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TOTEM FOR WIND AND SOLAR ENERGY HARVESTING

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Abstract: This project aims to discuss the practical application of an electrical power generation model based on the installation of a mechanism that is capable of simultaneously capturing energy from the winds and solar radiation. To this end, research and data collection were carried out, through content referring to clean, renewable and sustainable energy sources. From the surveys carried out, the proposal for a model project of totem equipment with airfoils and voltaic plates to capture wind and solar radiation was developed, adaptable to urban landscapes, that does not cause visual pollution and that has the primary intention of being installed on the Imigrantes highway, located in a mountainous region that has a constant movement of cars, being the main way of connecting the capital of the state of São Paulo to the largest port in Latin America, located in the city of Santos. The project was based on two experimental scientific papers on wind energy production already published, and seeks to develop a model of low environmental impact, non-polluting, and especially that is aesthetic to the point of being incorporated into the landscape in a natural and safe way. It was possible to conclude the feasibility and operability of the equipment, from comparative calculations of electricity consumption in conventional poles, used on the Imigrantes highway and calculations of solar cell production and wind production to be used by the totem, using estimated parameters of components used in the market. The results based on the production calculations of the prototype and the generated electrical potentials, within the design project's characteristics, it is estimated that the totem is viable, both in terms of production cost and its capacity to generate electrical energy for road power supply. In other words, it is operational and economically viable.

Keywords: Energy; Wind; Solar; environmental impact; Immigrants Highway.

INTRODUCTION

This essay aims to elucidate the issues surrounding the production of electricity, defining aspects that determine the growth in demand and the real need to develop clean and renewable sources.

The problem to be answered is based on the question of how, and if, it is possible to supply energy to power public lighting from sources that produce clean and renewable energy, minimizing the negative effects of these forms of production on the environment.

In this context, the scientific work proposal aims to present concepts, definitions, and tools necessary to offer a viable alternative, in the form of a mixed energy production totem, with reduced costs, and that is efficient to the point of being implemented on public roads and roads, producing benefits that can either complement or replace current systems.

Bearing in mind that it is necessary to present alternatives for sustainable development, we started from the hypothesis that it is possible to associate the way of producing wind energy with a system of solar panels, guaranteeing the efficiency of the system in different climatic conditions.

CONTEXTUALIZATION AND MARKET DEMAND

The growing and current global water and energy crises are a reality that needs to be brought to the awareness of the general public, of public governance in all spheres, and of the means of production. However, this should be done so that the usage is conscious and, at the same time, that there is time and possibilities to find clean, renewable, and accessible sources so that the panorama can be reversed and/or controlled before greater sacrifices become necessary.

The author Carolina Pimentel[1] cites

a Mapping from the Ministry of the Environment, which reports that part of the impacts on the country's clean water sources are due to the creation of hydroelectric plants. Although the 12 hydrographic regions of Brazil have different regimes for recovering degradation due to human action in the region, she also cites the advancement of agricultural frontiers as another aggravating factor, mainly in the Central-West region of the country.

The energy that currently supplies us also includes a portion of clean and renewable energy within the context of the energy matrix and represents productive capacity capable of expansion and technological improvement.

According to the guidelines established by the United Nations (UN) and in our Federal Constitution of 1988, both clean and potable water, as well as basic infrastructure in which energy is inserted, both electrical and necessary for economic development, are essential for the well-being of the human person.

Many institutions, researchers, and investors have, over the last three decades, been seeking and developing viable alternatives in terms of production, as well as in terms of implementation and distribution costs.

We can mention the project by Fernando Eduardo Lee, considered one of the renowned Brazilian scientists and precursors of sustainability in the 1960s, responsible for the idealization and development of Ilha dos Arvoredos, located on Pernambuco beach in the city of Guarujá in São Paulo. Ilha dos Arvoredos, represented in Figure 1, is an open-air sustainability laboratory with the capacity to self-manage and fully supply the island with energy, food, and water. In the mid-1970s, the island had a lighthouse that functioned as a wind generator and one of the first solar panels in Latin America, which had been developed by the North American Aerospace Agency (NASA) and installed on the island.

Figure 1 : Arvoredos Island

Source: https://url.gratis/Go6p0I. Accessed on: 10/28/2021.

Brazil is a country recognized worldwide for its potential in the production of renewable energy, which generates great expectations for it to be one of the first major nations in the world to use 100% renewable energy in the near future.

In 2023, the country reached an installed capacity of 10.3 Gigawatts (GW), according to data from the National Electric Energy Agency (ANEEL). This milestone reflects the growth in the use of solar energy and other renewable sources.

The proposal of this work is based on Sustainable Development Goal (SDG) number 07, where the proposition of producing clean, sustainable, and accessible energy is made possible in the face of market and technological advancement. Based on this, the prerogative of this document is to establish and carry out a feasibility analysis for installing a combined wind and solar energy generation system in cities and urban centers.

WORLDWIDE ENERGY MATRIX

The context of the global energy matrix is much more complex than one can imagine in a simplified analysis, which seeks only to understand the generation chain and its various forms of production.

Oil has become an important influencing

factor in contemporary geopolitical relations, since it became the cornerstone of the energy matrix driving the modern economy.

Large multinationals, financial conglomerates, state-owned companies, and regulatory bodies are directly involved in the dynamics of operations, services, and prices in the international oil and natural gas market, acting from an economic perspective, but also as influencers on geopolitical issues. Oil and natural gas are admittedly important assets in generating wealth, and are reasons for commercial, financial and diplomatic disputes.

The need and demand for electrical energy increase progressively and proportionally with technological development and demographic growth, driven by new social, consumption, and production habits in modern societies. This transformation has turned urban life in large cities into a constant cycle of industrial operations, companies, and commercial establishments, consequently ensuring the availability of lighting, transport, and electrical energy to supply

Control of the energy market determines the maintenance and continuity of productive sectors, based on current trends, including sources such as coal, oil, natural gas, nuclear energy, and hydroelectricity.

EXAMPLES OF USING WIND AND SOLAR ENERGY

One of the first perceptions of wind energy was introduced in navigation, and later for the movement of mechanisms used to grind grain and pump/lift water. Likewise, solar radiation was originally used as a source of heat, to dry and dehydrate food, and to illuminate environments, configuring the diverse and possible applications to solve issues that we consider elementary, but we only have this vision because we are accustomed to the use of technologies.

Currently, we contextualize the development of technologies based on economic viability and the possibility of return on investments [5]. Investment in the use of wind energy is of great importance for the diversification of Brazil's energy matrix. Currently in the country, the most suitable places for the production of this category of energy are located in the northeast and south regions.

The choice of appropriate locations for capturing wind and solar energy is of vital importance so that there is the possibility of constant production, and must take into account the positive and negative factors of these types of energy generation and production.

China is currently the largest producer and consumer of solar energy in the world. The great government incentive and the rapid growth of production have made the price of photovoltaic systems increasingly cheaper, which ends up making this method of energy production more competitive in relation to coal and oil . The estimate is that by 2030 solar energy production in China will reach 10% of all primary energy [6].

A good example of the use of solar energy today is the private acquisition of residential and industrial solar panel systems, which has been growing in Brazil due to the cheaper modular systems and the launch of products such as photovoltaic tiles (Figure 2) Tégula Solar (registered trademark), and another produced by the company Eternit.

Figure 2 : Solar Tile

Source: https://celere-ce.com.br/sistência/telha-solar-tegula-solar/ - Accessed on: 08/11/2021.

There is the possibility of implementing wind and solar systems in degraded areas or unproductive land, in order to generate capital for the possible recovery of these same areas.

Currently there are some attempts to develop residential wind systems: Such as the TESUP turbine models Atlas 2.0 and Atlas X developed in Europe and transported to Brazil by the company Amazon ; Although experimental in nature, they are being valued and researched in the market by people who are sympathetic to sustainable energy production methods. Figure 3 shows an example of a wind turbine.

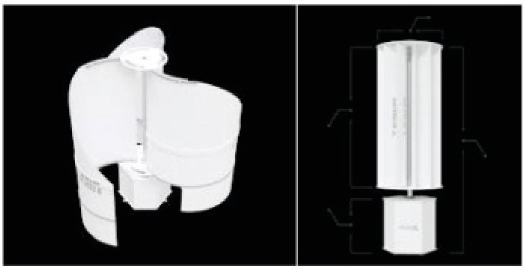

Figure 3 : Example of Wind Turbines

Source: https://www.tesup.com.br/ - Accessed on: 08/11/2021.

Advances in technology and information provide accelerated improvements and the discovery of new materials, seeking to reduce costs and increase the efficiency of solar and wind models. Like everything involving economics, the principles of demand and scarcity are inserted in the context of renewable energy production, directly affecting investing companies, manufacturers, and consumers at all levels.

GUIDING PROJECTS

In the project presented here, the design was considered based on constituent elements of other projects already in use, such as the wind tree, proposed and developed by the French company NewWind referred to in Figure 30.

Figure 4 : Newwind Project Wind Tree

Source: https://www.dw.com/pt-br/turbina-e%C3%B3lica-em-forma-de-%C3%A1rvore/a-18359728 - Accessed on: 04/15/2021.

In addition to this, the project developed by the company Deveci Tech from Turkey also served as inspiration, the aforementioned company developed a vertical wind turbine, called Enlil , illustrated in Figure 31 and capable of generating 1 kW/h. Both projects are still experimental.

Figure 5 : Vertical Wind Power Generator in Liu

Source: https://url.gratis/j6PSfP - Accessed on: 04/15/2021.

The guiding projects encouraged the development of our idea, and therefore, with the intention that the application and implementation of our initiative is in fact viable, that is, capable of materialization and mass production, or that it can undergo adaptations that make it viable, constituting a project that can bring benefits and transformation in some way.

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Within the scope of the project's economic viability, we developed strategies for using the constituent elements of the model as possible spaces available to sponsor the initiative, or even to ensure the maintenance of equipment, which, according to our expectations, can be put into operation.

DESCRIPTION OF THE WORK PROPOSAL

The proposal aims to conceptualize a model for electrical energy production, merging the concepts of solar and wind energy projects, with low cost and reduced environmental impact, which should also be easily implemented and maintained.

We initiated our conceptualization based on an existing model in nature; trees. We determined that the part resembling the trunk should serve as the structure housing the motors for kinetic energy conversion, wiring, and frequency inverters. The tree canopy exhibits a similarity to branches, with leaves serving the function of capturing both wind and solar kinetic energy.

The so-called "airfoils" represent and serve as blades, responsible for wind capture, which is then converted into kinetic energy, further transformed into electrical energy. These are microturbines designed to capture wind energy, even under minimal wind conditions. They store electricity to convert watts into kilowatts.

At the top of these airfoils, tiny photovoltaic panels will be integrated, allowing for dual capture of clean energy, ultimately converted into electrical energy.

The vertical axis rotor is the component to which the leaves are attached, responsible for transmitting kinetic energy to a rotational multiplier, thus producing energy with minimal force from the incident wind.

From an aesthetic standpoint, our goal is for the structure to blend seamlessly with the landscape, reducing visual pollution. The tree-like shape optimizes space utilization. We encountered some difficulty at this stage of conceptualization and project development in defining equipment or installation height standards, recognizing variations in wind intensity relative to positioning.

ANALYSIS OF POSSIBLE INSTALLATION LOCATIONS

ROADS

The installation in the Anchieta-Imigrantes System (SAI), which is currently the main route connecting the Port of Santos and providing access to the Metropolitan Region of Baixada Santista with the metropolitan region of São Paulo, spans approximately 176.8 km, offering ample space for project implementation. Annually, approximately 40 million vehicles pass through this system, typically traveling at speeds above 30 km/h.

For instance, the Imigrantes highway, with a length of 58.5 km or 58,500 meters, is illuminated by at least one lamppost every 400 meters. This makes it feasible to install totems along the highway to produce energy consumed on-site.

CALCULATION AND OPERATION MEMORIAL

- Number of posts:

Extension/visual measurement by Google Earth = 58500m/400m = approximately **147 light posts** .

- Electrical consumption:

A highway lamppost produces lighting of 9000 lumens and has a power rating of 75 watts. Assuming the lamppost operates for 12 hours on a winter day, totaling 372 hours of operation in a month, the electrical consumption can be calculated as follows:

- Delta t: Time: 12 hours *31 days = 372 hours/month.

- Electricity consumption = Eel .
- Power (kWh) = P.

Eel = P* deltaT Eel = 0.075*(12 hours*31 days) Eel = 0.075*372 Eel = 27.9 kWh/month per lamp/pole.	Or	Eel = P* deltaT Eel = 0.075*12 hours Eel = 0.9 kWh per pole Eel = 0.9 kwh * 31 days = 27.9 kWh/month per lamp/pole.

Table 1 : calculation of electrical consumption per public lighting pole; copyright 2021.

TARIFF-BASED CONSUMPTION:

The energy production in the country varies according to seasons, biomes, and regions. ANEEL modulates tariff prices accordingly. Below are the estimated prices considering lamppost consumption and possible tariff flags, including Yellow Flag (less favorable conditions), Red Flag 1 (unfavorable conditions), and Red Flag 2 (very unfavorable conditions).

Estimate of Monthly Highway Expenses according to the Tariff		
Formula: number of posts * tariff * days (month)		
Value of the yellow flag tariff = Vba . Number of posts * Vba * month 147*0.026343*31= 120.045051 reais per month , or approximately: **R$120.05**	Red flag tariff value 1= Vbv1 . Number of posts * Vbv1* month 147*0.056133*31= 255.798081 reais per month , or approximately: **R$255.80**	Red flag tariff value 2= Vbv2 . Number of posts * Vbv2* month 147*0.08397*31= 382.65129 reais per month , or approximately: **R$382.65**

Table 2 : Estimated Monthly Highway Expenses according to Tariff; copyright 2021.

ARVOREDOS ISLAND

Arvoredos Island is located 1.6 kilometers from Pernambuco Beach in Guarujá, on the coast of São Paulo. It serves as an installation dedicated to sustainable tourism and environmental research, occupying an area of 36 thousand square meters and consuming approximately 270 watts in lighting (30 9W LED bulbs).Calculation and operation memorial

Electrical consumption:

Currently, the teams that manage the island have two quantifications of energy expenditure:

1. 30 9W LED bulbs; It is
2. 26 kWh per month.

Since the island's energy resources are not utilized every day, we assume daily usage with 6 hours of operation.

- Delta t: Time: 06 hours *1 days = 6 hours/month.
- Electricity consumption = Eel .
- Power (kWh) = P.

Eel = P* deltaT Eel = 0.009*(6 hours*1day) Eel = 0.009*6 **Eel = 0.054 kWh/day per lamp.** Eel = P* deltaT Eel = 0.27*(6 hours*1day) Eel = 0.27*6 Eel = 1.62 kWh/day for 30 lamps (total consumption).	Eel = P* deltaT Eel = 26*(6 hours*1day) Eel = 26*6 **Eel = 156 kwh/month.**

Table 3 : Electricity consumption per public lighting pole (off grid); copyright 2021.

As it is an *off-grid network* , there is no tariff calculation, as there is no electrical coverage from the concessionaire.

TOTEM ENERGY PRODUCTION

Totem solar production by solar cell

A survey of photovoltaic energy generation capacity was conducted using a voltaic cell model composed of crystalline silicon (c-SI), considering it to be the least efficient, with only around 20% in capturing radiation, with 3W of power and 0.6V.

The radiation used as a parameter for the installation estimate 1, on Rodovia Imigrantes, was 4.5 kWh/m², obtained in Santos - SP, coordinates Latitude 23º 56' 26" south and Longitude 46º 19' 47" west, through the website of the Reference Center for Solar and Wind Energy Sérgio de S. Brito (CRESESB), in the month with the lowest solar intensity (June).

Similarly, for the installation estimate 2 - Ilha dos Arvoredos, the radiation was 4.5 kWh/m², obtained in Santos- SP, coordinates Latitude 23º 58' 00" south and Longitude 46º 10' 0" west, through the CRESESB website, also in the month with the lowest solar intensity (June).

Considering the table above, we can conclude that just one 3w solar cell with only 20% energy efficiency is capable of meeting the daily energy demand on Ilha dos Arvoredos and Rodovia Imigrantes. However, it is important to highlight that each totem will not have just one solar cell, but several depending on the number of wind mechanisms it will have.

As an analysis, the calculation was carried out for single-phase and two-phase installations. This data is necessary for the process organization stage, so that the frequency inverter must meet the local network and/or the stationary battery used.

Totem wind production by aerofolha

The rotation generated from the air turbulence after the cars pass can generate up to 6v, however in an inconsistent manner. The significant and energy-producing rotation begins at 10m/s, above that, energy generation increases production through the rotation of the equipment.

VIABILITY ANALYSIS

Economic viability entails the acquisition and/or production of components within the market's purchasing and selling capacities, compared to the savings generated as a financial counterpart for transitioning the energy source.

Below are the items common to both on-grid and off-grid installations, along with the current market price for each component compared in retail mode through virtual stores. The quotation estimate was based on average prices obtained from 5 Google Shopping ads.

3D PROJECT STRUCTURE

In order to make the project tangible not only from a marketing perspective but also feasible in terms of engineering, the assemblies and composition of the 3D structures were carried out using AUTOCAD software.

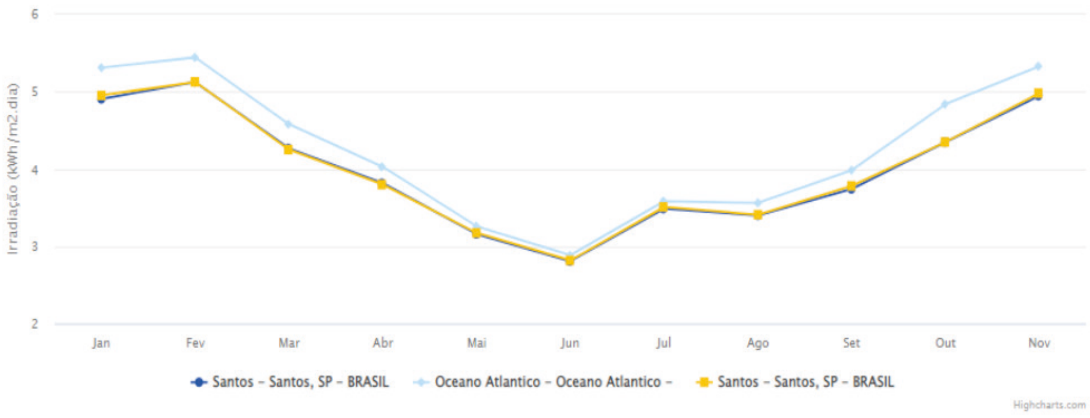
The structure of the airfoils with the solar panels and their potential installation on lighting posts already installed on public roads is depicted in Figure 6 below. The wind rotors feature a central rod to which the solar panel will be affixed, providing stability for capturing and converting energy. The union of these structures' spans approximately 20 centimeters, enabling the installation of multiple capture structures, thus composing the tree.

FINAL CONSIDERATIONS

The initial aim of this work was to establish a comprehensive context of the energy issue, presenting relevant data to inform an understanding of the topic's significance in terms of market competitiveness among nations, as well as the impact of energy generation processes both domestically and internationally.

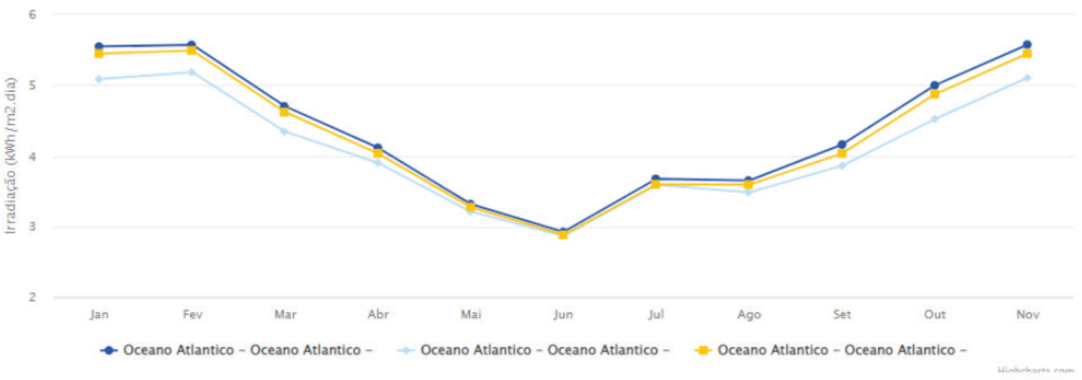
It is undeniable that there is still a clear global dependence on fossil and mineral energy sources, coupled with a predominance of electricity generation systems based on hydroelectric, thermoelectric, and nuclear plants.

Several factors, such as the exponential increase in the world's population, shifts in human behavior and consumption patterns, and the ongoing development of technologies aimed at facilitating communications and enhancing quality of life, contribute to the



Graph 1 : Solar irradiation in the horizontal plane for Rodovia Imigrantes.

Source: Accessed on: 04/23/2022.



Graph 2 : Solar irradiation in the horizontal plane for Ilha dos Arvoredos.

Source: Accessed on: 04/23/2022

Calculation carried out for the production of a totem solar cell	
Estimate 1. Rod. Imigrantes – *on grid*	
Production = power*solar irradiation*capture.	Production – consumption.
3w*2.81 kWh/m²*0.20 = 1.686kwh/day *31 days = 52.266 kwh/month generated by solar cell.	52,266 - 27.9 = 24,366 kWh/month production surplus.
Estimate 2. Ilha dos Arvoredos – *off grid*	
Production = power*solar irradiation*capture.	Production – consumption.
3w*2.86 kWh/m²*0.20 = 1.716kwh/day*31 days = 53.196 kWh/month generated by solar cell.	(With 1.62 kWh/day): 1,716 – 1.62 = 0.096 kWh/day production surplus. (With 156kwh/month): 53,196 - 156 = -102.804 kwh/month in production.

Table 4 : Calculation carried out for the production of a totem solar cell; copyright 2021.

Charge for Electric Current: A pole with 110v and 75W needs a current (I) of ___A: I= W/V = 75/110 = approximately 0.682º. A pole with 220v and 75W needs a current (I) of ___A: I= W/V= 75/220 = approximately 0.341st.

Table 5 : Loads and conversions for installation in electrical currents; copyright 2021.

COMPONENT	PRICE/UNIT	METHOD OF OBTAINING
Silicon photovoltaic cell (c-SI) 0.6v, 3w	R$ 7.00 - 1 photovoltaic cell	Purchase
6v motor per propeller	R$ 50.00 - one engine	Purchase
PVC trunk structure	R$ 300.00 reais - 3 PVC pipes with a diameter of 15cm	Purchase and modeling
Wires	R$ 100.00 reais – 100 meters of thread	Purchase
15cm 3D wind propeller	R$ 150.00 reais – 100 meters of filament	3D printing

Table 6 : Economic viability of items; copyright 2021

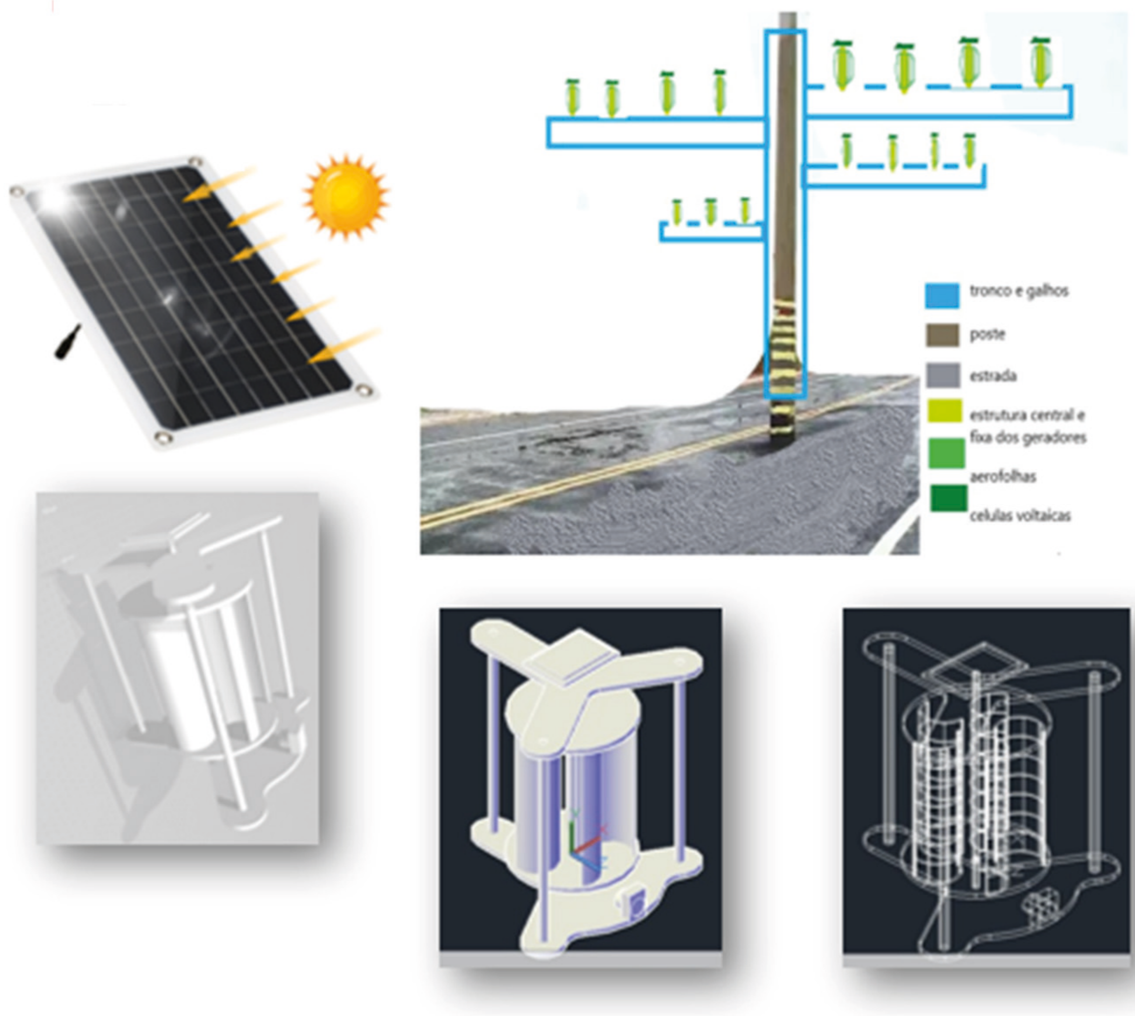


Figure 6 : Totem Structure

escalating need for energy production.

Public lighting has become a necessity due to the changing behavioral patterns of modern urban societies, enabling nighttime activities to be as productive and economically active as daytime.

The utilization of wind and solar energy generation and their market penetration have been steadily increasing due to their recognition as clean and renewable energy sources. It's worth noting that while they do have some environmental impact, it is typically lower in scale compared to conventional energy sources. Both wind and solar energy systems are continuously evolving and improving to maximize energy utilization.

Given the progressively growing demand for energy, particularly electricity, and the understanding that it is imperative to produce more to meet the needs of a burgeoning population while simultaneously reducing the use of non-renewable natural resources and minimizing waste generation, there is a need to develop new methods of generating clean energy with minimal environmental impact.

This work aims to develop an ecologically designed totem capable of generating electrical energy through simultaneous wind and solar generation, combined within a single device resembling a tree.

The totem is designed to harness wind energy from the flow of wind and the vacuum created by moving vehicles on roads and highways while simultaneously capturing and generating solar energy through photovoltaic cells. Its purpose is to fulfill the lighting needs of these roads, either independently or in conjunction with the existing electrical grid. When installed in areas without a wired electrical network, it is intended to operate autonomously without the need for cabling.

Having conducted production calculations for the prototype and assessed the electrical potentials generated within the project's design parameters, it is estimated that the totem is viable both in terms of production cost and its capacity to generate electrical energy for road lighting. In essence, it is operational and economically feasible.

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