

**Analysis of the energy efficiency promoted by the implementation of  
solar panels in hospitals in brazil and other countries**

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#### **ABSTRACT**

The growing world's population demands large electric energy production for the functioning and development of the modern society. With the increase of energy consumption and environmental changes caused by these processes, it is fundamental that public and private sectors search for alternative energy sources, which must be not only sustainable but also efficient for the development of their activities. In this context, renewable energy causes less impact to the environment, mitigating the emission of gases that contribute to the greenhouse effect. Among the main renewable energy sources, the photovoltaic solar energy stands out, with the advantage of being installed in small spaces and requiring minimum changes in such spaces. The photovoltaic solar system is one of the alternative energy options that have received considerable investments worldwide, because solar radiation is an abundant and inexhaustible energy source incident on the Earth's surface. Large buildings, such as hospitals, despite being essential to well-being and health care, present a great polluting potential, in the sense that they may cause indirect hazards to the environment, due to the amount of energy that they need to perform a series of procedures. The present study aims to present the main projects of photovoltaic solar energy implementation that aimed at energy efficiency in hospitals. The study is based on bibliographic research and adopted a qualitative approach to assess study cases in Brazil and in some other countries. Among the main results, the projects implemented in hospitals in Europe, Africa and Brazil are highlighted, because of the attested efficiency reached after the implementation of photovoltaic solar panels, minimizing the amount of CO<sub>2</sub> launched in the atmosphere and achieving energy and financial savings.

**KEYWORDS:** Energy efficiency. Photovoltaic solar energy. Hospitals.

#### **1 INTRODUCTION**

Modern society demands energy in order to function and develop, once it is necessary the generation of fuels, the operation of machines, and the development of urban centers so as to supply the exponential growth of the world's population (GOLDEMBERG; LUCON, 2007). With the increasing exploitation of natural resources to meet the demand for energy, there is also an increasing gas emission, e.g. carbon dioxide (CO<sub>2</sub>) during energy generation processes. In this scenario, developed and developing countries find it difficult to comply with the increasing energy demand and, at the same time, to investigate alternative energy sources that can provide economic growth (ALTOÉ *et al.*, 2017).

With the increasing energy consumption and environmental changes caused by these processes, it is paramount the pursuit of alternative resources, which are not only sustainable but also efficient for the development of social activities and procedures. Therefore, the diversification of the energetic matrix in order to achieve new forms of energy generation is a primordial quest (PACHECO, 2006). In this context, renewable energy systems cause minor environmental impacts, as they minimally change the site where are installed. Besides, the renewable cycle takes place naturally, leading to a drastic reduction of environmental pollution, when compared to the indices resulting from fossil fuel burning (BIZZARRI; MORINI, 2004; BIZZARRI; MORINI, 2006). Therefore, countries at different development stages have invested in research, innovation and implementation of abundant, alternative energy resources, such as wind, sun, biomass, and waves (ROSA, *et al.* 2018).

Solar energy stands out among the renewable energy sources. Sunlight is a vital element for the existence of mankind and constitutes a renewable energy source, being an alternative to mitigate hazards to the environment, supplying the energy demand of different societies (ANGELIS-DIMAKIS *et al.*, 2011). For example, in Germany, regulations and governmental financial and tax incentive programs have been developed to promote the implementation and use of photovoltaic solar energy (SANTOS; JABBOUR, 2013).

Brazil is geographically well-positioned relatively to the tropics, which encourages the use of solar cells for the conversion of sunlight into electric energy by means of photovoltaic

panels, making energy generation with low emission of greenhouse gases (GHG) possible, besides allowing small- and large-scale electric energy supply. However, the laws that regulate such actions are still at initial planning and implementation stages in the country (PAINES, 2018).

Regarding new strategies to provide great urban centers, such as São Paulo city, with means to comply with their high energy demand, Brazil has encouraged the use of solar panels both in public and private sectors. Large buildings located in great cities consume more than 20% of the global energy supplied to these cities (U.S Energy Information Administration, 2019).

The sustainability of buildings constructed under the perspective of renewable energy, e.g. energy used in ventilation, heating and cooling of systems, illumination, and new equipment, focuses on energy efficiency, in order to put the Zero Energy Buildings (ZEB) plan in practice. ZEB was defined by Espinosa, Hernández and Espinoza (2018) to mitigate CO<sub>2</sub> emissions, so as to make large buildings energy self-sufficient.

Hospitals are examples of large buildings essential to society; however, they have the polluting potential able to cause damage to the environment by the amount of energy that is demanded to run all processes and procedures 24 hours a day (SANTOS; JABBOUR, 2013).

## **1.2 OBJECTIVE**

To present the main projects proposed in Brazil and other countries regarding the implementation of photovoltaic systems in hospitals as a means to achieve energy efficiency using solar radiation.

## **2 THEORETICAL REFERENCE**

The environment has undergone impacts caused by anthropic actions, such as the emission of greenhouse gases (GHG) during processes of energy generation. The more energy modern society needs to perform most of its every-day activities, the more environmental changes are intensified each year. Consequently, studies regarding renewable sources for energy generation have become socially and environmentally desirable.

### **2.1 ENERGY GENERATION AND THE ENVIRONMENT**

After the Industrial Revolution that took place from 1760 to 1840, and in particular during the 20<sup>th</sup> century, the increase in population, production and consumption have caused the increase in natural resources exploitation and the use of technologies at large scale to comply with energy demands (INATOMI; UDAETA, 2005). Thus, the risks to the environment have become significant, especially when related to fossil fuel burning (GOLDEMBERG; VILLANUEVA, 2003).

The energy system based on the use of fossil fuels is responsible for ca. 75% of CO<sub>2</sub>, 41% of lead, 85% of sulfur and 76% of nitrogen oxide emissions. The combination of sulfur with nitrogen oxides has an important role in the production of acids in the atmosphere, resulting in acid rain, which causes damage to forested areas, agriculture and corrosion of manufactured materials (JANNUZZI, 2001).

GHG emission has been a matter of debate since 1992, year in which the United Nations Conference on Environment and Development took place. During this conference the

Kyoto Protocol was proposed, establishing a reduction of circa 5% in GHG emissions between 2008 and 2012 in developed countries (INATOMI; UDAETA, 2005).

Since then, the concerns with fossil fuel consumption for energy generation, together with the increase of the energy demand, resulted in the collective interest for the use of sustainable and renewable energy (AHMED; SARKAR, 2019). The sustainable development in the energy sector has been affected by environmental, economic and social issues, making the insertion of new renewable energy sources that represent minimal impact to the environment necessary, in order to preserve natural resources and to maintain the equilibrium and life on Earth, concomitantly with energy generation and continuous development of the society (INATOMI; UDAETA, 2005; UDAETA, 1997).

## **2.2 RENEWABLE ENERGY**

Renewable energy results from practically inexhaustible energy sources with capacity of short-term regeneration. These renewable energy sources are also called non-conventional, that is, unrelated to fossil fuels or large hydroelectric plants (AZEVEDO; NASCIMENTO; SCHRAM, 2017). According to the World Energy Outlook report, renewable sources are crucial and will contribute with circa 25% of the world energetic matrix until 2040, thus avoiding the announced energy collapse (International Renewable Energy Agency [IRENA], 2015). Up to 2016, the contribution of renewable sources to the world electric energetic matrix was circa 24%, whereas in Brazil, according to EPE (2019), it was circa 80%, thanks to the hydroelectric plants. However, recent blackouts and the water crisis have forced the various sectors of the Brazilian society to rethink the dependability on water resources to energy generation.

A zero-carbon energy solution would maximize financial and social benefits, would generate wealth, and solve the problem of energy scarcity, enabling the access to clean energy and the growth of a variety of sectors (IRENA, 2020). However, despite being more economic, the renewable energy concept has slowly grown among the main energy-consuming (e.g. industrial) sectors, in which the implementation of a zero-carbon strategy is still at levels below those expected for an efficient energy system (KÄBERGER, 2019).

Renewable energy sources are not equally distributed, because they are constrained to geographical location and climatic conditions. New approaches help overcome economic barriers, allowing a fast implementation of energy-producing equipment of low impact to the environment (IRENA, 2020). Therefore, energy generation alternatives can supply the world demand. However, it is necessary that such systems include strategies to integrate renewable sources to technological systems in the economic ambit, having in mind the efficiency in energy production (PEREIRA, 2012).

Tidal energy is an example of renewable energy that can be used in strategic sites around the planet. Also called tidal power, this energy is generated by means of the natural movement of tidal waves (GUERREIRO, 2012). Wind energy is another example of renewable energy, which is produced by the strength of air masses caused by the uneven heating of the Earth's surface. Despite the successful use of wind turbines to capture and convert wind energy, large areas are needed to install such equipment (JUÁREZ-HERNÁNDEZ; LEÓN, 2014).

Biomass energy, which refers to the chemical energy produced by plants in the process of photosynthesis in the form of carbohydrates or in the burning of biomass through the carbon

cycle, releasing CO<sub>2</sub> into the atmosphere. Dependent on the sun for your processes to happen. A successful experience with electricity generation via biomass was the installation of 159 power plants in the State of São Paulo, which used sugar cane bagasse, a by-product of the sugar and alcohol production, to generate an equivalent to 952 MW (GOLDEMBERG; LUCON, 2007).

### **2.2.1 PHOTOVOLTAIC ENERGY**

Solar radiation has been used since the beginning of human history, after the prehistoric men learned how to start a fire and with it, to heat their homes, water and food (BELESSIOTIS; PAPANICOLAOU, 2012). For a certain period in the 20<sup>th</sup> century, the interest for solar energy dropped, due to the increasing use of low-cost fossil fuels. From the 1970's, with the rise of fossil fuel prices and the energy crises caused by wars in oil-producing countries, the interest in solar radiation as an alternative for energy production has increased worldwide among other energy sources, such as biomass, fossil fuels, winds and hydroelectricity (*Agência Nacional De Energia Elétrica –ANEEL*, 2008).

From the beginning of the present decade, solar energy generation has exponentially increased in the world, and it has become an important source for electricity production, allowing more diversification of the energetic matrix and aiding the increasing supply of clean energy (SANTOS; JABBOUR, 2013). Solar energy can be used to produce electricity by means of the photovoltaic effect, which is the direct conversion of sunlight into voltage and electric current. Certain materials are able to absorb photons and release electrons, thus generating an electric current that is collected and processed by controllers and converters. It can be used directly or stored in batteries and systems connected to the power grid (VILLALVA; GAZOLI, 2012).

Among the processes by which solar energy is harnessed, the most used nowadays are water heating and photovoltaic generation of electricity. The photovoltaic energy has the potential to become in the long term the major electricity source in the world, thanks to its abundance, distribution, and investments in technologies to improve implementation and efficiency (FERREIRA et al., 2018).

Germany, despite its unfavorable geographic position relation to solar radiation, has developed a robust program of diversification and simultaneous “cleaning” of the local energetic matrix, investing in renewable matrices for energy generation throughout the country, having almost 50% of the world's total of installed potential of photovoltaic solar cells. Until 2007, Germany responded for 13.4% of the photovoltaic panels in operation in the world, totalizing 41.2 GWp and promoting 40% of the energy generation from alternative sources, such as solar energy, contributing to the national economy and reduction de environmental impacts (PORTAL SOLAR, 2017).

In Brazil, despite the great potential for solar energy generation, the encouragement for such generation at a large-scale is still weak (SILVA, 2018). As mentioned by the World Wide Fund for Nature Brazil (WWF-Brazil, 2012), in order to a country to grow, and therefore achieve the dominance of the photovoltaic value chain, it is necessary that policies to encourage the photovoltaic energy generation at large scale be established.

Besides the dominance of the world chain, the insertion of the electricity generation via solar radiation will promote the reduction of electric energy costs paid by public and private

buildings sectors, because most of the large buildings are distributed in cities with circa 1,000,000 inhabitants (GOLDEMBERG et al., 2004).

The State of São Paulo, which is the largest industrial park in Latin America with more than 45 million inhabitants, has presented until the first months of 2012 electric energy consumption of the order of 135 TWh/year, having solar radiation the capacity to generate the equivalent to 512 TWh/year (*SECRETARIA DE ENERGIA*, 2012). Such indices show that to implement projects, it is necessary to expand the incentives for the generation of photovoltaic solar energy, once such investments will expressively promote the economic growth (PAO; FU, 2013), giving to Brazil the opportunity to become a leader in renewable energy, and consequently improving the competitiveness with developed countries in the search of an efficient energy system, besides reducing the deterioration of the environment (BONDARIK; PILATTI; HORST, 2018).

### **2.3 Energy efficiency**

Global warming is one of the most serious environmental problems we must deal with nowadays. It has been caused by the accumulation of greenhouse gases (GHG) in the atmosphere, such as CO<sub>2</sub>. GHG mostly result from the burning of fossil fuels to produce energy (TORRALBA, 2013).

The accelerating growth of great urban centers is the major factor that leads to the increase of energy demand, because the number of inhabitants, residences and large buildings has exponentially increased in the cities. Therefore, there is a fast growing consumption of energy, which causes a disproportional exploitation and inadequate redistribution of resources (SILVA, et al., 2015).

According to the World Energy Outlook 2015, the energy efficiency has a major potential of reaching the goal of reducing GHG emissions, allowing the nations' growth and development with minimum impact to the environment (IRENA, 2015). In order to achieve energy efficiency, an equilibrium is necessary between obtaining benefits and exploiting existing resources, having in mind the reduction of the impact to the environment (MADRID, 2014).

As mentioned by Torgal (2013), the increase of energy efficiency in new and existing buildings is fundamental for the transformation of the energy system in great cities. Large buildings have a significant and increasing impact on the environment via the high CO<sub>2</sub> emission rates related to energy production (BOCASANTA, et al., 2017).

Existing buildings demand much energy; hospitals alone are responsible for ca. 6% of the total energy consumed by the utility buildings sector (TEKE; TIMUR, 2014). Some private institutions have invested in the implementation of programs aiming at energy efficiency by the reduction of operational costs, minimization of pollution, and diversification of the energetic matrix.

In order to assess energy efficiency in large buildings, two approaches are proposed by Carlo (2008): a prescriptive approach with the time evolution and baseline of the local energy efficiency, and a performance approach, which determines the efficiency evolution and the calculation methods for comparison with pre-established limits.

Regarding the sustainability in large buildings, one of the items taken into consideration has been energy efficiency by means of the installation of photovoltaic solar

panels, once the technologies that promote the use of energy derived from sun radiation are in constant development, seeking to provide economy, low environmental impact, and implementation in small spaces (YEPES; ARRIETA; AMELL, 2019).

However, to implement such technologies, public policies are necessary to encourage energy efficiency, aiming at the regulation and organization of information and services (MEJÍA, 2014), thus allowing the implementation of environmental strategies and energy efficiency measures, so as to achieve energetic and economic growth and development (SCHILLER; EVANS, 2005).

The investment in energy efficiency in large buildings is an important issue and it has been even more debated specially among the public sectors, aiming at allying energy saving and cost reduction (FERRADOR FILHO; OLIVEIRA; KNISS, 2018). Regarding public institutions, it is necessary that the government should plan, prepare and put into effect laws of incentive for energy efficiency, with the objective of providing financial conditions and the sustainability of the operations (DUAIK et al., 2019).

The concept of an energy-efficient building has been increasingly debated and has covered regulations for planning and construction, incentive mechanisms to promote energy efficiency in existing buildings, besides the pursuit for energy conservation, with the use of methods and technologies that contemplate the optimization of the necessary resources, with planning and efficiency (BITENCOURT, 2006).

### **3 METHODOLOGY**

A qualitative approach was adopted for this study, aiming at the understanding of the theme and the objective proposed here. Being the character of this study exploratory, data were collected via bibliographic research, so as to assess the information on hospitals that have implemented energy efficiency projects in national and international contexts. Scopus and the *Portal de Periódicos da CAPES* were the databases used in the research. The following keywords were chosen: “*energy efficiency*” and “*photovoltaic solar energy*” and “*hospital*”, plus their translations in Portuguese and Spanish. The survey indicated 127 relevant papers, with data regarding hospitals that are at different stages of implementation of photovoltaic solar energy projects.

### **4 RESULTS**

Contextualizing the theme of this study, international and national cases of energy efficiency projects applied to hospitals will be presented below. The cases to be reported are being developed or have already been implemented.

#### **4.1 INTERNATIONAL CASES**

According to Vaziri, Rezaee and Monirian (2020), the implementation of renewable energy systems as secondary energy generation sources is one of the strategies to reach efficiency. Solar panels can be used simultaneously and connected to the existing power grid. In emergency situations, the hospital building can have energy supplied by the power grid. The hospital can even sell part of the extra energy to the grid and benefit from it. This model was



developed in a hospital in Iran, and based on the analysis and discussions, the authors concluded that a reduction by 2.7% of the energy costs can be achieved.

As well as the project developed for the Farah Woman and Child Hospital in Amman (Jordan), in which a photovoltaic system was connected to the existing power grid to reduce energy consumption by 24.9% on average. The project sought to meet energy reforms that the Marrocco government has been adopting with the objective of transforming energy efficiency in priority. The prediction is to achieve until 2030, an energy saving by 20%, following one of the National Energy proposals, which is to turn existing hospitals into green buildings (NOURDINE; SAAD, 2020).

Another example in Marrocco is the Ibn Sina specialities hospital in Rabat, in which a 150-kWp photovoltaic roof was installed. Energy savings totalized 260 MWh/year. A similar implementation was the introduction of 1,000 m<sup>2</sup> of solar panels in the Ibn Rochd hospital in Casablanca, leading to an economy of circa 890 MWh/year (NOURDINE; SAAD, 2020).

A major hospital located in Alexandria, Egypt, invested in energy saving, using as model a project that aimed at exemplifying energy savings that can be applied across the country, so that the energy modernization of buildings can take place (RADWAN, et al., 2016). After the development of such energy saving prototype, which included replacement of lamps, windows, and the implementation of photovoltaic panels, it was observed that the change of the illumination system and the implementation of solar panels, a drop of 7,068,178 kWh/year would result, representing an economy of circa 3,500,000 Egyptian pounds/year (RADWAN et al., 2016).

Most of the hospitals built until 2000 around the world had been designed and developed following care, comfort, and safety criteria, without considering the energy performance. Therefore, the high energy consumption was not taken into consideration during the development of old hospital projects (NOURDINE; SAAD, 2020).

Two large hospital buildings located in Romania – the Oradea Clinical County and the Spitalul Clinic Municipal Dr. Gavril Curteanu, built respectively in 1968 and 1989 – developed energy efficiency and modernization projects, aiming at reducing GHG emissions by supplying new solutions that involve renewable energy sources, using and integrated design (PRADA et al., 2020). From the perspective of this model, the efficiency achieved by both enterprises was attested, after the implementation of the projects, considering the amount of CO<sub>2</sub> launched in the atmosphere during a year.

One of the highest indices of solar panel implementation is attributed to Germany, a country of the European continent that, as mentioned before, is geographically not favorably located. An example is the Agatharied hospital in Munich, with an useful area of 42,250 m<sup>2</sup>. A nursery, a ward, a nursing school and 80 flats for staff members are linked to the hospital. Three combined solar modules of 736 kW electric power and 1.250 kW thermal power each were installed in the hospital. Necessarily integrated to the electric lines, the hospital has two emergency generators with a power output of 480 kW and 229 kW. The resulting economy was 730 kW, which is considerable, having in mind that the hospital initial demand was 900 kW of electric energy (LEITTRETTTER, 2005).

Differently from the Asian continent, China has experienced fast urbanization and development of its infrastructure. As mentioned before, hospitals and health units are among



the utility buildings that consume much energy. Such large buildings in China consume a substantial percentage of the total commercial energy of the country. The Chinese are known as the least energy efficient people (WANG et al., 2016). According to the Beijing Municipal Committee of Health and Family Planning, circa 50% of the municipal hospital buildings in Beijing were constructed before the 1990's, when the sustainable building concept was not widely discussed. Despite not being efficient, these buildings should be ready for the implementation of alternative energy systems and to reach energy efficiency (WANG et al., 2016).

Since 2006, the Chinese government has developed and implemented policies with the objective of making energy efficiency feasible in public hospitals. Notable results were observed in administrative/economic pilot projects. However, financial, technological, and legal incentives and applicable regulations are still in need of greater governmental support (TEKE; TIMUR, 2014). Therefore, cases with positive impact have not been found in our bibliographic research, and according to Wang et al. (2016), energy efficiency is still far from being successful in Chinese hospitals.

#### **4.2 NATIONAL CASES**

As previously mentioned, the availability of renewable resources in Brazil is high. The use of these sources promotes even more projects that focus on energy efficiency, in order to reduce the consumption of fossil fuels (LA FORGIA; COUTTOLENC, 2009).

The project proposed to the University Hospital of the Federal University of São Carlos (HU-UFSCar), located in São Carlos city (State of São Paulo) is an example of the development of a photovoltaic system. The insertion of photovoltaic panels in the HU-UFSCar parking lot was proposed, so as to maintain the functionality of the chosen area. The structure will supply approximately 25% of the HU-UFSCar total energy consumption in the first year of operation. Calculating the return, seven years would be necessary for the cash flow to equate the money invested in the project, making the enterprise viable (DUAIK et al., 2019).

Another example in São Paulo city is the *Sociedade Beneficente Israelita Brasileira Albert Einstein* (SBIBAE), which is a non-profit civil society that provides assistance to health, teaching and education, innovation and research, and social responsibility (SBIBAE, 2018). The goal of SBIBAE was to reach energy efficiency of the hospital activities by creating the *Sistema de Gestão da Energia* (SGE – Energy Management System) in 2018, with the objective of organizing and managing the energy performance. Also, in 2018, the works performed in the Morumbi unit were: replacement of 18.550 conventional lamps by LED, with energy savings of 2,150 MW/hour/year; the installation of solar photovoltaic panels, and the replacement of vacuum pumps used in surgical procedures for more modern and economic equipment. Such actions were taken in partnership with *Eletropaulo* (SBIBAE, 2018). In 2017, the renewable energy consumption was 184,530 GJ, rising to 197,053 GJ in 2018 and supplying most of the SBIBAE energy demand.

A program developed in favor of the betterment of public hospitals and their entire area of expertise and that is currently underway is the *Programa CPFL nos Hospitais*, developed by CPFL *Energia* and the CPFL Institute. The objective is to help public and philanthropic institutions to reduce their electric energy bills. Firstly in 2019 the program mapped circa 80 hospitals, having in mind that these institutions should reduce costs with electric energy and

should invest the money thus saved in services to the public, benefiting the communities and the neighboring regions. It is expected that the selected hospitals will save approximately R\$ 18 million per year. Another objective of the program is environmental gains with the minimization of electric energy consumption, consequently reducing the emission CO<sub>2</sub> to the atmosphere and strengthening the use of a renewable and clean energetic matrix (REI, 2019).

The *Centro Infantil Boldrini* and the *Santa Casa/Hospital Irmãos Penteado*, both located in Campinas (State of São Paulo), are examples of hospitals that joined the projects proposed by CPFL. Other health units of the states of São Paulo and Rio Grande do Sul will be covered by this project, which includes the installation of solar energy systems and illumination LED, offering a clean process, so as to comply with environmental protection norms and generating savings between 30% and 50% regarding energy costs (REI, 2019).

Until 2021, this program will benefit circa 200 public and philanthropic hospitals, reducing energy costs and environmental impact, thus promoting sustainable development e energy efficiency (REI, 2019). To better exemplify the study cases, Table 1 presents a summary of present and future saving percentages to be achieved with the implementation of photovoltaic solar panels by hospitals.

**Table 1: Indices of the hospitals mentioned in this study**

| International |                          |                              |                           |
|---------------|--------------------------|------------------------------|---------------------------|
| Country       | Hospital                 | Savings                      | Prediction for the future |
| Marroco       | Farah Hospital           | 24.9% on average             |                           |
| Marroco       | Ibn Sina                 | 260 MWh/year                 |                           |
| Marroco       | Ibn Rochd                | 890 MWh/year                 |                           |
| Egypt         | -                        | 3.500.000 L.E./year          |                           |
| Romania       | Oradea Clinical County   |                              | 60% until 2050            |
| Romania       | Doctor Gavril Curteanu   |                              | 60% until 2050            |
| Germany       | Agatharied               | 350 KW-h/year                |                           |
| National      |                          |                              |                           |
| Country       | Hospital                 | Savings                      | Prediction for the future |
| Brazil        | UH-UFSCar                | 25% of the total consumption |                           |
| Brazil        | SBIBAE                   | 2.150 MW/h/year              |                           |
| Brazil        | Centro Infantil Boldrini |                              | 30% and 50%               |
| Brazil        | Hospital Irmãos Penteado |                              | 30% and 50%               |

Source: The author.

## 5 CONCLUSIONS

Besides the potential to diversify the energetic matrix and being an alternative to fossil fuels, renewable energy enables the access to technologies related to renewable resources. The use of renewable energy sources, such as photovoltaic solar energy, can favor the establishment of energy generation distributed in the country and abroad, allowing the diversification of the energetic matrix and the mitigation of the emission of gases that contribute to the greenhouse effect.

The photovoltaic solar system is one of the most promising alternatives to energy generation worldwide, because of the abundant and inexhaustible sunlight incidence on the Earth's surface. EPE (2019) data show that the photovoltaic energy will improve from the least

representative energy source in 2016 to a much better rated resource in the energetic matrix in 2040, representing circa 32% of the matrix.

It is worth stressing out that, among the main benefits of such system, it is noiseless and the panels are static, making their use in small areas, such as roofs, possible. Their installation is relatively simple. Another benefit resulting from the implantation of photovoltaic solar energy is financial, once the decrease of electric energy consumption resulting from self-production allows that the value saved be invested in the development of other areas (PORTAL SOLAR, 2017).

This study helped understand that the implementation of photovoltaic solar panels enables hospitals located in different areas to perform their functions and procedures, minimizing the use of electric energy and reducing the atmosphere-polluting particles. However, for such actions to happen, it is necessary that each case be considered individually, in order to receive installations that encompass such individualities and supply the energy demand. Besides a legal structure, the creation of laws at several instances is necessary, in order to promote support and growth of the use of photovoltaic solar energy. Public policies have a primordial role to encourage the use of such energy source. It is also fundamental that the monitoring of processes and numbers reached after the implementation of energy efficiency projects using this energy source can take place, so that the possible anomalies can be readjusted.

It is suggested as future research that multi-case studies be developed, analyzing some of the examples of hospitals identified in the literature, so as to gather more detailed information on the implemented energy efficiency projects and their contributions. It is also suggested a more detailed study regarding hospitals located in remote areas, so as to depict which are the main points to be developed during the planning of the solar energy systems, once in such areas the access to electric energy is usually very difficult, making solar energy the sole alternative as energy source.

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