SOLAR ENERGY AS A NEW RENEWABLE ENERGY SOURCE FOR CARS ON THE EXAMPLE OF LODZ SOLAR TEAM PROJECT

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Abstract

Transportation is one of the major factors influencing progressing global warming effect. To decrease the impact, different energy sources are being explored. The following study considers the experiment of Lodz Solar Team - group of students of Lodz University of Technology, Poland - with implementation of photovoltaic panels in two prototypes of electric cars, during years 2014-2018. Driving tests were conducted on 2 routes: for 3022 km in Australia and 2817 km in South Africa. Performance results of created prototypes were positive and qualify solar-powered cars to be suitable for everyday use. Development of infrastructure for electric cars and usage of solar energy in means of transportation like airplanes and trains can be seen as a positive feedback for this technology.

Keywords: Solar energy, solar-powered car, innovative technologies, renewable resources

1. INTRODUCTION

Transportation is one of the biggest factors, causing global warming. It does not only contribute to a huge amount of combusted fossil fuels. There is also an aspect of noise, biodiversity, soil and water pollution. Long-term programs are being developed to provide preventive actions. One of them is introduction of renewable energy resources in the industry. The biggest field of interest is transportation. The following study concerns the benefits of implementation of solar energy as a solution for self-sustainable cars for everyday use. It is based on observation of a group of Polish students, called Lodz Solar Team and its prototypes, produced during years 2014-2018. Different aspects of this technology are concerned: principles of operation, advantages and disadvantages for potential buyers and view on further development. As the team is the first such a project in Poland, there are no studies on this topic presented yet.

2. SOLAR-POWERED CARS PROTOTYPES

Transportation plays a huge role in greenhouse production, especially in an urban area (covering most of the Old Continent), the European Union has set a target level of renewable energy resources used in transport. Individual standard, established according to the development rate and abilities of each EU member, must be reached by the end of 2020. As the **Figure 1** shows, in 2016 there were only two countries that reached two-digit percentage share of renewable energy resources used in transportation. These are Sweden - 30.3 % and Austria - 10.6 %. Level of development in this range is varying, however, down to less than 1 % for Estonia. Poland in 2016 reached a level of 3.9 %, as depicted in **Figure 1**.

As a reduction of the emission of products of burned fossil fuels in transportation is required, the concept of introduction of electric cars is inevitable [2]. An electric car is a one that uses electric motors supplied by energy from a rechargeable battery pack. As a new trend, more and more well-recognized car brands like Ford, Toyota, Skoda or specialist in this field - Tesla are investing in the development of this branch. Worldwide known luxury brand - Bentley presented its new stunning electric EXP 12 speed 6E model during Geneva salon 2017. However, currently, the energy stored in a battery is delivered from “the socket” so from the power station using coal. Also, the battery, as a hazardous material, poses a major problem during the utilization

process. Therefore, the concept of usage of hydrogen or solar power for transportation seems to be a proper solution. Hydrogen is mostly used as a rocket fuel, however, in the USA there are about 500 cars [3], supplied with such a solution. Besides being eco-friendly, there is still an opinion among society that such system is of high risk, very likely to explode. No trust imposes a low demand for such cars, what prevents refilling stations from development and in turn the system development itself.

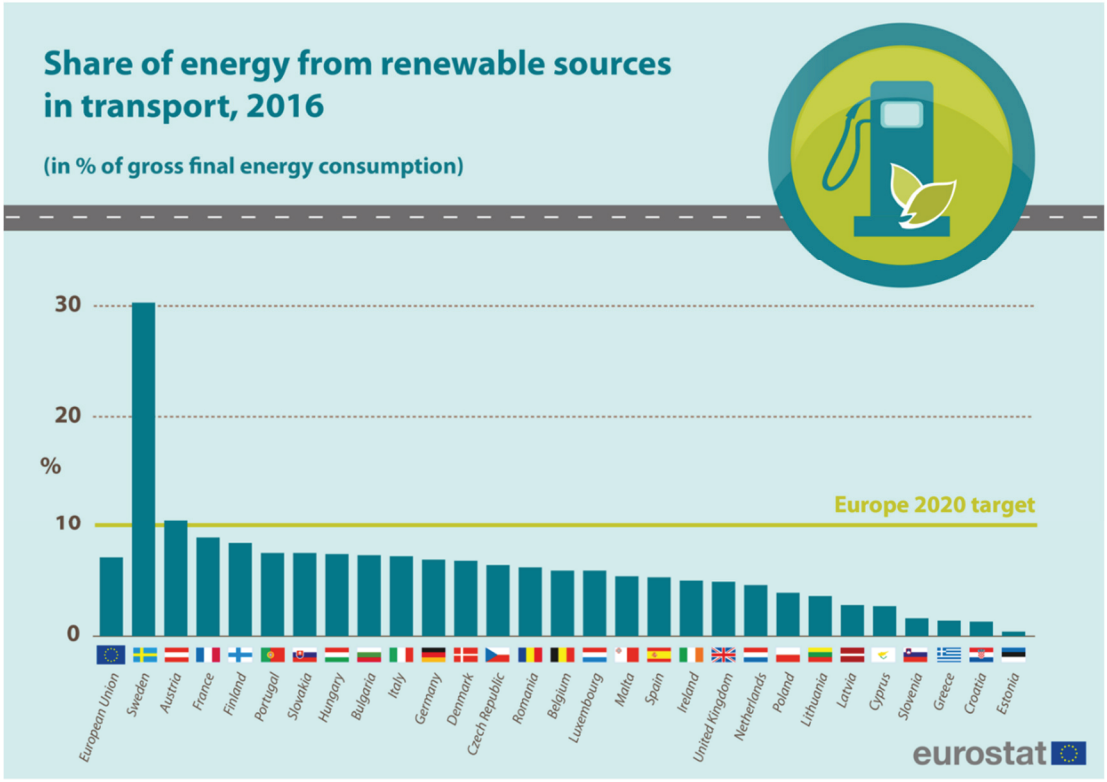

Figure 1 Share of renewable energy in fuel consumption of transport. [1]

In the case of the solar-powered car, there is no mass production of such a model for now. Usage of photovoltaic panels would, however, ensure fully eco-friendly driving. In an ideal situation, the car would be independent of any external power supply, gathering only energy from the sunlight reaching the Earth.

Several prototypes of such a car have been built in the best research centers all around the world. Besides fun-art, there are numbers of students' teams, that are constructing such cars to compete against each other in the most difficult races, taking place in very demanding environmental conditions. Races differ a bit between continents, however, the general idea remains the same: to push the limits of the technology and present the most efficient solar-powered car as possible. Contestants are divided into 3 groups: Challenger Class - cars that have to cover the route (around 3,000 km) in the shortest time possible, carrying the driver only, Cruiser Class - cars for at least 2 people that are supposed to cover as many kilometers per person as possible and Adventure Class for all participants that do not fit into other categories and drive for self-test.

The first team in Middle-Eastern Europe is one from Poland, called Lodz Solar Team, representing Lodz University of Technology. It consists of around 30 students of different specialties, that are divided into 4 sub-teams: mechanical, electrical, developers and marketing. The team presented its first prototype in 2015. So, called Eagle One is a two-seats city car, equipped with 5 m^2 of photovoltaic panels with an additional 1 m^2 mounted over windscreen at stops. The car is 1.8 m wide and 4.5 m long, weighing only 430 kg. The energy is stored in a battery of capacity 15 kWh and sent to two 5kW motors, mounted in wheels for better efficiency. As for the first-ever built car, performance outcomes are impressive: maximum speed reaches 120 km/h, while distance covered with optimum speed reaches the number of 1,500 km on one charge.

Figure 2 Eagle One during World Solar Challenge 2015 in Australia

The car was representing Poland in two the most important races in the world - in 2015 in Australia and in 2016 in South Africa. In 2015, the team has covered around 3,000 km per person, achieving the best result among debutants. It was also awarded with Safety Award for the safest construction of the car. During the following year, the team has participated in Sasol Solar Challenge in South Africa, where the team presented the first ever in the history of this race. Covering 2817 kilometers per person, Lodz Solar Team has set 3 new records for next editions of the event. The team was also awarded with Communication Award for the best media coverage from of the event.

A year later, Lodz Solar Team has released a new version of the car - Eagle Two. It appeared to be one of the two first 5-seats solar-powered vehicles in the world. The new car has refreshed silhouette, prepared by aerodynamic specialists in cooperation with students of Lodz Academy of Art. According to changes of the race's regulations, Eagle Two has only 5 m^2 of PV (photovoltaic) panels on the rooftop and smaller battery, which results in a range of 800 km on one charging only. However, this prototype has proved to be much more efficient during test during Bridgestone World Solar Challenge 2017 in Australia, setting new Polish record to 4,496 kilometers per person.

Figure 3 Eagle Two during World Solar Challenge 2017 in Australia

The principle of operation of such a car is quite simple. Solar energy is gathered by photovoltaic panels, mounted on the rooftop. A photovoltaic panel (PV) consists mainly of a semiconductor. This element has two parts - positive (p) and negative (n). Both of them are basically made of silicone but have different structures.

P part has Bohr atoms in the construction. These molecules have only 3 electrons on the last shell, one less than silicon, meaning that there is one, positively charged hole. N part, on the other hand, is created by silicone structure, where some of the silicon atoms have an additional fifth electron. As the system tends to equilibrium, holes of P part are being filled with loose electrons of part N. When a photon hits a PV panel, it extracts an electron, creating a pair of electrons and a hole. The movement of electrons creates potential difference, resulting in electricity flow. The semiconductor is connected with two electrodes which pass the electric impulses through MPPT to load, which in case of this car is a battery. The energy afterward is passed from battery to two motors mounted directly in rear wheels. The car is equipped also with a port for charging the battery from chargers for electric cars.

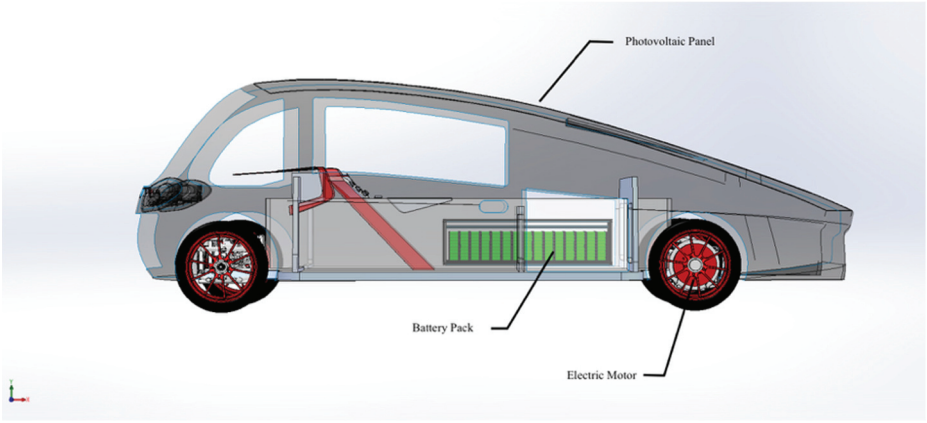

Figure 4 Cross-section of the car - "Eagle One"

The team is constantly improving car prototypes. Its research does not only investigate the boundaries of technology but also moves in the direction of adjusting the car features to the requirements of typical car users. For instance, solar-powered cars are being adjusted to use super-fast chargers for simple electric cars or possess typical modern facilities as USB ports for phone charging. The final outcome for mass production should fulfill the typical requirements of car users:

- Efficiency - low consumption of energy;
- Comfort - for the driver and passengers;
- Connection with the internet - being in constant connection with the world and safe usage of applications during driving;
- Eco - not producing any harmful substances during usage;
- Modern look - interesting shape, modern materials;
- Space for luggage - for short and long journeys;
- Safety - during normal use and in case of accident;
- Low mass - of particular components that result in better efficiency;
- High maximum speed - reaching destination points in the shortest time possible;
- Support for a driver - systems providing help during operations e.g. during parking;
- Monitoring driver's life parameters - prevention of accidents.

Amount of Sun's energy reaching Europe is widely perceived as not sufficient for supplying everyday use of a city car. As the map shows in **Figure 5**, the estimated energy collection potential varies depending on the latitude. The best results can be obtained around North Territory of Australia, South Africa, Sahara Desert, and adjacent areas, Arabian Peninsula, Andes and scattered regions among South USA and South Asia. The highest results are reaching the value of 2,500 kWh/m^2, while Europe is in the range of 1,000-1,500 kWh/m^2. For comparison, an average kettle uses 0.11541 kWh for boiling water for over 4 minutes. The solar energy, reaching the Earth seems to be a promising source that has not been popularly used so far [4].

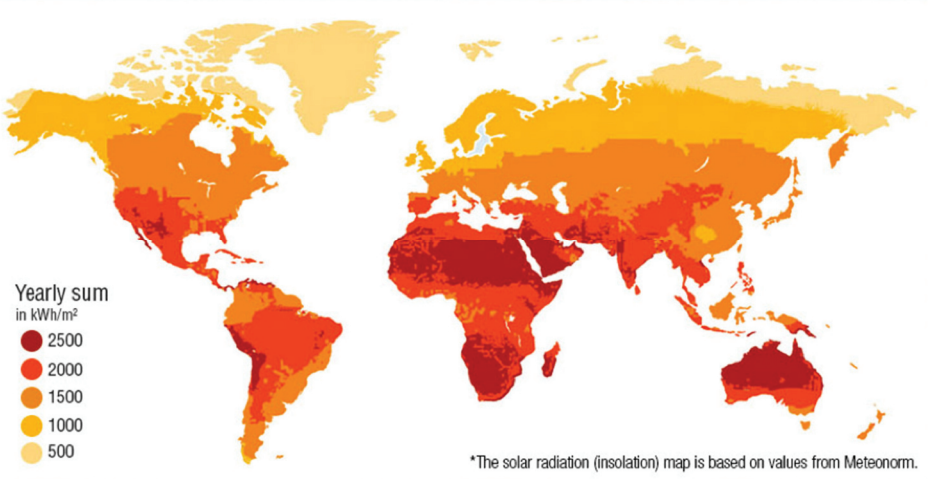

Figure 5 Yearly sum of solar energy reaching the Earth in kWh/m^2 [5]

As solar-powered cars are a new electric cars' version, it is worth investigating the current development of electric cars themselves. According to European Alternative Fuels Observatory's data, the infrastructure for this car type has experienced dynamic growth since 2010. Not only the number of charging stations is increasing but also diversification of their types can be observed.

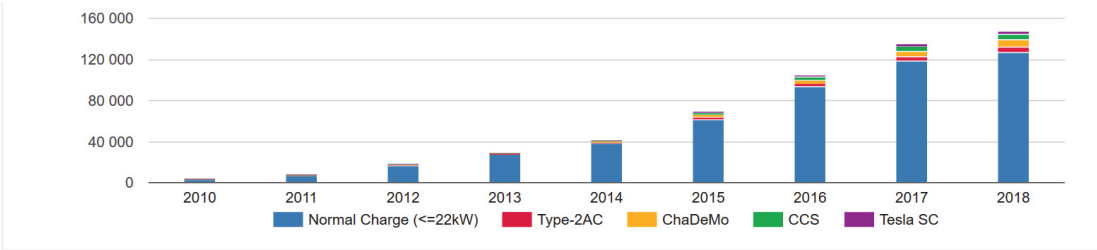

Figure 6 Total number of PEV charging positions [6]

What is more, governments of European countries are supporting the exploration of this technology. According to Multicriteria Analysis of Innovation Policies in favor of Solar Mobility in France by 2030 [7], France is investing in a concept, that could be understood as "inverse smart grid", meaning charging electric vehicles from house battery, supplied by PV panels on its rooftop. However, smart grid solution itself seems to be more efficient. In this case, a house is equipped with a battery, charged from PV panels, mounted on the roof of the car. In this way, solar energy is used to charge the car while driving, whereas the surplus of energy gathered by the parked car is used to supply the house battery.

Additionally, there are more examples of the implementation of solar energy in transportation. Poland besides solar-powered cars has also developed an award-winning solar-powered boat. Alumni members of one of the Dutch students' team, participating in World Solar Challenge have launched a startup, producing solar-powered cars, called "Lightyear". In 2017 Australia has launched the very first solar-powered train [8]. All these projects give hope for the future of wide usage of solar energy in transportation.

3. CONCLUSION

Transportation is one of the most significant agents, having negative impact on climate changes. Electric cars are gaining popularity, however, the energy used for charging is mostly produced from fossil fuels. Therefore, the development of alternative energy sources and implementation in this industry is crucial. Basing on the

outcomes of Lodz Solar Team project, investigation of solar-power usage in transportation seems to be worth exploration. There are several points that should be considered:

- Solar energy implementation in transportation is being explored by students around the world. Teams are building prototypes and subject them to extreme conditions during solar-car races.
- Lodz Solar Team from Poland is proving that even Europe inhabits good environment for everyday usage of solar energy to supply a car. Its prototypes expose several advantages over traditional cars, such as lower cost of maintenance due to the usage of electric motors as well as an elimination of harmful substances emission, produced by a traditional engine.
- Solar-powered car can be self-sufficient, as may be supplied only by the energy of the Sun. However, the range of these cars is more limited than in the case of traditional ones. Adjusted models can use fast-charging points for electric cars, which are constantly being developed and increase in number around Europe.
- Sun is an unlimited charger for these types of cars, however, time required for this process can disrupt the comfort of traveling.
- Although cost of the production currently is a disadvantage for this technology, there are many projects for different means of transportation where solar energy is successfully implemented and will be researched further.

The topic of solar energy implementation in transportation should be further examined and considered as one of the most recommended solutions for the future of the industry.

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