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# STUDY OF THE FEASIBILITY OF INCREASING THE EFFICIENCY OF SOLAR THERMAL COLLECTORS AS A WAY OF DIVERSIFYING THE ENERGY MATRIX THROUGH THE PRODUCTION OF HIGH-EFFICIENCY SELECTIVE SURFACES

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**Abstract:** Brazil is currently going through a period of population growth, the increase in the number of new homes and electricity consumption is directly related to this growth. The rate of this increase is greater in the north and northeast regions of the country.
In recent years, Brazilians have come across the terms "yellow tariff flag" and "red tariff flag" on the electricity bill, which are fees related to the generation of electrical energy. Climatic factors such as lack of rainfall can also directly affect the cost of energy generation.
In Brazil, geographic position and climate are factors that favor energy generation through hydroelectric plants. Recent research by ONS-BR shows that the biggest villain in electricity consumption in a home is the shower, consuming around 25% of energy demand, reaching up to 13% of national demand during peak hours, between 6 pm and 10 pm. However, there are still regions that do not have access to electrical energy, which is replaced by thermal energy generation processes, such as the burning of petroleum derivatives or sugar cane.
In the context of seeking solutions to increase energy supply, the viability of using clean renewable energies, which do not emit other pollutants into the environment, is now widely questioned and seen as an alternative to diversify the energy matrix in order to reduce energy consumption. dependence on the rainfall regime, sustain the country's growth and serve areas where energy generation is carried out by burning petroleum derivatives and sugarcane.
**Keywords:** sustainability, clean energy, environmental education, renewable energy.

## PROBLEMATIZATION AND SOLUTIONS IN SOLAR THERMAL ENERGY

Brazil is currently going through a period in which electricity consumption has gradually increased. In 2021 this increase corresponded to 5.2% of the previous year's energy consumption. The commercial class records the highest consumption value since April 2021, an expansion of 6.7% compared to the same period in 2020. The Electric Energy Trading Chamber (CCEE) demonstrated that Brazil recorded, in the first quarter of 2022, an increase of 0.9% compared to the same period in 2021.

Studies by the Energy Research Company (EPE) show the difference between the global energy matrix and the Brazilian energy matrix, concluding that renewable energy sources are still small compared to other forms of energy generation in Brazil, especially when considering the volume of generation of electrical energy from a solar source.

Solar energy can be converted in two ways, photovoltaic or photothermal. In the first, electrical energy is generated from the direct conversion of sunlight into electricity, for which the most used technology is plates made up of polysilicon cells. In the second, there is a conversion of sunlight into thermal energy, through an absorbing surface that retains much of the heat, transmitting it to a fluid.

In photothermal energy systems, energy is captured through solar thermal panels, also called solar collectors. Solar collectors are simple, economical systems known for converting sunlight into thermal energy that transmits this heat to fluids, in other words, the solar collector is the main component within a solar heating system. Those solar collectors are classified as low, medium and high collectors temperature, depending on the designed configuration. Current solar collectors provide useful heat at temperatures below 65degrees Celsius. Currently in Brazil they are used in homes and hotels to heat water for bathing in showers and swimming pools. Medium temperature collectors are devices that concentrate the solar radiation to provide useful heat to a temperature, higher, generally between 100oC and 400°C. They can be applied to Industry, condominiums, hospitals, among others. Because they have superior efficiency in thermal conversion, these medium temperature collectors can be applied to low temperature demands, as is the case in residential applications, but with a significant reduction in the solar collection area, that is, in the number of collectors required for the same heating system. High collector's temperature work at temperatures above 400°C. They are used in Helio thermal Power Plants, to generate electricity by moving turbines, for example.

However, to be able to meet the growing demand for energy generation in the form of heat, the solar energy industry needs to advance research and development in three major areas:

(i) new heat storage technologies;

(ii) new materials to increase the efficiency of solar collectors;

(iii) improve current projects, according to a study carried out by ESTTP.

In this context, the development of selective surfaces is one of the ways to compose Selective Fins (component responsible in the solar collector for converting solar radiation into thermal energy in the form of heat), to replace the normal fins currently used on the market (produced by paints automotive) and its adaptation in Solar Collectors forming a new line of national solar collectors: Selective Collectors using nanostructured coating technology, based on nano-particulate oxide structures of titanium, aluminum and other metals, with high stability and thermal conduction, generating an increase in its efficiency in capturing and generating energy.

This replacement of fins can lead to a considerable increase in energy conversion efficiency, reaching temperatures of 400ºC, depending on the design and architecture of the solar collector. In this case, the solar collector can be applied to new markets such as small condominiums, industries, hospitals and new products.

Data shows that 77% of all residential energy demand is thermal, that is, to heat or cool environments, and only 23% requires electrical energy.

The industrial segment is the largest energy consumer, accounting for more than a third of global energy demand (31% of total final energy consumption). However, despite the great potential to meet industrial energy demand with renewable sources, little progress has been made to transition the segment's energy consumption to renewable energy, especially for low-temperature processes in the range of 50ºC to 200ºC, which represent around 35% of the entire demand for thermal energy in the industry, as shown in figure 1.

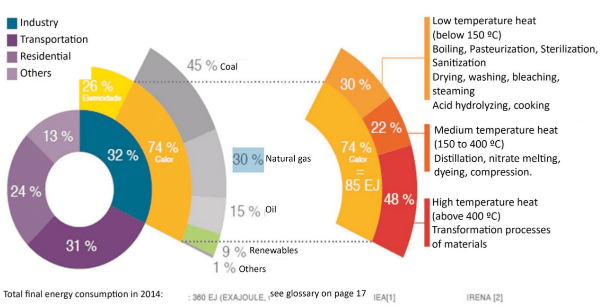


Figure 1: Final energy consumption [14].

The share of renewable energy in the industry increased by just 3.6 percentage points between 2011 and 2019, reaching 16.1%. Meanwhile, energy use in the sector grew 1% per year on average during 2010-2019.

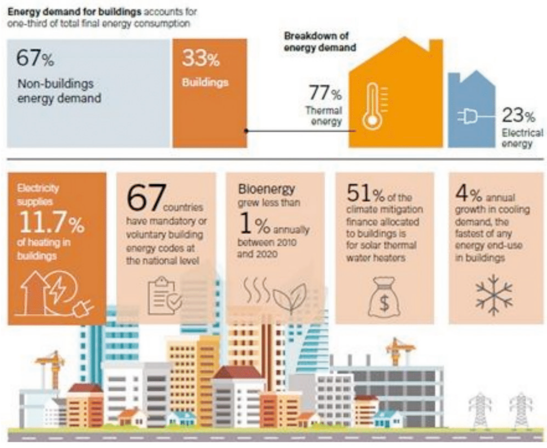


Figure 2: Residential energy demand in the world [15]

To conclude, it is observed that, despite the immense demands for thermal energy around the world, both in the residential and industrial markets, there is little market growth, which is reflected in low investments in 2021, as shown in the figure below:

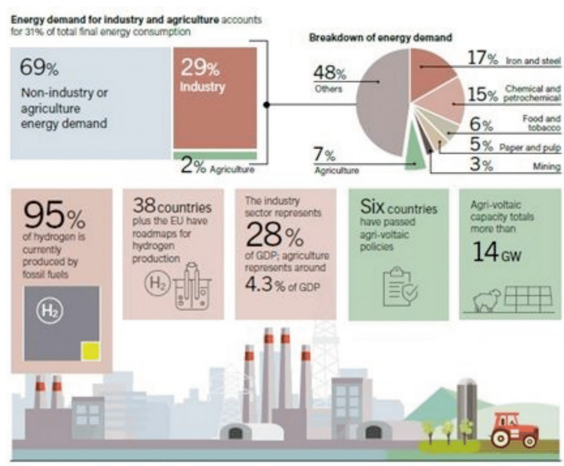


Figure 02: Renewable energy in industry and agriculture [15]

If we directly use heat at low temperatures, approximately 25.5 EJ can be directly converted into work such as boiling, pasteurization, sterilization, sanitization, drying, washing, bleaching, steaming, acid hydrolysis, cooking, among others.

Furthermore, it is indisputable that renewable energy sources are the answer to the world's growing energy demand in a sustainable way with the ability to reduce $CO_2$ emissions.

## SELECTIVE SURFACES

The application of solar thermal heaters in housing of social and industrial interest is seen today in Brazil as a common practice for reducing electricity consumption. However, the efficiency of panels for solar collectors is still low due to the lack of national technology, limiting the collectors' applications. By applying selective surfaces to traditional solar collectors with different designs and geometries, energy conversion efficiency can be increased.

Although Brazil is a country where the rate of solar irradiation is so high in relation to the rate found in other countries, it is important to increase the efficiency of collectors and nationalize the technology for producing selective surfaces, as the growing concern about the energy crisis makes with sustainable energy being considered a promising alternative with an increasingly important role [7].

In recent years, the search for solutions that aim to replace current energy matrices with renewable energy sources has intensified. In this sense, photothermal becomes one of the most developed forms of energy, mainly due to the growing energy consumption in residential use that can extend to industry [7].

The efficiency of solar thermal collectors can be increased by improving the properties of the surface that absorbs and converts sunlight into heat, such as increasing the absorptance coefficient in the visible spectrum (VIS - 0.3-2.5μm) and decreasing thermal losses using materials with low emittance in the infrared region (IR - 2.5-20 μm), [7,9,11,12]. Surfaces with these characteristics are called selective surfaces and present better performance reaching higher temperatures, increasing the range of applications and serving the industry with great efficiency, such as water heating for heat production and serving small condominiums.

Different materials and combinations of materials have been tested as selective surfaces with special interest in the development of micro- or nano-structured materials composed of small metallic particles dispersed in a dielectric matrix [1- 5]. Depending on the production conditions, these coatings may have different compositions and even variations in the number of metallic particles throughout the thickness of the coating, leading to interesting physical and chemical properties. It is possible to obtain surfaces with excellent optical properties (absorption greater than 96% and thermal emittance less than 10%) and greater resistance to corrosion, given by the increase in electrical conductivity and the decrease in the electric field in the oxide. An increase in the thermal stability of mixed oxides in relation to the stability of pure copper or aluminum oxide surfaces is also reported in the literature [7, 9, 11].

Among the possible ways of producing mixed oxides or nano oxide surfaces structured by metallic particles, electrochemistry is a cheap production technique that is easily implemented in a production line. On the other hand, it generates chemical waste that counteracts the clean nature characteristic of the production of renewable energy through solar absorption. Another technique that has been evaluated for the production of mixed coatings on a large scale is the physical deposition (PVD) technique by magnetron sputtering. Reactive Magnetron Sputtering allows the production of ceramic-metallic coatings, called cermet, with a defined portion of magnetic particles. With this technique, alloys of metal-oxides [3], metal-nitrides and even metal-oxynitrides [6] can be produced without generating waste, in a clean and environmentally friendly way.

Selective surfaces of $Al_yTi_{1-y}(O_xN_{1-x})$ were produced to validate the simulation design concept developed by I. Heras and excellent results were found confirming that this material can be applied to selective surfaces with good thermal stability up to 800ºC [8- 9].

Al films doped with CrN phase, in addition to presenting reflectance and absorptance characteristics of selective TiN surfaces in the solar spectrum region, between 300 and 2600 μm, exhibit natural characteristics of semiconductors and are recommended for materials for selective surfaces applied at high temperatures with good thermal stability [11].

Generally, these surfaces can be deposited on aluminum or copper substrates. Depending on the metals chosen to convert light into heat, it is necessary to use an intermediate binding layer that ensures adhesiveness and affinity between the substrate and the absorbing layer. The absorber layer can be composed of different materials or their oxides and finally an anti-reflective layer to prevent thermal losses.

## SOCIOECONOMIC AND ENVIRONMENTAL IMPACT

Selective fins are part of an Impact technology in solar collectors to generate thermal and electrical energy more efficiently than current ones in a single piece of equipment, reducing the size of collectors and reducing non-renewable energy costs, where each $m^2$ of solar collector installed generates an average saving of 1,600 kWh/year and avoids the emission of 2,000 kg/year of $CO_2$ into the atmosphere. Therefore, the implementation of this technology increases the possibility of training specialized labor and income.

Brazil is the fifth largest market for solar thermal collectors in the world. According to ABRASOL, in 2022 we already had 20 M $m^2$ of thermal collectors installed in Brazil with annual revenue of 1.4 B reais. According to ABRASOL, 170 thousand solutions are installed annually in Brazil, making this market generate more than 2.1 billion reais per year. In 2023, for the first time in Brazil's history, solar thermal energy appeared on the map of the Brazilian energy matrix, with a significant 0.7% of all energy generated in the country.

In Brazil, Nanotex, a company in the nanotechnology research sector, has been seeking solutions to diversify the national market in terms of modifying surfaces with nanotechnology to produce new selective fins.

## CONCLUSIONS

This article discussed the feasibility of adapting solar thermal collectors already on the market by replacing common fins with selective fins, forming a new product line capable of diversifying the country's energy matrix in accordance with the SDGs proposed by the UN.

To implement these selective fins, there is still a lack of investment for their production on an industrial scale in the country, but it is already underway by a private company.

Results of preliminary studies showed that the introduction of this material was favorable for market diversification and thus a new line of products.

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