Brazil market outlook for photovoltaic solar energy: A survey study

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ABSTRACT

There is great concern worldwide about increased greenhouse gas emissions and the consequences of climate change. Photovoltaic solar energy emerges as an alternative source of renewable energy with low environmental impacts. Through a bibliographical review on the subject, this paper presents an analysis of the scale insertion of this energy in Brazil, demonstrating the benefits that can be generated of this technology, impediments and future perspectives. The conclusion is that Brazil has great potential for the energy generation, collaborating to reduce the environmental impacts as a reduction of the greenhouse gases emission. The barriers to introducing photovoltaic solar energy have been lack of investment, lack of more aggressive incentive programs, technological capacity and professional training.

Keywords: Photovoltaic; Solar Energy; Renewable Energies; Climate Change.

1. INTRODUCTION

Electricity has become an indispensable and strategic resource for the socioeconomic development of countries and regions. However, the growing interest in the search for new renewable sources of energy has been triggered by environmental impact due to pollution, depletion of resources and climate change, with some effects more worrying than others [1].

The temperature of the earth's surface is expected to increase over the years. It is very likely that heat waves will occur more often and last longer, and extreme events of precipitation will become more intense and frequent in many regions. The ocean will continue to heat and acidify and the average level of the oceans will rise. Continuity of high emissions will lead to mostly negative impacts on biodiversity, ecosystems, services and economic development and could increase the risks to livelihood, food and human security [2].

Due to the growing concern about environmental issues and the need to achieve a sustainable economy, there is a necessity to develop new solutions and energy sources strategies with less environmental impact and economically viable [3]. In this scenario, the technologies for generating energy from renewable sources with low greenhouse gas emissions become increasingly attractive [1]. In recent years, in Brazil, photovoltaic energy generation has been considered as a renewable and promising energy technology [4]. Implanted gradually, it offers an option that complements the Brazilian energy matrix [5].

Brazil is a privileged country for the installation of these systems, considering the possibility of using the high solar radiation indices in the country compared to the developed nations [6]. The possibility of using the solar radiation in the urban environment for the energy generation makes the city more sustainable [3].

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For these reasons, given the importance of this subject in the world, this article analyze the photovoltaic solar energy insertion in the Brazil energy matrix, with the objective of verifying the implementation benefits, future perspectives and the new technology impediments to achieve large scale. This work aims to demonstrate that the increase of incentives can improve the economic and environmental results of the country.

2. METHODOLOGY

The methodology used in the research was the bibliographic review on the proposed theme. The research sought to identify, evaluate and interpret a set of documents available in academic collections and institutions and energy sector entities.

The selection criteria took into account the following aspects: (i) titles of articles aligned with the research theme; (ii) abstracts aligned to the research theme; (iii) result relevance filter; and (iv) full text of articles aligned with the research theme. There was no temporal delimitation of the publications. The analysis result of the information obtained was used for the article elaboration.

3. RESULTS AND DISCUSSION

This chapter presents the main concepts about the research basic theme, including considerations about the current energy matrix in Brazil, the country solar potential and future perspectives of photovoltaic solar energy in the world.

3.1 Brazil Energy Matrix

According to a report published by the Ministério de Minas e Energia [7], the Brazil electric energy generation in public service and self-producers has reached 581.5 TWh/year in 2015. The energy matrix is predominantly renewable, with hydraulics responsible for 64% of the domestic supply (Fig. 1).

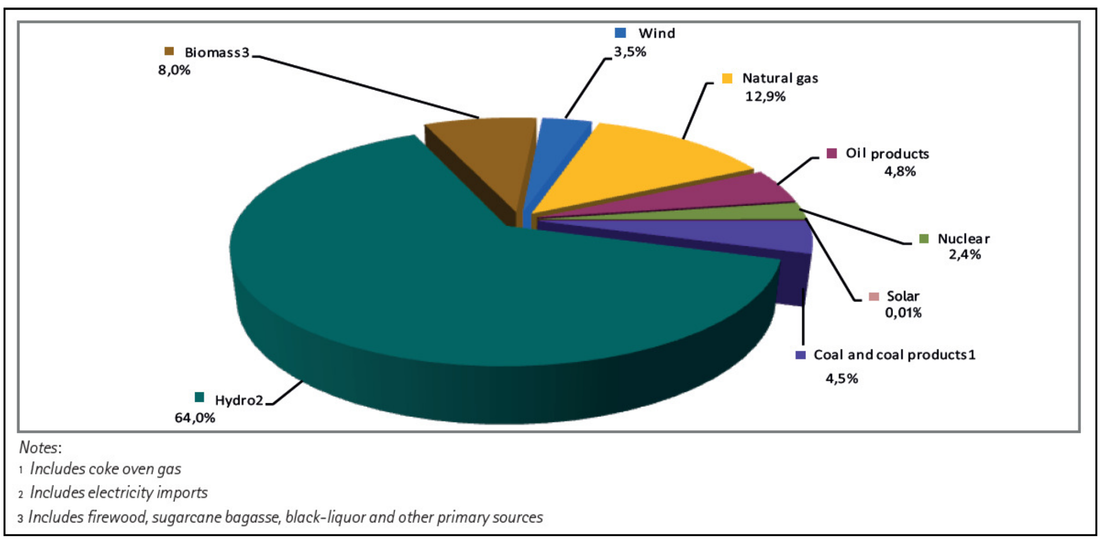

Fig. 1. Internal supply of energy by source [8].

On the other hand, the solar energy is the less representative resource with only 0.01% in Brazilian energy matrix. Thus, the next topics will present the expansion potential of the photovoltaic solar energy, besides of the future prospects in Brazil.

<u>3.1.1 Brazilian solar potential</u>

An inexhaustible energy source, the solar radiation use as both a source of heat and light is one of the most promising alternative sources of energy for human development [9]. Despite the different climatic characteristics observed in Brazil, the annual average of solar irradiation shows good uniformity, with relatively high annual averages. In addition, the incidence in any region of the country (1500-2500 $kWh/m^2/year$) is higher than in most European Union countries, such as Germany, which varies between 900-1250 $kWh/m^2/year$ and Spain 1200-1850 $kWh/m^2/year$ [10].

It is important to note that solar photovoltaic generation has a seasonal behavior differentiated by geographic region (Fig. 2). Long-term trends and cycles are negligible, with temporal behavior not correlated with other variable sources such as hydro and wind. Thus, it favors the integration of photovoltaic energy into the electric system to reduce uncertainty regarding energy availability [4].

Under clear sky conditions, photovoltaic solar generation can be predicted with great precision. However, at lower scales, the presence and random behavior of clouds may result in rapid variations in solar irradiance. This extreme variability complicates the large-scale insertion of solar in microgeneration (till 75kW) and minigeneration (till 5MW) into low voltage distribution circuits. The inverters are also subject to shutdowns in case of frequency deviation, short circuits or main voltage rapid variations. The generator parks spatial dispersion can significantly reduce the whole variability [4].

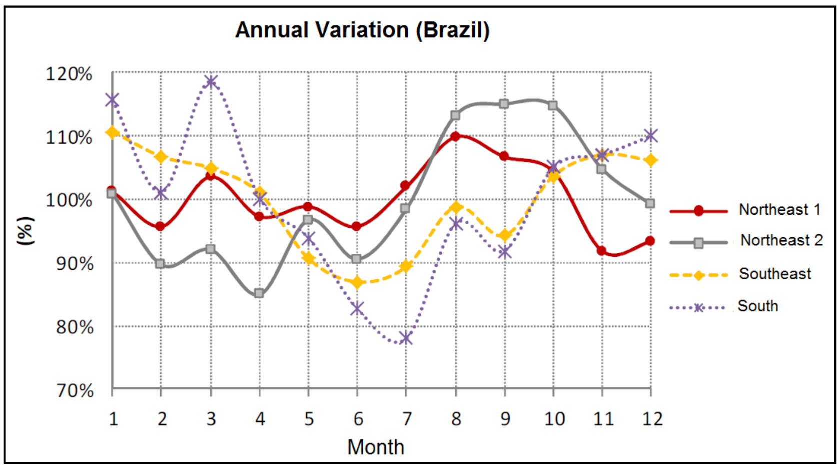

Fig. 2. Intra-annual variation of photovoltaic generation in relation to the annual average (average = 100%) [4].

The graph presented in Fig. 2 refers to the intra-annual variation of photovoltaic generation (%) throughout the year (Month), where the southern region of Brazil presents the greatest variations, whereas the regions of the Northeast 1 and Southeast present a generation Photovoltaic near the average of 100%. Regarding to electrical demand of the cities, the typical behavior of most capitals in Brazil is peak demand in the daytime, where the consumption of commercial buildings dominates, coinciding with the greater availability of the solar resource and night demand peaks in residential regions [10, 11]. For this reason, it is essential to analyze the regions where their use brings the greatest benefits [11].

In addition to analyzing the solar supply, it is necessary to study solar demand and supply in all periods of the year. The research highlights that as the south region has high consumption in the summer, importing energy from the southeast and west regions, and that in these months solar supply is the highest among all Brazilian regions, the insertion of photovoltaic energy in the south region may result in enormous benefit to the electrical system besides the economic advantages like jobs generation.

This type of energy does not replace the expansion of the installed electric system capacity, but can be seen as a clean energy source [4, 12]. During drought, the reservoirs volume in hydroelectric power plants is reduced by the lack of rainfall and energy diversity can take advantage of the lack of rainfall to complement the energy generation with solar photovoltaic generation, because precisely in the dry season with fewer clouds the sun shines with greater intensity [12].

3.1.2 Brazilian solar energy current situation

According to the Ministério de Minas e Energia and its projections for energy use [8], in 2050, the world will possibly present a reality quite different from what is known today. The Brazilian economy growth, bottlenecks resolution in infrastructure, social mobility improvement, and access to goods and services more elaborated due to the better quality of life of the population will lead to the need to increase the average consumption energy per capita. In this sense, it will be essential to seek new energy efficiency actions to reduce the need to expand energy supply in the long term, avoiding, for example, environmental impacts resulting from new projects. The Empresa de Pesquisa Energética (EPE) forecasts that between 2013 and 2050 total energy demand will increase slightly more than twice, with emphasis on natural gas, electricity and oil products.

In December 2015, the country made a commitment to the Paris Agreement during the United Nations Climate Conference to contribute to the reduction of global warming and to prevent global warming in excess of 1.5℃. In order to comply with this agreement, Brazil will need to reduce coal and gas power plants, and increase the share of renewable energy in its energy matrix in the coming years [13].

Based on these goals of reducing greenhouse gases and aiming to expand the energy matrix and for the country to present excellent conditions for all technologies for solar utilization, the Agência Nacional de Energia Elétrica (ANEEL) forecasts that by 2023 there will be an increase in the installed photovoltaic capacity of 1,173 MW in Brazil [14]. This increase is extremely relevant in terms of environmental benefits due to the fact that this generation has very low environmental impacts.

Photovoltaic solar energy can be considered a low-risk investment depending heavily on the region regulatory framework for the competitive potential of solar energy [15]. Regarding regulatory barriers for small-scale generation and the introduction of a new energy compensation system in Brazil, ANEEL published Resolução Normativa 482/2012, establishing general conditions access for microgeneration and distributed minigeration. Seventeen photovoltaic projects were selected, totaling 23.6 MW to be installed in several regions of the country [4], with microgeneration and minigeneration being responsible for the production of electric power from small generating plants connected to the distribution network with up to 5 MW of power [16]. By 2015, microgeneration and minigeneration with photovoltaic solar energy with 20 GWh/year of generation and 13.3 MW of installed capacity [7].

Another incentive to accelerate the implementation of these energy generation systems is the incentive program called Programa de Incentivo às Fontes Alternativas de Energia Elétrica (PROINFA), responsible for providing the effective use of renewable energy in the country. Funded by the Banco Nacional do Desenvolvimento (BNDES), it provides for the diversification of the energy matrix and reduction of greenhouse gases, besides the creation of jobs, training and training of labor [6].

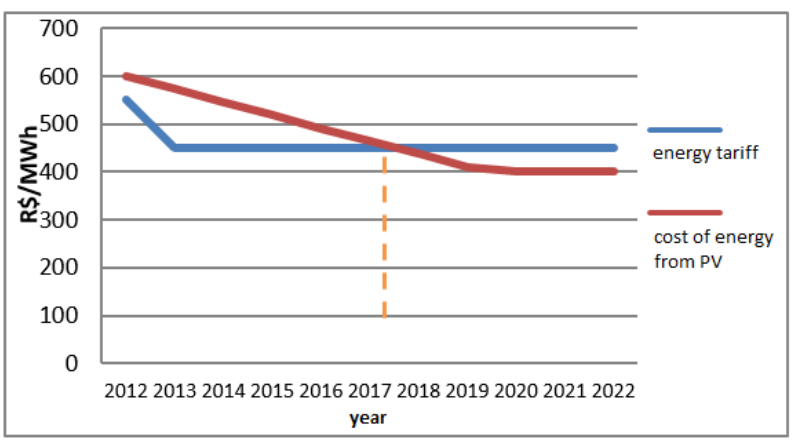

Fig. 3. Economic viability estimation of the photovoltaic systems [8].

One of the barriers to the introduction of the most intensive photovoltaic solar energy in Brazil has been the investments associated with this technology compared to other technologies installed in the country. However, costs are showing significant reductions over the years, increasing the competitiveness of photovoltaic [9]. There is a prospect that the tariff parity of photovoltaic generation will be reached even in this decade as shown in Fig. 3 [8].

3.1.3 Photovoltaic solar energy results of implementations in Brazil

A recent study indicates that the implementation of a photovoltaic system at Presidente Prudente's college would reduce the local energy consumption and avoid 55 tons of carbon dioxide per year over 30 years generating a positive environmental impact. It is concluded in his research that the payback would be approximately 12 years and 04 months, characterizing itself as economically viable project [3].

The implementation of grid-connected photovoltaic systems at a residence near São Paulo, for instance, demonstrated that the return on investment would be 19 years considering the 2014 charge for the local energy distributor. If the 2013 tariff were considered the return would be 12 years [17].

The Green Office of Federal Technological University of do Paraná located in Curitiba was inaugurated in 2011 and it was Brazil's first "carbon zero" sustainable office [18]. This system has already produced 11.67 MWh in the last five years of uninterrupted operation, which represents an average monthly generation of approximately 200 kWh / month and becoming a zero energy building (ZEB). In the summer months, as the generation reached 304 kWh / month, it was possible to export energy to other nearby facilities making a positive energy building [19].

In the research conducted by [20], considering the evolution of tariffs based on inflation and without incentives to distributed generation, there is economic-financial viability of microgeneration in most Brazilian capitals. In the scenario of increasing energy tariffs above inflation, there is viability in all Brazilian capitals.

3.1.4 Technology negative environmental impacts

Despite generating more energy, hydroelectric plants have large environmental impacts, while solar energy has reduced impacts [12]. Photovoltaic solar energy implies no greenhouse gas emission during operation and does not emit other pollutants (such as sulfur and nitrogen oxides); additionally, it consumes little or no water. As local air pollution and use of fresh water for cooling thermal power plants are becoming serious concerns in hot or dry regions, these benefits of photovoltaic solar energy become increasingly important [21].

However, a recent study [22] points out that although the negative impacts presented by photovoltaic systems are very small compared to the positive impacts and advantages of implementation, the problems that arise are presented at Tab. 1.

Tab. 1. Negative impacts on PV x possible solutions [22].

Environment	Negative impacts [22]	Possible solutions
Physical	Landscape alteration and/or degradation; solid waste generation and risks of soil contamination from human activities; dust and gases generation and quality of the air alteration during the work; generation or intensification of erosive processes and changes in water behavior and surface hydrological flow; morphological changes and temporary instability of the surface.	Integration of grid-connected photovoltaic systems through Building Iintegrated Photovoltaics (BIPV) and Building Attached Photovoltaic (BAPV), which can suply the demands of energy in the urban environment and in a decentralized way contributing to the reduction of peak daytime demand in cities. On the other hand, regarding the large power plans, it is possible expand the energy capacity by the installation of floating photovoltaic panels on the river and lakes in brazilian territory.
Biotic	Vegetal cover loss; change in the dynamics of local ecosystems; scaring and escaping local wildlife; reduction of ecological potential (environmental attributes and biodiversity); accidents risk with animals or caused by animals.	
Socioeconomic	Employment and income generation; local economy growth and increase in tax collection; flow of vehicles increase; materials consumption; work accidents risks; equipment efficiency increase; energy source use; security improvement, electricity reliability and supply.	Uses of electric vehicles could reduce the CO_2 emissions and can storage the exceed energy. Investing in technical trainning and sustainable processes could reduce both of work accidents risks as garantee security improvements in this activity and the material production.

It is important highlight that during its operation, the photovoltaic system does not emit pollutants and is a sustainable energy alternative. The most significant environmental impacts are caused during manufacturing, system assembly and implantation. However, most of the implantation phase negative impacts are temporary. While most of the positive impacts are consolidated in the operation phase, environmental control and monitoring are needed to minimize possible system degradation resulting from the Photovoltaic Solar Power Plant [22].

<u>3.1.5 Impediments and technology future prospects in Brazil</u>

The study related to future prospects, concludes that the market of micro and minigeration in Brazil are in an early stage of development and may be considered below their potential [23]. The possible barriers identified in the study include regulation, incentives, technological capacity and professional qualification, currently composing a non-development scenario required for the sector to prosper. It was pointed out that most Brazilians still do not know the about this topic. However, when presenting information on the subject, they proved to be in favor of renewable generation demonstrating the consolidation potential of these initiatives.

Large size centralized generation clearly is not competitive at the moment in Brazil. The economic viability for distributed generation is closer to happen [4]. The expansion of these systems is driven by self-consumption - the use of electricity directly in the same place where it is generated - being able to carry small amounts of negotiated energy [21]. The possibility of using already built areas to fix panels, reducing investments in transmission and distribution lines, contributing to the diversification of the Brazilian energy matrix [5]. Nevertheless, the main disadvantages are the high cost of solar cells, variation of the amount of energy produced according to the climatic situation and forms of storage still not very efficient. However, they point out that there is no type of energy that only brings advantages and the appropriate choice will depend on the priority aspect (cost, risk, short-term or long-term environmental impact, space, resources, among others) [1].

In terms of the photovoltaic systems costs, 60% are from solar panels, 10% from the inverter and the rest from support structures, auxiliary electrical equipment, as well as installation and assembly [4]. After analyzing photovoltaic systems in Brazil historical data, the total cost of implementing a complete system shows a downward trend, mainly due to the trend of reducing the modules value [24], as shown in Fig. 4. According to Solar Power Europe, the outlook is promising as the photovoltaic system price has dropped by 75% over the last 10 years [15].

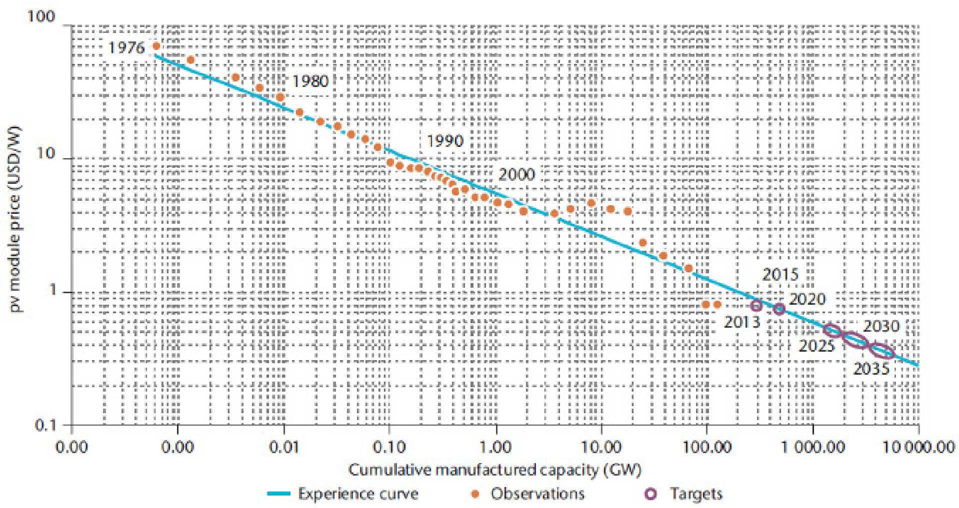

Fig. 4. Photovoltaic modules old prices and 2035 projection [21].

Another reduction that can occur is in the solar panels themselves. In October of 2016, an United States company announced the production of solar roofs with renewable energy which promises to accelerate the solar energy use with this new technology. This new type of roof promises to be more economical than the normal roof combined with the energy savings the new system offers [25]. This new market could further accelerate the use of solar energy over the next few years and create a new scenario for the future in terms of system cost.

At present, there are few research and development institutions in the area of solar panels in Brazil as well as excess solar panels with low cost being produced in other countries [4]. It would be necessary to present improvements and adaptations in the facilities available in Brazil both to develop materials for production of photovoltaic cells with thin film and also to include the production of silicon for solar use and complete modules assembly [26].

Photovoltaic solar energy stands out given its potential and the wide range of applications possibilities from technological innovations in various sizes and scales. Despite the barrier to cost and efficiency limits of systems, the use of this technology is fully feasible with the government incentive programs creation, changing the way to generate, distribute and consume energy, in addition to the rapid diffusion of existing technologies [27]. In this scenario, the government role is preponderant to spread to expand the use of this technology [4, 27].

Capital targeting decisions for the energy sector are increasingly shaped by government policy measures and incentives, rather than signals from competitive markets. Private sector participation is essential to meet the full energy investment needs, but the private mobilization and capital investors will require a concerted effort to reduce political and regulatory uncertainties [28].

Satisfactory incentive laws such as some mechanisms observed in Europe, establishing a tariff that the electricity distribution concessionaire pays for each kWh of energy produced, is capable of encouraging large photovoltaic energy markets at a cost that ends up being distributed among all electricity consumption, allowing production costs to fall due to an increase in the scale of production [27].

Among the incentive options, contracting models, financing models, tax incentives or even premium-rate offers can be reported [4]. About contracting models, there are two main strands in the area of incentive to solar generation: feed-in tariff and net metering. The first is the tariff payment generally higher than the local concessionaire's energy tariff sand the cost can be assumed by the national treasury or prorated by the energy consumers (this incentive form predominates in Europe mainly Germany and is also adopted by Japan). The second consists of the credits accumulation in concessionaires when solar energy exceeds local consumption. This model predominates in the United States. It should be highlighted that the net metering instituted by ANEEL in Brazil has an ICMS tax incidence in some states, which makes it impossible to apply this model in the country and making it difficult to evolve in this sector [29].

4. FUTURE GOALS AND PROSPECTS FOR PHOTOVOLTAIC SOLAR ENERGY IN THE WORLD

Despite the increase in energy consumption over the years, for the first time in four decades the carbon dioxide global emission associated with energy consumption stabilized in 2014 as the economy grew. This stabilization was attributed to the renewable energy introduction and improvements in energy efficiency. Globally, there is increasing concern that has impacted the implantation of these critical systems to reduce global warming, creating new economic opportunities and providing energy for billions of people. This type of energy is an extremely important element for global climate adaptation [30].

The year 2015 was extraordinary for renewable energies with the largest additions of global capacity till now although the challenges remain. The year has had several developments that have an impact on renewable energy, including a dramatic decline in global fossil fuel prices; a series of announcements on the lowest prices of all long-term renewable energy contracts; a significant increase in attention to energy storage; and a historic climate agreement in Paris that brought together the global community. Rapid growth was driven by a number of factors, including improved cost of renewable technologies, policy initiatives, improved access to finance, energy security and environmental concerns, increasing energy demand for developing and emerging economies and the need for access to modern energy. Consequently, new markets for both centralized and distributed renewable energy are emerging in all regions [31].

Since 2010, worldwide, there has been an increase in the photovoltaic systems capacity greater than had occurred in the last four decades. New systems were installed in 2013 at a rate of 100 MW of capacity per day led initially by Germany and Italy [21]. In 2014, 40 GW of capacity was added, reaching a total of 177 GW of global capacity [30]. By 2015, it has reached 227GW of global capacity. The countries that invested most in these systems were China, Japan and the United States, followed by Germany and the United Kingdom [31], as shown in Fig. 5a and 5b. Depending on the evolution of the solar energy markets in the coming years, the total capacity installed in 2019 could reach between 396 and 540 GW with the most likely scenario around 450 GW [15].

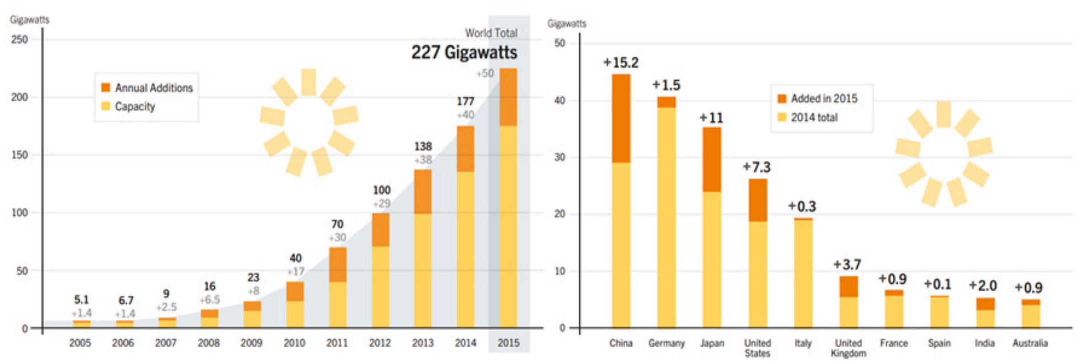

Fig. 5. Global Capacity of Photovoltaic Systems (a); Capacity and Additions in 2015 (b) [31].

With regard to global warming, the International Energy Agency (IEA) proposes to increase energy efficiency in industry, buildings and transport; to progressively reduce the use of less efficient coal-fired power plants and to prohibit their construction; increase investment in renewable energies; reduce subsidies for fossil fuel consumption and methane emissions from oil and gas production [32].

The road map established by the IEA [21] foresees the photovoltaic systems participation by 16% by 2050, a significant increase in the 2010 roadmap target of 11%. China is expected to continue to lead the global market, accounting for about 37% of global capacity by 2050. This forecast would imply 4,600 GW of installed capacity, avoiding 4 gigatons of CO_2 emissions annually, contributing to market development with a cost reduction of 25% by 2020, 45% by 2030 and 65% by 2050, leading to a range of $ 40 to 160 / MWh, assuming a cost of capital of 8%.

The investment path outlined by the IEA [28] is far short of achieving climate stabilization goals, as today's policies and market signals are not strong enough to shift investment to low carbon sources and energy efficiency in the scale and speed required. It is estimated that$ 53 trillion in cumulative energy supply and energy efficiency investment are required in the period up to 2035 (Scenario 450) to make the world follow an energy path compatible with the limiting global temperature increase to 2℃ goal, limiting the greenhouse gases concentration in the atmosphere by about 450 parts per million of CO_2.

5. CONCLUSION

There is scientific evidence that the Earth's temperature is warming and that recent changes in the climate are most likely due to an increase in greenhouse gases produced by human activities. The renewable energy use is one of the solutions to adapt to climate change, improving the resilience of conventional energy systems and contributing to a more diversified and distributed energy matrix [30].

The growing global concern about climate change due to the greenhouse gases increase on the planet has caused Brazil to commit itself to the Paris Agreement at the United Nations Climate Conference to avoid global warming above 1.5ºC [13]. In order to comply with this agreement, the country should increase the share of renewable energies in the energy matrix so that the technologies combination balances supply and demand and the country uses its natural resources better.

Based on the study presented, photovoltaic solar energy is a renewable energy option to complement the envisaged energy demand for the coming years, besides that it gives importance to the conservation of non-renewable resources and reduction of the gases emission from the greenhouse effect. The most environmentally sustainable policy proposals for Brazil have the scientific and technological challenge of developing and / or adapting the most eco-efficient solutions. When valuing natural resources, the green economy inserts a new way of using the territory and the natural patrimony contained in it [33].

Despite the energy sources in Brazil enormous diversity and all the photovoltaic solar energy benefits, the Brazilian energy policy has not yet created the necessary incentives to implement photovoltaic solar energy on a large scale and its potential is not used. It is evident that the government needs projects and incentives for massive implementation, removing regulatory barriers, increasing incentives, investing in technological capacity and professional training for the technology development. With more aggressive incentive programs, there will be rapid diffusion and implementation, contributing both to the supply and to the preservation of the planet and its ecosystems.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sartori S., Kuriyama G.S.K., Alvarenga T.H.P, Vieira B.S., Campos L.M.S. Os benefícios e desafios da geração de eletricidade no contexto da sustentabilidade. Engema. 2015.

2. IPCC.Climate Change 2014 Synthesis Report.Geneva, 2014.

3. Bertoncello A.G., Souza M.M., Silva N.S. Necessidade do fortalecimento de políticas públicas para implantação de energia renovável: estudo de caso FATEC Presidente Prudente. Revista Nacional de Gerenciamento das Cidades, v.03, n.16, 2015, p.138-156.

4. Brasil. Análise da inserção da geração solar na matriz energética brasileira. Ministério de Minas e Energia. EPE. Brasília, 2012.

5. Suzuki E.V., Rezende F.D. Estudo da utilização da geração fotovoltaica para auxiliar a suprir a demanda crescente de energia elétrica no brasil. Specialization' Monograph. Federal Technological University of Paraná. Curitiba, 2013.

6. Silva E.C.P., Santos E.C.M., Silva R.M., Novaes F.E.F., Ferreira I.E.C. Uma análise dos incentivos que podem favorecer o uso da energia renovável no brasil. XXX Encontro Nacional de Engenharia de Produção. São Carlos, SP, Brasil, 2010.

7. Brasil. Balanço energético nacional. Ano base 2015. Ministério de Minas e Energia. EPE. Brasília, 2016.

8. Brasil. Demanda de energia 2050. Nota técnica DEA 13/15. Série Estudos da Demanda de Energia. Ministério de Minas e Energia. EPE. Brasília, 2016.

9. Pinho J.T., Galdino M.A. CEPEL. CRESESB. Grupo de Trabalho de Energia Solar (GTES). Manual de engenharia para sistemas fotovoltaicos. Rio de Janeiro, 2014, 530 p.

10. Pereira E.B., Martins F.R., Abreu S.L., Rüther, R. Atlas brasileiro de energia solar. São José dos Campos: INPE, 2006.

11. Knob P.J., Riella H.G., Knob D. Energia solar fotovoltaica auxiliando na redução dos picos anuais de demanda. 10º Congresso sobre Geração Distribuída e Energia no Meio Rural. Universidade de São Paulo–USP. São Paulo. 2015.

12. Silva R.L. Viabilidade do uso da energia solar no brasil. Centro Universitário de Brasília. Instituto CEUB de Pesquisa e Desenvolvimento. Specialization' Monograph, 2012.

13. Greenpeace. Alvorada – como o incentivo à energia solar fotovoltaica pode transformar o Brasil. 2016.

14. ANEEL. Informações gerenciais. Dezembro, 2015.

15. Solar Power Europe. Global market outlook for solar power / 2015–2019. 2015.

16. ANEEL. Micro e minigeração distribuída: sistema de compensação de energia elétrica. 2. Ed. Brasília, 2016.

17. Esteves E.N. Estudo da viabilidade técnica e econômica para geração de energia elétrica utilizando painel fotovoltaico em uma residência no interior de São Paulo. Specialization' Monograph (Suistanable Buindings' Specialization Program), Departamentos Acadêmicos da Construção Civil, Universidade Tecnológica Federal do Paraná. Curitiba, 2014.

18. Escritório verde. Available on: <http://www.escritorioverdeonline.com.br>. Access on April 11, 2016.

19. Mariano J.D. Análise do potencial da geração de energia fotovoltaica para redução dos picos de demanda e contribuição energética nas edificações da UTFPR em Curitiba. Programa de Pós-Graduação em Engenharia Civil da UTFPR. Master Dissertation. Curitiba, 2017.

20. Nakabayashi R. Microgeração fotovoltaica no Brasil: viabilidade econômica. Instituto de energia e ambiente da USP. Master Dissertation. Laboratório de Sistemas Fotovoltaicos. São Paulo, 2015.

21. IEA. Technology roadmap solar photovoltaic energy.2014.

22. Barbosa Filho W.P., Ferreira W.R., Azevedo A.C.S., Costa A.L., Pinheiro R.B. Expansão da energia solar fotovoltaica no Brasil: impactos ambientais e políticas públicas. Revista. gest. sust. ambient., Florianópolis, n. esp, p.628-642. 2015.

23. Cruz D.T. Micro e minigeração eólica e solar no Brasil: propostas para o desenvolvimento do setor. Master Dissertation. Escola Politécnica Da Universidade de São Paulo. São Paulo, 2015.

24. Galdino M.A. Análise de custos históricos de sistemas fotovoltaicos no Brasil. Centro de Pesquisas de Energia Elétrica. IV Congresso Brasileiro de Energia Solar e V Conferência Latino-Americana da ISES. São Paulo, 2012.

25. Tesla. Solar Roof. Available on: <https://www.tesla.com/solar>. Access on November 7, 2016.

26. CGEE. Centro de gestão e estudos estratégicos. Materiais avançados 2010-2022. Ciência, Tecnologia e Inovação. Brasília, 2010.

27. Feitosa P.H.A. A transição tecnológica rumo à economia de baixo carbono: o papel da energia solar fotovoltaica. Federal University of Espírito Santo. Centro de Ciências Jurídicas e Econômicas Programa de Pós-graduação em Economia. Master Dissertation. Vitória, 2010.

28. IEA. World energy investment outlook. 2014.

29. BNDES. Desenvolvimento tecnológico e inserção da energia solar no brasil. Ministério do Desenvolvimento, Indústria e Comércio Exterior. BNDES Magazine. 2013.

30. REN21. Renewables 2015 global status report. Paris, 2015.

31. REN21. Renewables 2016 global status report. Paris, 2016.

32. IEA. Energy and climate change.2015.

33. CGEE. Centro de gestão e estudos estratégicos. Economia verde para o desenvolvimento sustentável. Ciência, Tecnologia e Inovação. Brasília, 2012.