Use of photovoltaic solar energy in built environments in accordance to NR 482/2012 and 687/2015

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ABSTRACT: In recent years, the energy photovoltaics has been recognized internationally as a very promising technology. International experiences have contributed to the analysis of market expansion, economies of scale and reduced costs for investors. From a strategic point of view, Brazil has a number of natural features favorable to this type of generation, as its high levels of insolation. Such factors potentialize the attraction of investors, as well as the development of an internal market, what highlights the important role what this technology can play in the energy matrix of the country. In 2012 came into force on Normative Resolution n° 482, which establishes the general conditions of access to the electricity distribution systems in case of distributed microgeneration systems and

distributed minigeneration systems, in order to reduce regulatory restrictions for the connection of small power generator in the electricity distribution grid and introduce the power compensation systems (net metering). This article was supported in the review of related literature and applicable regulations and aims to discuss the revision of the power compensation system what is described in normative resolution 482/2012, and modified by resolution normative 687/2015, and its effects on the expansion of solar PV in built environments, and its capacity in stimulate the use of new technologies, the increased of the efficiency and the expansion of distributed generation. It was found that, despite the advances that the normatives represent, the development of photovoltaic energy is still held back by the lack of mainly economic and legal incentives.

Keywords: *solar technology, renewable energy, the built environment, public policy.*

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1. INTRODUCTION

In the last half of the century XX a urbanization process was verified in developing countries, what resulted in large population concentrations in a few cities, aggravating the use of public spaces, urban mobility and income gap. Similarly, the Brazilian population has changed your profile in this same period, changing also its economy, mobility and característics of its built environment. According projections released by Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística – IBGE), the population follows a trend of growth to an increasingly slower pace until the 2040s, when it provides the beginning of a decline in population growth rates. Thus, it is estimated that by 2030, the average age of the Brazilian will be 36 years and 61.4% of the population will be over 30 years old (Ibge, 2008), that is, there will be more adult people able to form family and to demand housing (Eyt, 2008). This scenario provides a prediction that there will be a increased demand for buildings, accompanied by the expansion of consumption of inputs associated with the use and operation of the built environment, as energy. In addition, it must be noted that two thirds of global energy consumption occurs in cities. In view of this, considering such changes in the current model occupation, a considerable impact on the energy supply and demand is estimated across the country and across its the generation infrastructure, transmission and distribution of this energy. Therefore, the development of the public policies related to energy sector and able to meet such demands is necessary. The policies should to promote incentives and an effective change in the paradigms of the generation, transmission and distribution chain of energy.

2. CONTEMPORARY PERSPECTIVES ABOUT THE ENVIRONMENT BUILT

Since the beginning of the sedentarization process of humanity, and even more so with its consolidation, the human is changing the so-called natural environment with building an infrastructure capable of attend their basic needs for housing, security and mobility. However, only with increased industrialization, followed by the disorderly growth of the cities, it was established the concept of built environment or artificial (São Paulo, 2016), designated like a environment produced by the action of man to transform nature (Calil, 2016).

Usually, the relationship between the natural environment and the built environment are analyzed by the bias of the second impact on the first. However, in a holistic view, the human activity can be considered under a perspective where it is part of the environment, what make necessary also to analyze the influence of natural factors on the buildings, once what, in real cyclical relationship, these factors affect directly and indirectly the manner how the interference caused by human impacts the natural environment (Sousa Junior, 2006). In this context, it is necessary to seek a balance between human desires and the maintenance of the natural environment, within a concept of sustainable development, which must be effectively anchored in an environmental urban planning. The sustainability of a building comes from the characterization of the processes by which it has been designed and executed, as well as the sum of the various techniques used in relation to environment and the place, making use of available resources effectively and

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without exhausting them, not compromising the service capacity of the natural resources available in the environment for future generations (Barbosa Filho et al., 2016). Thus, several successful initiatives of sustainable constructions have been developed by cities around the world. Many of the programs treat the individual sectors of construction, such as public buildings, commercial buildings, schools or homes. Others programs set specific resource conservation goals, such as saving in water use, reuse of materials seeking to minimize the level of greenhouse gases emissions (GHG) level. However, it is evident on the world stage that private and public initiatives should implement and further expand their approaches and scope of its actions to the consolidation of this new paradigm of promoting sustainable development, including new building codes or new standards and incentives for public buildings, private and new ventures (São Paulo, 2011).

There are some consensus, which is increasingly growing in scientific discussions and policies, which the global warming and other climate changes and their consequences are not just a problem for future generations, and it is not a matter that governments can solve alone, but is a problem that requires the involvement of every individual and of the whole society. The broad participation of citizens should be seen and understood as a fundamental factor for the changes to be promoted and felt by all the different layers of society in an equitable way. Thus, some municipalities are already promoting campaigns and public engagement projects in order to encourage people, businesses and community organizations to be protagonists in proposing of mitigation and adapting solutions to new requirements and demands, including the energy (Sao Paulo, 2011). It is, therefore, by the popular participation that public policies can reach a level of greater efficiency and rapidly, both by its applicability as for their monitoring and maintenance.

This new energy context, influenced by the question of adaptive need throughout the contemporary built environment and future, makes evident the need for incorporation of non-conventional energy sources in the energy mix that feed the development of human activities, increasingly urban. Throughout the world, especially in countries with greater economic and social development index, they have been presented a smorgasbord of projects and programs aimed at the use of new generation technologies and non-conventional energy use, as well as their applications in different urban environments and suburban (São Paulo, 2011), especially with a concern focused on energy conservation and improved efficiency of energy conversion systems (Aguiar, 2004). The total energy required for the consolidation of a sustainable development model requires the proposition of a new paradigm, in order to cause the convergence of new and innovative technologies, with new institutional structures, new ways of doing public policies and behavior human, always in transformation (Sao Paulo, 2011). That way, there is a growing demand for energy services what ensure greater safety and systemic reliability, coupled with the need to reduce emissions of GHGs. The solution of these issues is related to creation of new investment in research and development and technological diffusion, as well as new policies and new behavioral models lifestyle.

2.1 Characterization of environmental built in Brazil and its prospects

As shown by Alves & Cavenaghi (2012), the 2010 census realized by IBGE demonstrates an increase in the number of households with five or more rooms, while there is a decrease in the average number of people in each house, which also happens with size of

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family. The data show that the total number of domiciles increased by 24.5% between the years of 2000 and 2010, outpacing the growth of 12.5% of the population in the same period. The average number of people per domicile has fallen from 5.3 people in 1970 to 3.3 people in 2010 (Alves & Cavenaghi, 2012) and can reach 2.3 people per domicile in 2050 (Epe, 2014). Finally, the census show that in 2030, Brazil will have 91.1% of the population in the cities (Figure 1).

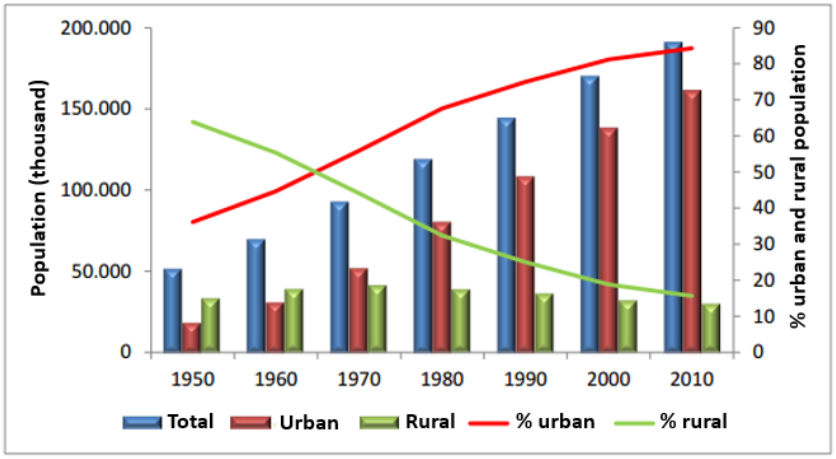

Figure 1. Stratification of the Brazilian population. Source: Alves & Cavenaghi 2012.

These factors are accompanied by an increased demand for services and products, occurring a growth of commercial, service and industrial sectors. Therefore, it is expected that will occur a booming of Brazilian built environment.

3. THE POTENTIAL OF USE OF SOLAR ENERGY IN BRAZIL.

The photovoltaic electricity generation is becoming increasingly interesting, either be the use of a renewable source (Hosenuzzaman et al., 2015), like by not have the magnitude of the environmental impacts often associated with other conventional forms of energy use. The photovoltaic systems, whether in centralized or decentralized generation, have experienced great global growth in recent years (Turney & Fthenakis, 2011), mainly due to increased demands and resource constraints, aggravated by the acceleration of environmental degradation.

3.1 Brazilian situation

The electricity generation in Brazil was developed strongly supported in hydroelectricity, however, the country has been facing some difficulties in its energetic scenario. Among them, it can highlight the physical and environmental constraints that hinder the construction of large reservoirs what cause the decrease of capacity of regularization of water flows of the power plants (Barbosa Filho; Azevedo & Xavier, 2013); and the decreased rainfall, which can be verified by the water crisis that hit mainly on the southeast of the country, at the end of the wet period of the biennium 2014/2015 (Cerqueira, 2015). Moreover, the energy sector is experiencing difficulties related to attendance the demand not only in the typically dry period, because the power supply capacity is greatly affected by atypical drought period by which spends Brazil, notably the Southeast Region. This situation has brought many adverse consequences, indicating that

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the supply when supported by a single source, may suffer complications related to its reliability and safety. There is, therefore, the need to insert up mechanisms to ensure increased supply of electricity together with the stability and quality of this energy over time (Silva et al., 2015).

In this context, Brazil has one of the highest solar radiation in the world. Most of the nacional territory is close to the equator, not presenting so large variations in solar radiation throughout the day (Brazil, 2008). The annual values of incident global solar radiation ranging between 1,550 and 2,400 kWh/m^2 throughout the national territory and are superior to the most European Union countries, for example Germany (900-1250 kWh/m^2) and France (900-1650 kWh/m^2) (Pereira et al., 2006).

According to Epe (2014) a study was conducted in partnership with the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ), approaching the total generating capacity in residential roofing, certainly one of the main applications in distributed generation (DG) (Tab. 1).

Table 1. Residential Photovoltaic potential of the Brazilian states

State	Residential photovoltaic potential (MWa)	State	Residential photovoltaic potential (MWa)
São Paulo	7100	Mato Grosso	570
Minas Gerais	3675	Rio Grande do Norte	555
Rio de Janeiro	2685	Piauí	555
Bahia	2360	Mato Grosso do Sul	505
Rio Grande do Sul	1970	Alagoas	505
Paraná	1960	Amazonas	420
Ceará	1430	Distrito Federal	410
Pernambuco	1410	Sergipe	350
Goiás	1220	Rondônia	265
Santa Catarina	1075	Tocantins	255
Maranhão	1020	Acre	110
Pará	1020	Amapá	80
Paraíba	655	Roraima	65
Espírito Santo	595	Brazil	32820

Fonte: EPE, 2014.

Considering the whole country, the potential is 2.3 times higher than consumption. This study of the EPE shows that the area is not a limiting factor for the massive integration of distributed photovoltaic systems in the country. In addition, the future increase in the number of households and the technological development of photovoltaics should raise the estimated potential (Epe, 2014).

The Brazilian potential for solar use, coupled with the current risk of electricity shortages, in a generator park based on large hydro and thermal power plants, serves as motivation to seek alternatives renewable energy.

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4. DISCUSSION ON RESOLUTIONS NORMATIVES 482/2012 AND 687/2015 AND THE PERSPECTIVES OF GROWTH OF THE USE OF PHOTOVOLTAIC SOLAR ENERGY IN BUILT ENVIRONMENTS

Following the international development of the photovoltaic sector, the Brazil, although still has small installed capacity, has sought to overcome legal and technical barriers, aiming to insert this source into its energy matrix (Abinee, 2012). The progress made in recent years include actions from multiple agents in various spheres, highlighting the regulatory, tax, research and development, and economic fomentation. As inference of the current energy model in Brazil and of the inexpressive participation of the country in installed PV capacity in the world, it can be said that, GD, and in particular photovoltaic solar source, is something still incipient and new. Still with regard to GD, it is possible that the greatest progress has occurred due to the regulation of mini and microgenerators with the publication of Normative Resolution 482/2012, which was updated by Normative Resolution 687/2015, both of National Electric Energy Agency (Agência Nacional de Energia Elétrica - ANEEL). In short, such normative resolution allows consumers install small generators in their consumer units and inject excess power into the grid in exchange for credits that can be discounted their electrical bills respecting certain periods of time (Brazil, 2012).

In general, the advancement of instalations of photovoltaic systems, especially in DG mode, favors the implementation of photovoltaic technology in Brazil, following a world trend and according to the characteristics of technical potential previously presented. However, before April 2012, there was virtually no legal support for installing this type of system in Brazil, especially regarding the regulation of connection to the electricity distribution network. Even before the publication of this resolution, the distribution companies did not have the technical and legal requirements to allow consumers compounders inject power in the low voltage network. The Electricity Distribution Procedures in the National Electricity System (Procedimentos de Distribuição de Energia Elétrica - PRODIST) were not adapted the figure of consumer-generator, requiring process too bureaucratic and framing projects as if they were accessing the medium voltage network, requiring operational studies for plants with installed capacity of several tens of kW. With the publication of the said Resolution, the module 3.7 of PRODIST (Brazil, 2012) was created and it describes the procedures to access of micro and minigeneration distributed to distribution system.

The enactment of normative resolution 482/2012, the consequent implementation of the Brazilian electric power compensation system and PRODIST modification, created a regulatory possibility for so-called micro and minigeradores, GD agents, and removed it one barrier connection and power generation. At the same time, there were declines in equipment prices in the international market, favoring that the distributed photovoltaic generation gained momentum and consolidating itself as one of the options to consider to the attendance the growing demand of the Brazilian energy market (Abinee, 2012). However, there was no incentive for these generators, excluding the increase in discounts in the Transmission System Usage Tariff (Tarifa de Uso do Sistema de Transmissão - TUST) and Distribution System Usage Tariff (Tarifa de Uso do Sistema de Distribuição - TUSD) from 50% to 80% in the first ten years of operation of solar power plants that go

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into operation until 2017 (Brazil, 2012), which have an installed capacity of until 30 MW and which are not classified as micro or mini generator (Brazil, 2015).

Since the publication of these regulations, it can be said that the market has become more dynamic, what gave rise to a number of opportunities on the technology, although it was too early to say the efficiency of the proposed model. There are still some technical, regulatory and economic barriers that prevent the full development of the technology nationwide. One of the difficulties in this beginning of the business development related to photovoltaic GD is little expression of the national industry, insufficient skilled labor and available local companies for the manufacture and installation of equipments. From economic and regulatory point of view, the adoption of premium tariffs (tarifas-prêmio) is perhaps the greatest incentive to distributed systems but Brazilian law does not potentiates actions in this regard, for the Law 10.848 / 2004 and Decree 5,163 / 2004 does not allow the trading of energy between the consumer and the distributor. Thus, despite the micro and minigeneration distributed be allowed, these are still discouraged by the legal limitations.

In a Public Hearing held by ANEEL in November 2015, the Normative Resolution 687/2015 amending the Normative Resolution 482/2012 was approved. In short, ANEEL has made it easier for people and businesses to generate their own energy from renewable sources (solar, wind, hydro and biomass). This revision brings the main changes described below (Brazil, 2015):

- Establishing of the modalities of remote self-consumption and shared generation, which provided the generation in sites away from the place of consumption (but still in the same area of the electricity distribution company) and for neighbors who want to participate in the power compensation system;
- Compensation possibility of energy credits between headquarters and subsidiaries of business groups;
- DG systems in condominiums (individuals and juridicals);
- Expansion of the maximum power of 1 MW to 5 MW;
- Extension of the duration of electricity credits from 36 months to 60 months;
- Reduction of the deadline of processing of access requests by the distribution companies of eletricity;
- Standardization of access application forms for the entire national territory;
- Submission and tracking new orders of conection over the Internet from 2017.

Furthermore, for the connection of distributed generation technology in existing consumer unit with no need to increase the available power, the distribution companies of eletricity may not require adaptation of the input pattern of the consumer unit due the replacing the existing measurement system, except in the case duly proven of technical impracticability.

The Normative Resolution 687/2015 seeks to meet the appeal of a new consumer market profile, seeking above all encourage the growth of the photovoltaic generation technology in GD mode. The reclassification of micro and mini generators with new power limits, and the possibility of carrying out shared generation, tend to conduct the market and create new businesses. The implementation of these new systems, as well as their integration

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into the built environment, are notable advances related to the attendance the demands of a new energy paradigm by inserting the DG as a tool to be considered in urban planning.

The normative resolution 482/2012, of ANEEL, as amended by normative resolution 687/2015, inaugurated a new model for the Brazilian electricity system enabling micro and mini distributed generation, approaching Brazilian law of similar practices already adopted in other countries, where the generation renewable is more expressive. However the compensation system currently adopted by legislation, it is little attractive from a financial point of view of the consumer-generator, due the impossibility to sell, in fact, the generated energy and the high cost of installation of DG. There is also the need of energy planning policy more efficient and integrated to the effective development of DG in Brazil through the inclusion of renewable sources in the energy matrix.

5. CONCLUSIONS

Minimize the consumption of natural energy resources, the emissions of greenhouse gases and promote the use of energy from renewable sources consciously and efficiently, all this within a context of broadening of the built environment and of the urbanization processes are characterized as high challenges to urban planners. A feasible possibility is the application of DG, since, the renewable energy sources, with emphasis on solar photovoltaic, due to its low energy content and other particular characteristics of conversion technologies, are able to meet located and small demands so quite efficiently, showing a clear space to be occupied by them.

The normative resolutions 482/2012 of Aneel, institucionalizou a new model for the Brazilian electricity system that allows micro and mini generation distributed, as has already happened in other countries. The normative resolutions REN 687/2015 of ANEEL, changed the scope of micro and minigeneration distributed and brought new perspectives for the sector, with remote self-consumption and also the shared generation characterized by meeting consumers within the same area of concession or permission, through a consortium or cooperative, made up of natural or juridical person who possesses consumer unit in different location of the consumer units in which the excess energy will be compensated With the enactment of these resolutions, it is expected a increase of use of photovoltaic solar energy in Brazil, as has already been observed. However, the compensation system currently adopted by legislation, is not sufficiently attractive to consumers, because there is no rate parity. The current model is lacking in economic incentives, represented by possibility marketability actual energy generated by micro and mini generators. What is needed is a more efficient energy planning policy with support grants such that enables the integration of renewable sources in the effective development of DG in Brazil.

Therefore, is evident the need for discussion by society and the government on the need to draw up an urban and energy planning more efficient for the development of DG in Brazil, under the context of sustainable cities.

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