GENERATION OF RENEWABLE ENERGY THROUGH ROADS, BRIDGES AND CYCLE PATHS

GERAÇÃO DE ENERGIA RENOVÁVEL POR MEIO DE ESTRADAS, PONTES E CICLOVIAS

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Abstract: The economic growing and technological development brought advantages to society. However, the adoption of the sustainable development is necessary so the future generations will not be compromised. In this way, the present work has as its objective presenting a bibliographical review about roads, bridges and bike lanes that generate renewable energy. The photovoltaic panels are very important to generate energy on the roads and, as an example, the acoustic barriers on the roads can be exchanged or implemented with photovoltaic panels to maintain the function of sound barrier and of generator of electric power at the same time. Another way of generating renewable energy are bike lanes, in the Netherlands, as an example, it is utilized a special concrete, superimposed by a layer of highly resistant glass with photovoltaic cells, so the installed floor can convert sunlight into energy. The piezoelectric energy can also generate energy in bike lanes using a pressure-sensitive floor with friction from bicycle tires. When it comes to bridges, a project developed in Italy intends to place solar panels and wind generation turbines in a bridge as a way of generating energy, generating around 40 million kW/h in one year. The proposal of this bridge is to fulfill empty spaces among the existing pillars on the bridge to integrate the system of wind turbines in the structure. It can be concluded that, throughout time, the renewable energies have been standing out and civil construction has shown an important role in this sector, presenting technological solutions and taking advantage of spaces in relation to the implantation of roads, bridges and bike lanes.

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Resumo: O crescimento econômico e o desenvolvimento tecnológico trouxe vantagens à sociedade. Entretanto, é necessária a adoção do desenvolvimento sustentável para que as gerações futuras não sejam comprometidas. Desta forma, o presente trabalho tem como objetivo apresentar uma revisão bibliográfica sobre as estradas, pontes e ciclovias que geram energia renovável. Os painéis fotovoltaicos são muito importantes para a geração de energia nas rodovias e, como exemplo, as barreiras acústicas das rodovias podem ser trocadas ou implementadas com placas fotovoltaicas para manter a função de barreira sonora e, ao mesmo tempo, de geradora de energia elétrica. Outro meio para gerar energia renovável são as ciclovias, na Holanda como exemplo, é utilizado um concreto especial, sobreposto por uma camada de vidro altamente resistente com as células fotovoltaicas, sendo assim, o pavimento instalado consegue converter a luz solar em energia. A energia piezoeelétrica também pode gerar energia em ciclovias com o uso de um piso sensível à pressão com os atritos dos pneus das bicicletas. Em se tratando das pontes, um projeto desenvolvido na Itália, pretende colocar painéis solares e turbinas de geração eólica em uma ponte como forma de geração de energia, podendo gerar em torno de 40 milhões de kWh num ano. A proposta desta ponte é preencher os espaços vazios, entre os pilares já existentes na ponte, para integrar o sistema de turbinas eólicas na estrutura. Pode-se concluir que, ao longo do tempo as energias renováveis vêm se destacando e a construção civil tem demonstrado um papel importante neste setor, apresentando soluções tecnológicas e aproveitando espaços em relação as implantações de estradas, pontes e ciclovias.

Palavras-chave: Sustentabilidade. Energia Renovável. Placas Fotovoltaicas. Energia Piezoeelétrica. Energia Eólica.
1 INTRODUCTION

According to Tessari (2006), the economic growing caused by technological development brought great advantages to society. However, coupled with population growth and inadequate consumption, it resulted in several side effects, thus verifying the need for adoption to develop with sustainability. Corresponding to Torresi et al. (2010), developing with sustainability means the development that satisfies the present needs, embracing the environmental, social and economic concepts.

In accordance with Torresi et al. (2010), the consumption of electrical energy has been growing globally each year. That said, Nascimento et al. (2012) explains the importance of renewable energy, because it presents a great alternative for the recurring problems from the raise of the consumption of electric power, climate changes and to decrease the crises in the environment. For Torresi et al. (2010), it is a duty to search for alternatives for consumption of fossil fuels in the production of electrical energy.

According to Nascimento (2004), the search for new sustainable technologies to generate electric power, which generates clean energy from abundant source and is considered inexhaustible, is fundamental. Besides, it presents advantages such as the decrease on the construction of thermoelectric, nuclear power plants and hydroelectric dams, which generate several environmental impacts. That said, the present work has as its objective presenting a bibliographical review about roads, bridges and cycle paths for the generation of electrical energy.

2 DEVELOPMENT

2.1 Principle of the Solar Energy Operation

The solar energy is created through the use of solar radiation launched over our planet, and the photovoltaic plates convert this solar radiation into
electrical energy (PENA, 2019). For the production of photovoltaic solar energy, a device with semiconductor material is necessary: the silicon, which is the fundamental unity of the conversion process. According to Nascimento (2004), the doping of the silicon is essential, adding exact quantities of other elements, such as Phosphorus and Boron, for the material to become an electrical conductor. Phosphorus-doped silicon becomes a material with negative charges, type N silicon. The material doped with Boron is obtained with a material with positive charges, type P silicon. That said, the photovoltaic cells present a thin layer with material the type N, and a thicker layer with the material type P. Therefore, with the presence of sunlight in the photovoltaic cell, the photons shock with electrons in the silicon structure, providing power, which is generated by the electric field in the junction of the layers P-N. Thereby, the electrons are oriented and flow, generating an electric current. The photovoltaic cells are placed in modules and connected in series, which provides a sum of each voltage generated by each cell to have the desired voltage level (PINHO and GALBINO, 2014). However, the photovoltaic plates produce a continuous current, requiring an equipment known as “inverter”, responsible for converting direct current into alternating current (RUTHER, 2004).
2.2 Forms of Generating Electric Power in Cycle Paths

2.2.1 Solar Cycle Paths

According to Borges (2017), the Solaroad cycle path in Holland was the first cycle path built with solar panels. The photovoltaic plates used were prefabricated in concrete, recovered by a superior layer of tempered glass and under this glass are installed the photovoltaic cells (TRICHES, 2016). Also, the author Triches (2016) explains that for the system to work properly it is necessary that the layer above the solar cells is translucent for the solar radiation to reach the plates. Besides, it is necessary to repel most of the dirt that can stay over the system, and the upper layer must be non-slip and resistant enough to proportionate a safe surface for users. The figure 2 illustrates the assembly and the photovoltaic panels (BORGES, 2017).

Source: adapted from Souza (2016).
The electric power generated by these prefabricated plates can provide energy for posts, electric cars or send to the local electrical network (BORGES, 2017). Another way of generating solar energy in bike lanes is utilizing coverages with photovoltaic plates, as the figure 3 demonstrates. That said, it is possible to enjoy and share the use of spaces. In addition, it provides shade and a safer space for cyclists (ROSA, 2016).

According to Miwa (2015), in South Korea, it was constructed a cycle path with 32 kilometers of range with 20 thousand photovoltaic panels. This cycle path connects two cities, Daejeon and Sejong, and the users can ride their bikes in high speed. The figure 3 presents the cycle path installed in South Korea.
2.2.2 Piezoelectric Energy in Cycle Paths

A technology of Japanese origin captures the vibration emitted by pedestrians and cyclists and converts it in energy (PELANDA, 2018). This electricity is used to activate an intelligent system of signalization at intersections and also in monitoring sensors of the cyclists’ flow (JUNGES, 2016).

According to Lobo (2016), in Berlin, Germany, and in Curitiba, Brazil, cycle paths were built with a pressure-sensitive floor capable of generating electrical energy through friction with the bicycle tires. This energy generated through the cycle path generates light to illuminate its entire route and also guarantees safety to the cyclists that ride in it. The figure 4 illustrates the cycle path power generation system.
2.3 Forms of Generating Electrical Energy in Roads

2.3.1 Acoustic Barriers that Generate Electrical Energy

According to Rocha (2015), some researchers of the Eindhoven University of Technology, in Holland, developed a method that uses acoustic barriers from a road to generate electrical power. This method uses translucid panels that concentrate sunlight to generate renewable energy. Cravo (2014), explains the importance of the photovoltaic panels for the production and generation of energy in roads, because the acoustic berries and be switched or implemented with photovoltaic panels. That said, the plates can maintain the function of sound barrier and, at the same time, generate the electric power.

Some tests from the researchers of Eindhoven University of Technology, in Holland, point that one kilometer with the barriers with photovoltaic panels could provide electrical energy for fifty families for one year, or provide energy for a battery of an electric car with enough power to conduct 900 thousand kilometers (ROCHA, 2015).
According to Cravo (2014), the sound barriers with power generation panels, as exposes the figure 5, could be inserted as well in railways with great potential of generation.

**Figure 5 – Electrical Energy Generation in Acoustic Barriers**

Source: Rocha (2015).

### 2.3.2 Solar Asphalt in Roads

France inaugurated the first solar road in the world in the city of Tourouvre (Figure 6). This road is paved with solar panels capable of providing energy for public illumination of a small town with approximately 5 thousand habitants. Besides, it is worth highlighting that this technology can enjoy the infrastructure of the road to generate electrical power without occupying new spaces (WELLE, 2016).

According to Higa (2017), approximately 2 thousand drivers travel every day through the roads of Tourouvre and it is still in analysis to verify if this technology really is viable.
The idea is also being analyzed in Germany, Holland and the United States of America, which present roads occupied by cars in only 20% of the time, thus, it offers vast expanses of surface to absorb the sun rays (WELLE, 2016).

Figure 6 – Road with photovoltaic panels in Tourouvre, France

Source: Welle (2016).

Higa (2017) points, as well, the disadvantages of this system. One of them is that this technology has a high cost, because the solar panels need to be more resistant to support the weights of bicycle, cars or trucks. Also, for being on the pavement and without the possibility of changing the angle to follow the movement of the sun, the solar panels generate approximately 30% less energy than if they were in a roof, for example. However, according to Welle (2016), the responsible for the project of the Tourouvre road, sustain that the price of the infrastructure will decrease the measure that increases the demand, which will also ease the cost of the energy produced.
2.3.3 Wind Turbines that Generate Energy in Roads

According to Gardin and Dimenstein (2018), a Turkish company (Deveci Tech) developed a project that utilizes a wind turbine capable of generating renewable energy with the wind created by the passage of vehicles in avenues and roads.

According to Mendes (2018), the equipment that consists of the wind turbine system is three blades coupled on a vertical axis, which are capable of generating one kilowatt per hour of renewable energy (figures 7 and 8). The Turkish company explains that this is enough to supply the demand of two houses for an entire day (POLICARPO, 2018).

Figure 7 – Road with photovoltaic panels in Tourouvre, France

![Road with photovoltaic panels](image)

Source: Gardin and Dimenstein (2018).

Besides, each generator has a photovoltaic plate on its top to capture solar energy. This energy generated will supply the system and internal functions of the prototype. Also, it has some technologies with seismic sensors that will help control earthquakes, and even an IOT system that provides information of
efficiency in each unity through an app and readers of CO₂ emission (GRADIN and DIMENSTEIN, 2018).

Figure 8 – Simulation of the movement of wind turbines

Source: Mendes (2018).

2.4 Forms of Generating Electrical Energy in Bridges

2.4.1 Wind Turbines in Bridges

An architectural project of the professionals Francesco Colarossi, Giovanna Saracino and Luisa Saracino was presented to the Italian Government and intends to revitalize a deactivated bridge in the country and make it capable to produce electricity to around 15 thousand houses in the country (figure 9). This project is named Solar Wind (SPITZCOVSKY, 2016).
Figure 9 – Project presented to the Italian Government

Source: Spitzcovsky (2016).

According to Ribeiro (2015), the project of the bridge Solar Wind proposes to use the empty spaces in the bridge span to install 26 wind turbines, which could generate approximately 36 million kWh per year. Besides, the 22 kilometers of lane will be coated with solar panels that will generate electrical energy (SPITZCOVSKY, 2016). Also, Ribeiro (2015) explains that the operation of these solar panels could generate an additional 11 million kWh per year.

2.4.1 Bridges that Generate Solar Energy

According to Franco (2014), London inaugurated a bridge with the highest potential of generating renewable energy with photovoltaic plates in the world. This bridge is over the River Thames and it was installed over the Blackfriars train station, which is in the bridge. That said, Franco (2016), explains that the roof of the station is covered with solar plates with approximately 4,400 panels in more than 6 thousand square meters that capture, stores and convert the sun energy into electrical energy, just like shown in figure 10.
Figure 10 – Bridge with Photovoltaic Plates over River Thames

Source: Franco (2016).

According to Franco (2014), the bridge’s power generation capacity is enough to supply half of the consumption of energy in London’s train stations. That said, it is expected that this bridge can reduce the emission of carbon gas with the generation of energy for the electric trains.

3 FINAL CONSIDERATIONS

In fact, over time, sustainability has had its assumption in society and the civil construction has demonstrated an important role with the use of new technologies and sustainable principles. Treating about the generation of renewable electrical energy in roads, bridge and cycle paths, these new technologies provide better utilization and sharing of the spaces without damaging the environment, avoids the construction of new nuclear power plants, hydroelectric dams and even decreases the use of thermoelectric, which utilizes fossil materials for generation.
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