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STUDY OF THE EMISSION OF POLLUTING GASES IN THE ATMOSPHERE DUE TO THE MANUFACTURE OF PHOTOVOLTAIC CELLS IN THE PRODUCTION OF SOLAR PLATES

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Abstract: The research aims to discuss the emissions of polluting gases into the atmosphere, from the manufacture of solar panels, in view of the growing demand for this clean energy and the fulfillment of the UN agenda, in addition to demographic growth (not only national, but global) and the increase in electricity consumption. This article seeks to discuss the environmental impacts of mass manufacturing of solar panels through a qualitative literature review, using articles published on online platforms to conclude that the component of the solar panel that pollutes the most is the photovoltaic cell or solar cell. The already mentioned emission of gases comes from the process in which, in order to manufacture the cell, semiconductor materials are necessary, such as silicon, derived from silica. The review exposes that, in order to obtain polycrystalline silicon, it is necessary to use chemical reactors that heat the material to temperatures above 1900 °C, thus generating the emission of pollutants in the air.
Keywords: Emission of gases; Photo-voltaic cells; Clean energy;

INTRODUCTION

Sustainability and the creation of renewable technology were issues that recurrently entered the discussion of many countries during the late 20th and early 21st centuries. In June 1972, the UN held the Stockholm Conference, one of the first meetings of the organization to talk about development and the environment. The conference dealt with environmental pollution as a result of industrial advancement and stipulated some principles to be followed, in addition to the creation of the United Nations Environment Program (UNEP).

In the following years, several other meetings took place to address technological advances that contribute to sustainability. As the use of clean energy is one of the central focuses, the UN has an agreement with 193 countries, Brazil is one of them, which has goals for 2030. One of these goals is clean and sustainable energy.

However, most of the country is still powered by hydroelectric dams. Considering that the country has approximately 203 million inhabitants (according to IBGE estimates during the last census) and that fifty years ago the population was 90 million inhabitants, the logical analysis is that the demand for electricity from hydroelectric plants. In view of the commitment to the UN, and the environmental impacts caused by this model of energy generation, it was necessary to encourage the consumption of solar panels in recent years.

The solar panel is the solution that aims at the lowest environmental impact and greater sustainability, in addition to solar radiation being one of the most renewable. It is a great solution to try to meet the 2030 agenda, however, it is necessary to assess whether the manufacturing process for this equipment does not harm the environment.

Solar panels have the following components in their assembly: photovoltaic cell, photovoltaic glass, encapsulating film for the solar panel, PVC box and some frames. The most important material is the photovoltaic cell, which, through a physical-chemical reaction, transforms sunlight into electrical energy. The production of photovoltaic cells is a complex process that involves the use of different materials, such as silicon, aluminum, copper, glass and plastic, in addition to chemical products such as hydrochloric acid, hydrofluoric acid and nitric acid. The manufacture of these materials and chemicals can emit greenhouse gases during extraction, transportation and production.

It is important to point out that the manufacturing process of these solar cells

needs high temperatures, above 1900 °C, commonly achieved by burning fuels, such as coal, which releases carbon dioxide and other greenhouse gases.

THEORETICAL FOUNDATION

Sustainability is classified as: "the ability to create means to meet the basic needs of the present without affecting future generations, normally related to economic, social, cultural and environmental actions." Based on this principle, the present work consists of carrying out a bibliographical review on sustainable energies and on how the race to manufacture these technologies has aggravated the emission of gases into the atmosphere.

Initially, the process of operation and manufacture of solar cells will be considered to understand the reason for the need for further studies on this topic. Studies, such as an article in the journal Renewable and Sustainable Energy Reviews (2014) and another in the Journal of Cleaner Production (2016), highlight the environmental and socioeconomic impact of large-scale production of solar cells and the carbon footprint associated with energy production, transportation of materials and chemical products, in addition to the use of sulfur hexafluoride (SF6).

This gas is one of the most potent greenhouse gases, with a greater global warming potential than carbon dioxide (CO2). The use of these gases during manufacturing contributes to an increase in the concentration of pollutants in the atmosphere.

To make solar cell production more sustainable, it is necessary to reduce the use of sulfur hexafluoride and look for more sustainable alternatives. Although solar panels are a renewable and clean source of energy, the manufacture of the photovoltaic cells that make them up can be polluting and contribute to greenhouse gas emissions. Milanez (2021) published a study on the potential environmental impacts during the life cycle of a solar panel and cites three important conclusions about the equipment:

a) Most of the studies cover the system considering from the extraction of the raw material to the final disposal of the product. However, all present the production phase of solar panels as the main cause of potential environmental impact.

b) Most studies contemplate conventional technologies, thus associating the main causes of environmental impacts with the components: glass, copper and aluminum. When analyzing unconventional systems such as plates composed of PET and PVC, these are the main indicators of environmental impacts.

c) When compared to a photovoltaic system, the solar thermal system has less influences due to environmental impacts.

METHODOLOGY

The present work was carried out through bibliographic research in scientific articles related to the theme. The articles used to support the research were indexed in the academic google database. To carry out the search for documents to discuss the topic, the terms "Pollution generated by solar panels", "manufacture of solar panels", "gases generated by the manufacture of photovoltaic cells" were used.

This qualitative study was carried out to prove that solar panels emit polluting gases during their manufacture and that due to the race to accelerate the process of switching to clean energy, people have been polluting more in order to pollute less.

The sources were analyzed using the qualitative data analysis method. It is a more subjective form of research and aims

to interpret data collected from qualitative research. Data organization was carried out, based on the interest of the work, and then interpretations and conclusions regarding the theme were drawn. Thus, resulting in two phases: exploration of the archives and interpretation of the results.

RESULTS AND DISCUSSION

Solar panels are equipment whose function is to capture the sun's rays and transform them into solar energy. The solar panel works thanks to the photovoltaic effect, which guarantees the transformation of solar energy into electrical energy.

This equipment is composed of: Photovoltaic cells, photovoltaic glass, EVA encapsulating film, backsheet (white plastic material), junction box, solar panel frame and anodized aluminum.

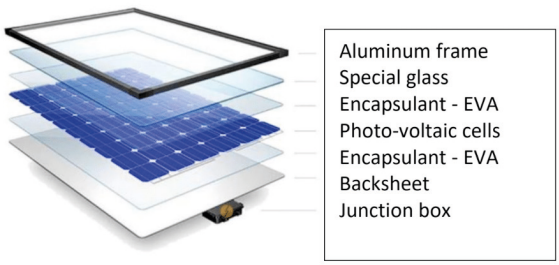

Figure 1: Solar panel

The photovoltaic effect is what happens when sunlight is converted into electrical energy. This phenomenon occurs through the participation of semiconductor materials, which have energy bands, that is, one side composed of electrons and the other empty. The material used is usually silicon.

The atoms of this material have four electrons in their valence layer, which make connections with others that are around, creating a kind of network of electrons. As five-electron atoms are inserted into the bond, there are excess electrons in the lattice. So as a result of this characteristic and with little variation in heat, this electron moves to the empty side. The phosphorus atom can be used as an example of five-electron atoms, being called electron-donating dopant or n-dopant (CRESEB, 2006).

> The addition of three electrons characterizes a lack of electrons, which is called a hole; in this case, with little thermal energy, an electron that is around can move to occupy this position, displacing the gap. Boron can be used in this example as the three-electron atom, being called an electron acceptor or p-dopant (CRESESB, 2006).

When phosphorus and boron atoms are inserted into pure silicon, a pn junction occurs. Thus, the electrons that are free on the n side move to the p side where there are holes. This results in an accumulation of electrons on the n side, thus making it negatively charged.

According to the Brazilian Atlas of Solar Energy, published by INPE in 2006, the basis of the operation of photovoltaic cells is given by:

> If the pn junction is exposed to photons with energy greater than the gap, electron-hole pairs are generated; if this happens in the region where the electric field is different from zero, the charges will be accelerated, thus generating a current through the junction; this displacement of charges gives rise to a potential difference which we call the photovoltaic effect. If the two ends of the silicon "piece" are connected by a wire, there will be a circulation of electrons.

Silica, the primary source of silicon, is obtained from sources such as quartz sand, which is primarily composed of SiO2. The sand is washed and purified to remove impurities, then mixed with a reducing agent, usually carbon, and other additives, such as fluxes, to lower the melting temperature and improve process efficiency. This mixture is heated in an oven at very high temperatures, where the reduction reaction takes place. The carbon reacts with oxygen from the silica, releasing

carbon monoxide (CO) and producing silicon metal. The chemical reaction is:

$SiO2 + 2C \rightarrow Si + 2CO$ (reaction 1)

The resulting silicon metal is condensed and forms a molten liquid. This liquid is solidified and can give rise to two types of cell: the monocrystalline or polycrystalline silicon cell. The difference between these cells is the conversion efficiency, since monocrystalline cells are more efficient, but more expensive. Polycrystalline cells are more used because of their cost. These then, when cut, are called wafers. (Costa, 2020)

FINAL CONSIDERATIONS

Through the literature review carried out, it can be inferred that, according to the literature, the photovoltaic cell is the most valuable element for the correct functioning of a solar panel, in addition to being the main pollutant during the manufacture of solar panels. Thus, the polluting vectors were identified and analyzed, and it was concluded that it is during the manufacture of polycrystalline silicon where there is the greatest potential for pollution, which is, for the most part, the emission of gases during the reduction process carbothermic. More studies and greater investment in research related to pollution resulting from the manufacture of photovoltaic cells are needed, since Brazil increases the production of such equipment every year, without taking into consideration, the environmental impacts. The qualitative research method was used in the study, under the guidance of Izete Celestina dos Santos Silva.

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