MW)	SHP potential (MW)	SHP future installed capacity (MW)
China	65,680	128,000	73,341 (2015)
US	6785	8041	9485 (2025)
Brazil	4676	22,500	6700 (2019)
India	3496	20,000	5596 (2017)
Turkey	1490	16,500	5200 (2025)
Canada	3372	15,000	6492 (2025)
Japan	3518	10,267	Unknown
Russia	1300	Unknown	Unknown
Norway	1778	Unknown	Unknown
Germany	1732	1830	1830 (2020)

creation of governmental organs, development policies for infrastructure, the use of water resources, protection of the environment, for the sectorial support programs, the conclusion of contracts among agents, the processes of authorization from Granting Authority, for environmental licensing, among others, providing support and stability to the changes (Table 6). All changes are ensured by law [29].

Since the start of regulations until today, more than BRL 1 billion was invested by private investors in the development and environmental licensing in approximately 1000 basic engineering projects, totaling more than 9000 MW in projects, which after developed, they were filed in the ANEEL. But, nowadays, the evolution of the numbers has difficulties to continue increasing. Internal policies and growth of other renewable sources present as obstacles for SHPs, especially [22]:

- Analysis of projects: Fig. 5 shows that the number of projects registered in each year is higher than the number of projects authorized to enter in operation by ANEEL. In 2014, 116 projects were registered and only 7 projects were authorized. Lack of employees to review projects is the explanation of ANEEL for this obstacle [24].
- Energy auctions: since the frustration by achievers of SHP with the alternative energy auction in 2007, realized by government, where only 6% of registered energy was commercialized, the projects of SHP are directed to the exclusive service of free market, since they are not viable in the energy auctions. While the government practiced unfeasible policies for SHP's base price, it bought energy of the thermoelectric sector with higher prices. (Fig. 6) [30,31]. In the past eight years, just 1% of total energy was purchased from SHP (Fig. 7).
- Evolution of other energy sources: another challenge is the competitiveness with other renewable energy. Wind power and biomass, compared with SHP, have been benefited with strong technological development, reduction in the average installation cost, fiscal benefits, and, for this, increased their generation capacity. It is estimated that in 2020, the generation of biomass and wind evolve 74% and 1000%, respectively, while the power generation using the SHP increase by 56% [28]. Fig. 8 shows the evolution of the cost of implementation of these three alternative sources in past few years.

To combat these obstacles, agencies, such as ABRAPCH (Brazilian Association of Development of Small Hydroelectric Plants) and ABRAGEL (Brazilian Association of Clean Energy), that support the generation of energy from renewable sources and small hydropower, have several meetings during the year to discuss the future of SHPs in Brazil.

For students, entrepreneurs and politicians of the area, it is believed that some key actions must occur for the broad potential of SHPs in Brazil to be well spent.

To deploy a program of specific annual auctions with maximum quantities contracted defined and adjusted with the demand, to simplify the procedures for approval of studies and projects in ANEEL, rules for habilitation of the participation of SHP in energy

Table 6
Regulations in the Brazilian electricity sector for the generation through the SHP.
Source: ANEEL [29].

Regulations for SHPs	Legal base
Authorization no-cost to explore the hydraulic potential	Law no. 9074, of July 1995 and Law no. 9427, of December 1996
Discounts superiors to 50% in the taxes of use of the transmission and distribution systems	Law no. 10438, of April 2002; ANEEL Resolution no. 281, of October 1999; ANEEL Resolution no. 219, of April 2003
Free commercialization of energy with consumers, whose load is less than 500 kW	Law no. 9648, of May 1998; Law no. 10438, of April 2002
Free commercialization of energy with consumers, situated in isolated electrical system, whose load is less than 500 kW	Law no. 10438, of April 2002
Exemption related to the financial compensation for use of water resources	Law no. 7990, of December 1989; Law no. 9427, of December 1996
Participation in the division of Fuel Consumption Account when replacing thermal oil generation, in isolated systems	Law no. 10438, April 2002
Exemption application, annually, of minimum one percent of operational net income in research and development of the electricity sector	Law no. 9991, of July 2000
Commercialization of energy generated by SHP with public concessionaires	ANEEL Resolution no. 248, of May 2002
PROINFA – Incentive Program for Alternative Sources of Energy established with the objective of increasing the participation of electricity produced by independent producers, designed based on SHP, wind power and biomass	Law no. 10438, of April 2002; Law no. 10762, of November 2003; Decree no. 4541, of December 2002
Review of the producers and criterions used in environmental licensing that determine the procedures and deadlines to be applied	CONAMA Resolution no. 237; of December 1997, e CONAMA Resolution no. 279, of June 2001

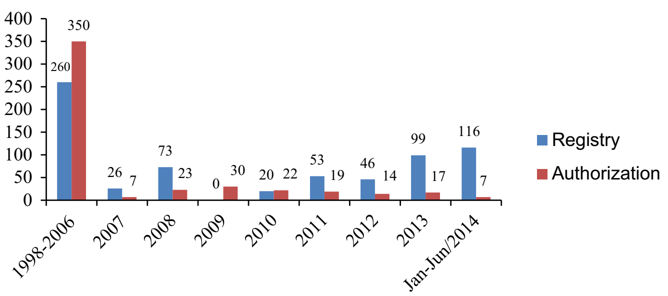

Fig. 5. Registry and authorization of SHP projects in Brazil.
Source: ANEEL [4].

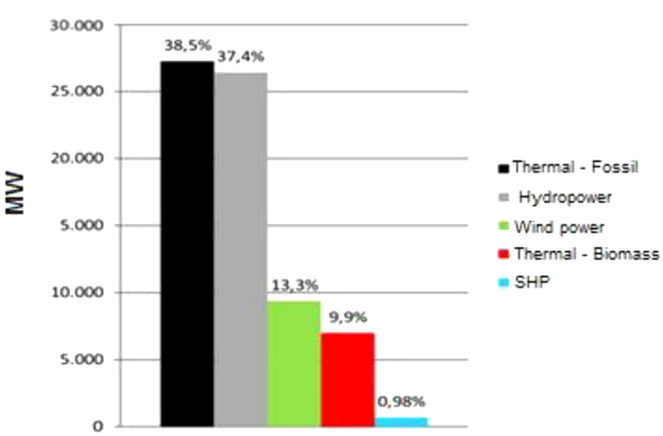

Fig. 6. Percentage of purchase in energy auctions in Brazil in the last eight years.
Source: ABRAPCH [22].

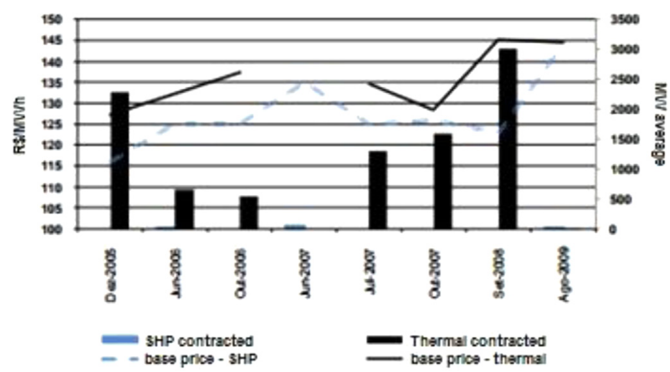

Fig. 7. Comparison of the base price and purchased power in recent auctions of energy between thermal and PCH.
Source: [30,31].

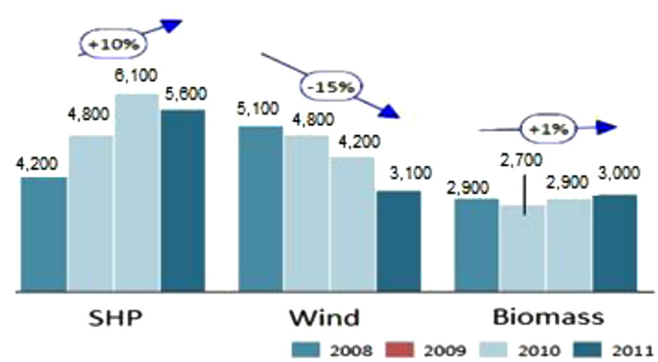

Fig. 8. Installation cost.
Source: ABRAGEL [26].

auctions more flexible, fiscal equality in comparative analysis with other sources, to encourage studies at universities and technical schools on the theme PCHs, to disclose the developments made and to encourage companies in the sector are relevant actions which can increase the number of SHP in Brazil [26].

With these actions, it is possible to increase 5000 MW in the SHP installed capacity in the next 10 years and increase the investment potential of BRL 35 billion only in the construction of power plants [26].

5. Financial reality for SHP's enterprises

In Brazil, SHP investments are generally made through bank loans, mainly from the National Bank for Economic and Social Development (BNDES) for which the main credit line is project financing, following the premises listed here [18]:

- Loans participation of up to 80% in power generation, up to 70% in transmission lines and up to 50% in energy distribution.
- Shortage deadline of up to six months after the submission of the project begins commercial operation.
- Amortization deadlines: generation-up to 16 years.
- Amortization: constant amortization system and French system of amortization (PRICE).

According to Tiago Filho et al. [32], the entrepreneurs have found some degree of difficulty in obtaining financing to meet capital requirements, such as the following:

- A lender's score with the financial agent being excessively high.
- Terms of insufficient funding to achieve the balance point between maturation versus the terms of the capital return.
- The historical lack of business expertize with in the energy generation for the mitigation of risks surrounding the project/jobsite/operation.
- A lack of collateral to support any default.
- A lack of initial capital for project complementation of costs and project processes until a fundable phase is reached, with all licenses included.
- A lack of capital to cope with the equity related to the contracted loan.
- A lack of tools to mitigate risks, used as collateral in financing engineering, supported by international insurers confronted by investors.

In 2014, these difficulties are encountered by investors of the sector who cannot obtain the financing easily and with high interest rates.

6. Conclusion

Considering the changes presented in the Brazilian electric sector to insert the SHP as an alternative energy source, it is possible to observe that there was an increase of its potential generation in Brazil, 855 MW in 2001 to 4799 MW in 2015. But, another change to harness the large Brazilian hydroelectric potential and, mainly, government policies which favor the energy generated by SHP, which currently is buying more energy from non-renewable sources than from renewable sources, as SHPs. Only 1% of the energy generated by the SHP was bought in energy auctions in the last 8 years. The bank financing for the construction of new renewable energy source plants should provide agility in the process and lower interest rates. Another factor that must be observed, besides the Brazilian hydropower potential, is the environment. It is clearly positive that actions developed by SHP help to preserve the environment.

To implement a program of specific annual auctions with maximum quantities contracted defined and adjusted with the demand, to simplify the procedures for approval of studies and projects in ANEEL, rules for habilitation of the participation of SHP in energy auctions more flexible, fiscal equality in comparative analysis with other sources, to encourage studies at universities and technical schools on the theme SHPs, to disclose the developments made and to encourage companies in the sector are relevant actions which can increase the number of SHPs in Brazil.

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