Current Overview of the Use of Solar Energy in Brazil

Panorama Atual do Uso da Energia Solar no Brasil

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Abstract

Brazil is a country with a high amount of solar radiation, with a great potential to exploit the use of solar energy. The solar market is in full development in the world. In Brazil, this market has great growth potential and current perspectives on the use of solar energy are great. They are based on the programs of the Federal Government of Brazil such as the program "My House My Life", the "Light for All" and a resolution of the National Agency of Electric Energy (ANEEL), which allows consumers to micro and mini generation using photovoltaic solar energy.

Keywords: Sources of Energy. Solar Energy. "Light for All".

Resumo

O Brasil, pela sua posição geográfica privilegiada, é um país com alta quantidade de radiação solar incidente o que o leva a ter um grande potencial de aproveitamento do uso de energia solar. O mercado de energia solar está em pleno desenvolvimento no mundo. No Brasil, este mercado tem um grande potencial de crescimento e as perspectivas atuais do uso de energia solar são grandes. Elas estão baseadas em programas do Governo Federal do Brasil como o "Programa Minha Casa Minha Vida", que está incentiva o uso de aquecimento solar, o "Programa Luz Para Todos", que incentiva o uso de energia solar fotovoltaica e uma resolução da Agência de Energia Elétrica - ANEEL que permite que consumidor faça micro e a minigeração com energia solar fotovoltaica e use um sistema de compensação na fatura de energia elétrica.

Palavras-chave: *Fontes de Energia. Energia Solar. "Luz para Todos".*

1 Introduction

In Brazil, the generation of electricity by photovoltaic conversion had a noticeable boost through government and private projects, attracting interest from manufacturers in the Brazilian market. In addition, the amount of radiation solar incident is another very significant factor for the utilization of solar energy (GABRIEL FILHO; CREMASCO; SERAPHIM, 2010).

Oil, natural gas and coal were formed as a result of from plants and animals residues. Chemical reactions in the decomposition of organic matter in the soil process. The evaporation process, which allows the damming of water etc. It is noticed that the sun's energy is indirectly responsible for almost all the energy on earth (ANEEL, 2005).

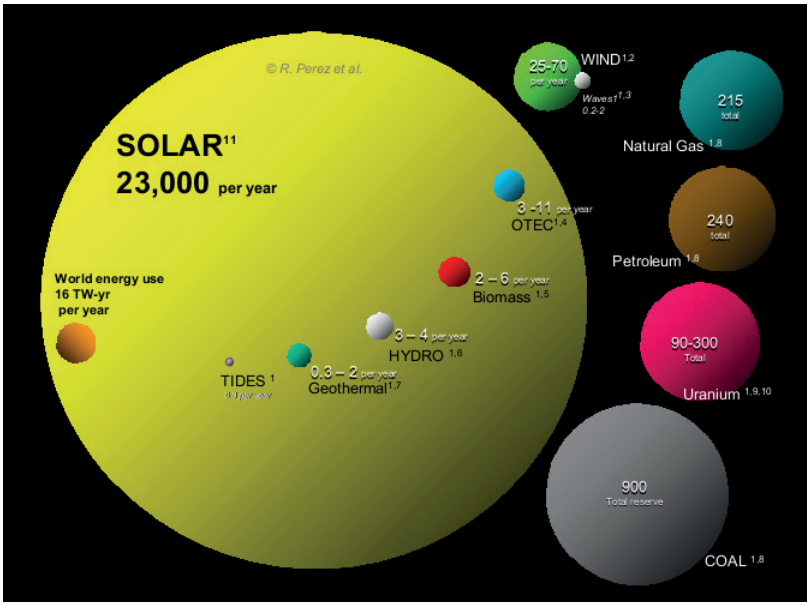
Techniques such as fuzzy theory, especially in hybrid systems for generating solar photovoltaic and wind power represent a significant increase in the use of renewable energy (CANEPPELE; SERAPHIM, 2010; CANEPPELE *et al.*, 2013).

The sun as a source of heat and electricity is one of the most promising energy sources to meet the energy crises of this millennium, since several technologies use this energy source. Energy from the sun is responsible for numerous natural phenomena that occur on this planet, including the formation of zones of high pressure responsible for wind flow, for example (TOLMASQUIM, 2005).

Almost all energy sources - hydro, biomass, wind, fossil fuels and energy from the oceans - are indirect forms of solar energy. Moreover, the solar radiation can be used directly as a source of thermal energy for heating and fluid environments, and to generate mechanical or electrical power. It can also be converted directly into electricity through effects on certain materials, among which stand out the thermoelectric and photovoltaic system (ANEEL, 2005).

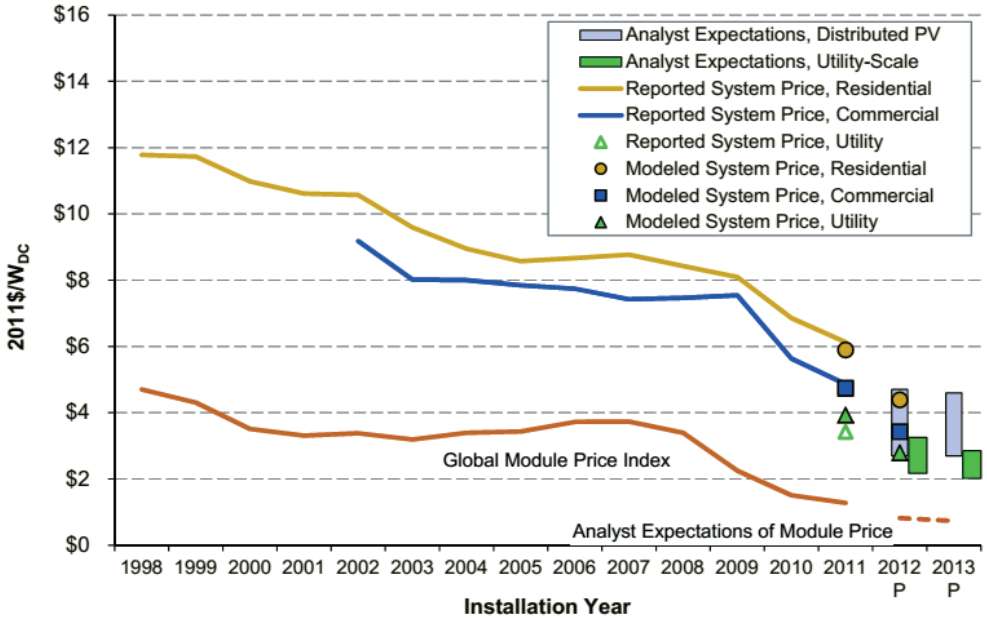
Figure 1 shows a comparison between renewable and nonrenewable energy. The volume of each bead is the total quantity of energy involved (PEREZ; PEREZ, 2009; PEREZ *et al.*, 2011). Renewable sources are not all equivalent. The solar resource is over 200 times greater than all the others together (PEREZ; PEREZ, 2009; PEREZ *et al.*, 2011). In Figure 2 are shown the prices of solar energy systems in the United States. Among systems installed in 2011, the average price was $ 6.13 / W for small residential / commercial systems and systems 10 kW or less and $ 4.87 / W for greater than 100 kW commercial systems. This indicates that there is strong possibility of expansion of solar energy systems and a promising market (NREL, 2012).

Figure 1: Comparison of finite and renewable planetary energy reserves (Terawatt-years). Total recoverable reserves are shown for the finite resources. The annual potential is shown for renewable energy sources.



Source: (PEREZ; PEREZ, 2009; PEREZ *et al.*, 2011).

Figure 2: Reported, bottom-up, and analyst-projected average U.S. PV system price over time.



Source: ((NREL, 2012).

2 Development

2.1 Technologies for solar energy utilization

Solar radiation can be used directly as a source of thermal energy for heating and fluid environments, and to generate mechanical or electrical power (ANEEL, 2005).

Among the various methods of harnessing solar energy, the most used today are water heating and photovoltaic power generation. In Brazil, the first is mostly found in the South and Southeast regions, due to climatic characteristics, and the latter in the North and Northeast regions, in isolated communities of the electricity network (ANEEL, 2005).

To use this energy by a direct process, some techniques are employed such as: Bioclimatic Architecture, Photothermal Solar Energy, Photovoltaics and Concentrated Solar Thermal Energy (CRESESB, 2014).

a) Bioclimatic Architecture

The bioclimatic architecture aims to harmonize the buildings to climate and local characteristics, aiming only human welfare at home or workplace, taking advantage of

solar energy through the natural convective currents and microclimates created by appropriate vegetation. In other words, it is the adoption of architectural and urban solutions adapted to specific conditions of each place using the energy that can be directly obtained from local conditions (CRESESB, 2014).

b) Photothermal solar energy or solar heating

This is based on the phenomenon of absorption of thermal energy by the body from solar radiation. A basic system of heating water by solar energy consists of solar collectors (plates) and thermal reservoir (Boiler).

c) Photovoltaic solar energy

It is the power that can be obtained directly from solar energy converted through special devices called for Photovoltaic Cells. The photovoltaic effect, evaluated by Edmond Becquerel in 1839, is the phenomenon that causes the appearance of a potential difference at the ends of a structure of semiconductor material, produced by light absorption.

Currently available technologies are monocrystalline silicon, polycrystalline and amorphous (thin film). The energy produced by a silicon module over its useful life (thirty years) is 9-17 times greater than the energy consumed in its production, mainly in the chemical process of purification of silicon (the mineral to the cells). For amorphous technology (thin film), the ratio is about two times larger.

Regarding the segmentation of the solar PV market may have residential, commercial, industrial plants and systems and all these systems can be isolated or connected to the network. The components of photovoltaic systems vary according to their application, being composed of the PV module and may have batteries, inverters and charge controllers.

d) Concentrated solar thermal energy

Generally, CSP uses concentrating high-reflective mirrors to generate high-temperature thermal energy that is fed into conventional stem or gas turbines for the production of utility-scale power. Within CSP systems, the most mature are the parabolic trough systems, which concentrate the energy from the sun by means of parabolic cross section. Next popularity are tower systems, which use a large field of numerous flat mirrors (heliostats) to concentrate the solar direct radiation into receiver located at the top the tower (LEMUS; DUART, 2012).

2.2 Evaluation of the solar potential in Brazil

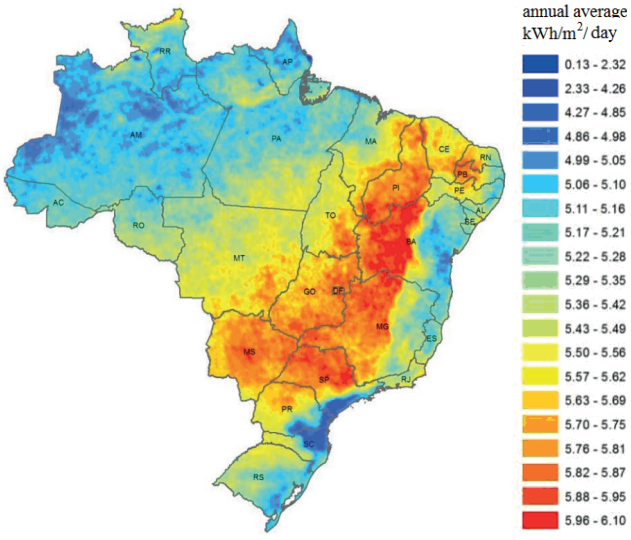
Solar radiation depends on climatic and atmospheric conditions. Only a portion of the solar radiation reaching the Earth's surface, due to reflection and absorption of sunlight by the atmosphere. Even so, it is estimated that the solar energy incident on the Earth's surface is of the order of 10,000 times the world energy consumption (ANEEL, 2005; CRESESB, 1999).

In Brazil, the most effective assessments of the availability of solar radiation are as follows (ANEEL, 2005):

- Solarimetric Atlas of Brazil (2000), an initiative of the Federal University of Pernambuco - UFPE and São Francisco Hydroelectric Company - CHESF, in partnership with the Reference Center for Solar and Wind Energy Sérgio de Salvo Brito – CRESESB (UFPE; CHESF; CRESESB, 2000).
- Atlas of Solar Radiation in Brazil (1998), prepared by the National Institute of Meteorology - INMET and the Solar Energy Laboratory - LABSOLAR, Federal University of Santa Catarina - UFSC (INMET; UFSC, 1998).
- Brazilian Atlas of Solar Energy (2006), prepared by the project SWERA (Solar and Wind Energy Resource Assessment), National Institute for Space Research - INPE and the Federal University of Santa Catarina – UFSC (INPE; UFSC, 2006).

The following map (Figure 3) shows the global solar radiation (annual average) of Brazil. It is observed that the country has a good solar irradiation by its tropical location (ABINEE, 2012).

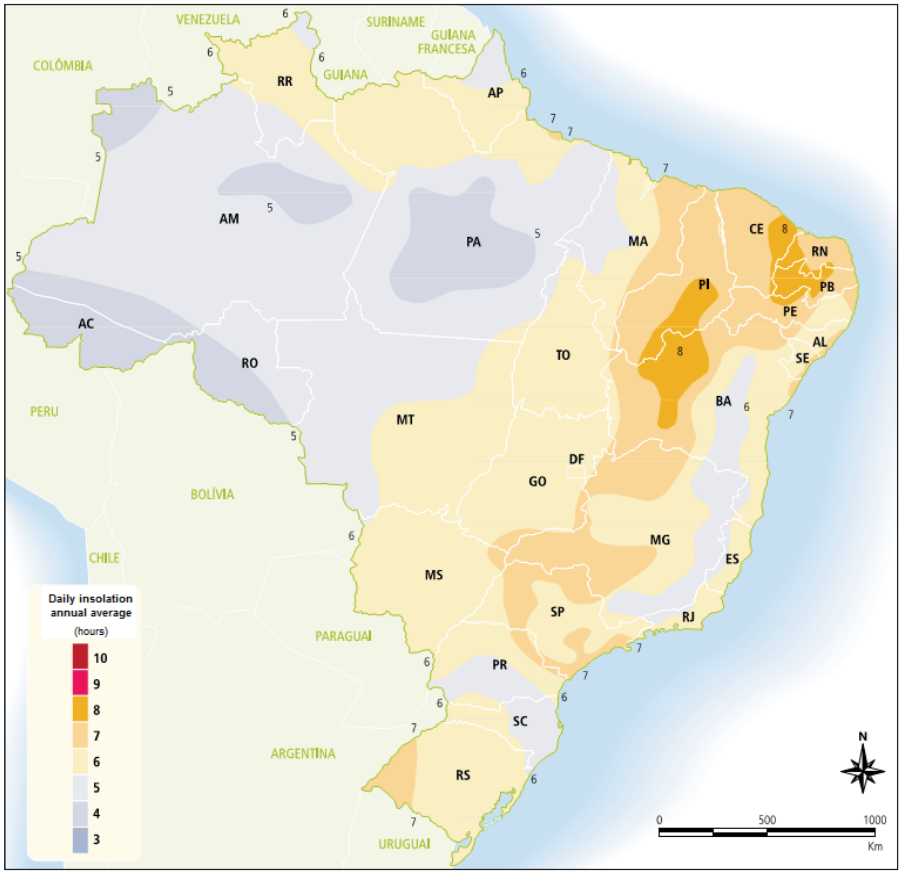
Figure 3: Total solar irradiance plane whose slope is equal to the latitude of the location



Source: ABINEE (2012).

Most of the Brazilian territory is located relatively close to the equator, so that there are wide variations in solar day length. However, the majority of the Brazilian population and socio-economic activities of the country is concentrated in more distant regions the Equator line (ANEEL, 2005). In Figure 4 is shown the annual average insolation. Thus, to maximize the utilization of solar radiation, the position of the collector or solar panel may be adjusted according to the local latitude and time of year that requires more energy. In the Southern Hemisphere, for example, a fixed solar collection system should be oriented to the North, with tilt angle similar to the local latitude (ANEEL, 2005).

Figure 4: Annual average daily insolation



Source: UFPE; CHESF; CRESESB (2000).

2.3 Current overview and energy matrix

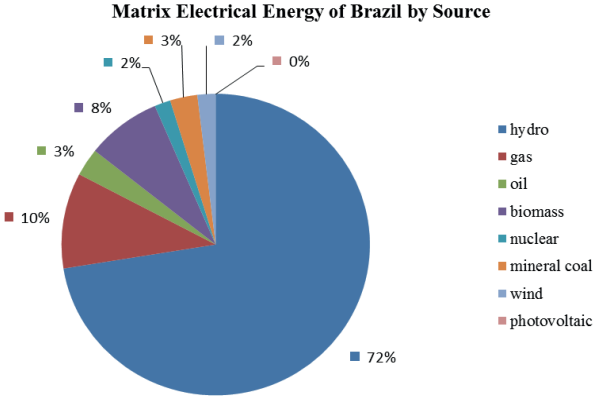
In Brazil, ANEEL created and maintains the BIG - Bank Information Generation, to disseminate a series of data on the Brazilian power generation park. The BIG universalizing and standardizing information, giving agents full knowledge of the market, foreign and domestic investors, government authorities as well as society in general, on the generation of electricity in Brazil.

According ANEEL (2014a), in October 2014, Brazil has as a total of 3,416 projects in operation, totaling 131.665.236 kW of installed capacity. Also according to data from BIG, it is observed that in the coming years, there will be an increase of 35.633.369 kW capacity of power generation in the country, from the 165 projects currently under construction and 604 concessions.

Of the generating plants and plants operating in Brazil, only 55 are Central Solar Photovoltaic Generating totaling 14,474 kW. There is still hope for the next year an increase of 30,000 kW, starting from construction projects and concessions.

The Brazilian energy matrix, by source, in relation to electricity generation is shown in Figure 5.

Figure 5: Brazil's energy matrix by source, in relation to the generation of electricity



Source: Adapted from ANEEL (2014b)

In Table 1, Brazil's participation is significant in terms of investments in hydroelectric capacity and ethanol production, but by observing the distribution of sources, the share of energy solar heating or photovoltaic, is still not significant on a world stage in renewable energy (REN21, 2012).

Table 1: Investment in new renewable energy capacity

	Increase / Annual Production in 2011					
	Investment in new capacity	**Solar PV capacity**	**Wind capacity**	**Solar capacity for water heating / heat**	**Production of biodiesel**	**Ethanol Production**
1	China	China	Italy	China	USA	USA
2	USA	Vietnam	Germany	Turkey	Germany	Brazil
3	Germany	Brazil	China	Germany	Argentina	China
4	Italy	India	USA	India	Brazil	Canada
5	India	Canada	France	Italy	France	France

Source: Adapted from REN21 (2012)

2.4 Current perspectives in Brazil

There are several current governmental actions that encourage the use of solar energy in Brazil, including:

a) Solar Heating in "Program My home My life"

The deployment of solar water heaters is part of the current (2013) housing policy of the Federal Government of Brazil, aiming at the promotion of quality and sustainability in housing developments, providing energy saving and hence improving the quality of life for future residents (CEF , 2009; CEF, 2011).

The goal is ambitious and has been fulfilled: to build two million homes, prioritizing families with gross income of up to R$ 1,600.00, but that also covers families with income up to R$ 5,000.00. This program has a broad partnership among federal, state, municipalities, entrepreneurs and social movements. It is an unprecedented effort in our country, but necessary and feasible.

The solar heating systems are necessarily included in the designs of detached houses (story houses - type 1) and optionally in the projects of multifamily dwellings (apartments - type 2) located in all regions of the country.

The government incentive through the state bank is an important stimulus to the domestic industry of solar heaters, that uses almost entirely national technology and generates employment in Brazil.

With the use of solar water heating reduces the use of electric shower that, at peak times, is largely responsible for the high consumption of electricity, requiring high demand by generators.

It is estimated that with the installation of a heating system water can be a savings of up to 50% on the electric bill. In general, the return on investment takes among 18 and 36 months and the life of the set is about 20 years on average.

b) Photovoltaic Solar Energy in "Light for All Program"

The Federal Government, in November 2003, launched the Light for All Program. It was created to serve remote locations, for which the extension of the distribution network brings cost prohibitive. This program incorporated the PRODEEM - Program for Energy Development of States and Municipalities, created in 1994, which promoted the purchase of photovoltaic systems through international tenders (BRASIL, 2010).

The rural electrification program of the Federal Government of Brazil, Light for All, reached its initial goal of bringing electricity to 10 million Brazilians in 2009. It is estimated that by March 2012, the program has reached reached around 14.4 million rural residents throughout the country.

The current challenge for the agents of the program is to reach the most isolated communities in the country, mainly in the Amazon region, as well as areas of extreme poverty in the North and Northeast Regions.

The difficult access to certain localities, where often it is impossible to carry poles and transformers, the program requires agents to seek alternative energy sources.

c) Photovoltaic Solar Energy - SmartGrid

In April 2012, the ANEEL established the general conditions for access micro generation (up to 100kW) and mini generation (100kW to 1 MW) distributed to the distribution systems of electric power and the compensation system of electricity pa be practiced in Brazil.

This resolution encourages the generation of energy from renewable sources in Brazil, mainly micro and mini generation, including solar. Consumers who have a surplus generation by using own energy sources, can accumulate credits for cashing in your invoice.

3 Conclusion

In Brazil it has been a predominantly hydroelectricity-based and this source is abundant and low cost generation. This fact makes it unattractive commercial investment in other energy sources of electricity.

Some companies have received grants from the ANEEL and different stages have solar plants under construction and/or operation which together reach the order of hundreds of megawatts (MW) capacity.

Stages of the World Cup 2014 which was held in Brazil, received photovoltaic panels and solar collectors. This will certainly bring a little country to the international projection, for showing concern in generating energy with minimal environmental impact with less.

Currently the Federal Government of Brazil has been investing through various direct and indirect programs in the diversification of the energy matrix. The impacts of investment and diversification strategy must be long term.

The solar market is in full development in the world. In Brazil, the market has great growth potential and is promising.

It is important that more government investment in technologies to foster the creation of technology-based companies, in addition to maintaining the incentives already present in research.

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