TRAFFIC LIGHT SIGNALIZATION BASED ON RENEWABLE ENERGY SOURCES: FEASIBILITY AND CHALLENGES

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Abstract: *On the path to carbon neutrality, the leaders of the European Union have agreed to cut greenhouse gas emissions by at least 55% by 2030. The Republic of Serbia and Bosnia and Herzegovina are following the same path and plan to increase the share of renewable energy sources to at least 40% by 2040. During our research as part of the project "Application of Systems Based on Renewable Energy Sources in the Area of AP Vojvodina and the Republic of Srpska" (2022-2023), funded by AP Vojvodina, we concluded that the availability of solar powered traffic light signalization is very scarce in the territory of Serbia and the Republic of Srpska. In our research, we used an ad-hoc questionnaire and personal interviews to collect data from representatives of all municipalities in the Republic of Srpska as well as from representatives of the City of Novi Sad. The results of this research, in addition to the overview of the current situation, will provide the basis for understanding the challenges and potential issues of the substitution of conventional traffic light signalization with signalization based on renewable energy sources on a national scale.*

Key words: Renewable energy, Carbon-neutral, Solar energy, Traffic signalization, Green energy

1. INTRODUCTION

According to the 2030 Climate Target Plan, the European Union set a path to achieve climate neutrality by 2050, while stimulating the creation of green jobs and continuing the EU's track record of cutting greenhouse gas emissions. This plan is in line with the Paris Agreement objective to keep the global temperature increase well below 2°C and pursue efforts to keep it at 1.5°C (European Commission, 2023). The Green Plan states that "No person and no place is left behind", which means that the proposal includes mechanisms for fair transition that should facilitate transition to regions that depend on thermal power plants and coal mines.

Serbia and Bosnia and Herzegovina have also committed to achieving carbon neutrality by 2050 and to aligning with the European Green Deal's key elements by endorsing the Green Agenda for the Western Balkans at the Summit in Sofia in 2020 (Regional Cooperation Council, 2023). The European Green Deal covers all sectors of the economy, from biodiversity to energy and from transport to construction. It includes key policies and measures such as the Farm to Fork Strategy and the New Circular Economy Action Plan.

In March 2021, the Government of Serbia adopted a law on climate change that set a legal framework for future action on reducing greenhouse emissions. Additionally, in April 2021, Serbia adopted a package of important energy laws, including new laws on renewables and energy efficiency and set strategies for the transformation of its energy sector. One of the main targets of this strategy is to increase the share of renewable energy sources to at least 49.6% by 2040, compared to 26.3% at the end of 2020 (Chamber of Commerce and Industry of Serbia, 2023). Bosnia and Herzegovina have significant renewable energy potential, particularly in hydropower, solar and wind power capacity. Hydropower provided 37 percent of the country's total electricity production in 2021 and there is room for additional growth. Recently, solar and wind power plants have emerged but remain a small percentage of the overall energy mix at about 5 percent (International Trade Administration, 2022). The main issue with further migration from the current main energy source, coal, is the lack of initiative from the already established coal industry and outdated legislation that is not in line with the energy sector trends (Miljevic et al, 2020).

There are many challenges when switching to renewable energy sources, as there is an issue with their availability. Renewables, such as solar power and wind power, are available in sufficient supply during

certain seasons or times of day, and in certain regions. Therefore, battery storage system or connection to the grid must be deployed. Determining an appropriate diversification of renewables that can enable uninterrupted energy supplies and satisfy various requirements, such as budgets and national regulations, is a great challenge for all governments (Nguyen et al, 2021; Mulugetta et al, 2022). When defining the spatial allocation of wind turbines and photovoltaic power plants, environmental impacts and disturbance to humans must be taken into consideration (Drechsler et al, 2017). This is also the case when using hydropower, as it can affect aquatic ecosystems and increase cross-sectoral water conflicts (Gonzalez et al, 2023). In order to maximize the benefits of hybrid wind/solar solutions and provide energy stability, it is important to strongly promote regional cooperation (Liu et al, 2020).

Traffic light systems are universally and widely used signalling devices for traffic regulation around the world. They have undergone many changes since they were first introduced in the nineteenth century. However, there are many aspects of its functionality that can be improved and aligned with the progress of both the information technology and energy sectors. There is significant research centred around increasing the energy efficiency of traffic light systems by switching to renewable energy sources and light-emitting diodes (LEDs). Widespread replacement of incandescent bulbs with LED lamps has been conducted in most regions, but they are still mostly powered by a high-voltage power supply (Diong, 2014). Recent developments have the goal of reducing costs and improving the energy efficiency of traffic light systems by providing a low voltage power supply, usually while relying on renewable energy sources and a backup battery storage system. Proposed solutions (Costa et al, 2010; Jeon et al, 2015; Saji et al, 2019) validate the energy efficiency of such systems, while (Diong, 2014) and (Chiradeja et al, 2020) verify their economic feasibility.

This paper presents the results of the research conducted as part of the project “Application of Systems based on Renewable Energy Sources in the Area of AP Vojvodina and the Republic of Srpska” (2022-2023), funded by AP Vojvodina. Solar panels have been chosen as a renewable power source due to their price decrease and increasing lifespan. Considering the questionnaire results and interviews with transportation sector representatives, current setbacks and challenges have been analysed. The results of this research can be used to broaden understanding of the potential issues and challenges that can emerge when solar powered traffic light systems are implemented.

2. MATERIALS AND METHODS

Our research has been conducted in Serbia and Bosnia and Herzegovina, during 2022 and 2023. We used an ad-hoc questionnaire and personal interviews to collect information from representatives of all municipalities in the Republic of Srpska and from representatives of the City of Novi Sad. The questionnaire required information about the current state of traffic light systems in the municipality, the availability of solar powered traffic lights, availability of other solar powered traffic signalization and whether there are any funds allocated for their implementation in the future.

In the City of Novi Sad, the largest municipality and the capital of the Autonomous Province of Vojvodina, we also carried out personal interviews with the supervisors, engineers and the Head of Department for the Development and Traffic Management for the City of Novi Sad. In the interview, we gathered information about challenges that could arise if traditional traffic lights were replaced with solar powered traffic lights.

3. RESULTS AND DISCUSSION

Based on the data received through the questionnaire that has been answered by the officials for the development and traffic management of the City of Novi Sad, there are no solar powered traffic lights on the territory of the City of Novi Sad and no resources are allocated for their future implementation. However, there are a dozen solar-powered road traffic counters and solar-powered flashing traffic signs (Figure 1).

Figure 1: Solar-powered flashing traffic signs

Current state is similar for all fifty analysed municipalities of the Republic of Srpska, where there are no traffic light systems powered by solar panels. However, there are 55 solar-powered road traffic counters and 10 solar-powered flashing traffic signs. Same as in the City of Novi Sad, there are no resources allocated for the future substitution of conventional traffic lights with solar powered traffic lights.
When discussing potential issues that could emerge if solar panels replaced conventional power sources for traffic light systems, the traffic sector representatives pointed out that the priority of traffic lights is to enable safe and reliable traffic flow. Their uninterrupted functionality must not be hindered under any circumstance, which can be a potential problem if solar panels are used as the main power source. Despite the favourable photovoltaic potential of the region, the number of sunshine hours and photovoltaic power output is not uniform across the whole year (Figure 2). Therefore, a solar panel on its own cannot always generate a sufficient amount of electricity. This issue can be solved by using a battery storage system and connection to the grid, but their integration into the system introduces new issues. With several power supplies, it is more difficult to supervise the system and ensure that a continuous power supply is available at all times. In case of damage to the solar panel or the battery, the system would have to immediately switch to the grid.

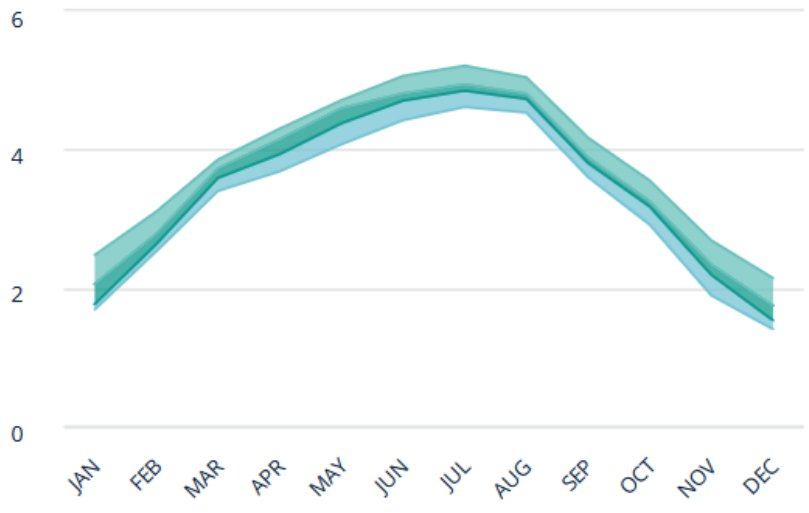

Figure 2: Monthly variation of photovoltaic power output (ESMAP, 2020)

Regular maintenance of such systems would be problematic due to several reasons. The first is their location. Solar panels require regular cleaning, which can interrupt traffic. Repair of solar panels would cause an even greater disturbance to the traffic, as in this case the equipment would have to be approached with a crane or similar vehicle that can block an intersection. The second issue is a lack of trained manpower that can handle the maintenance of traffic light systems, which would be even more persistent if solar powered traffic lights would be introduced. Lastly, the manufacturers of solar panels require that the equipment is maintained through the official manufacturing channels, but this service only includes regular maintenance and could not provide enough support for emergency repairs and replacements needed for normal functionality of traffic light systems.
The officials also pointed out the issue of installing the equipment in such way and position that does not interfere with traffic. If the solar panel would be the main source of electricity for these systems, it would be important to position them in such a way that they do not block the signalization or distract the traffic participants. The battery must also be properly stored, which can take up a lot of space. However, the storing container must be according to the standards, as the batteries are sensitive to low temperatures and their capacity could be greatly diminished if they are not well protected. The battery containers of the currently installed solar powered traffic signalization, with their large cases (Figure 3), have protected the batteries well from harsh temperatures. However, when scaling this battery to a more demanding traffic light intersection, this case could be too cumbersome and would take too much space.

Figure 3: Solar powered traffic sign battery case

An additional issue that is aggravated with the introduction of solar powered traffic systems is the cost of each piece of equipment in the system, which leads to a high price for their replacement. Apart from regular replacement due to equipment malfunction or exceeding the equipment lifespan, there is also the case of vandalism. Comparing to the conventional traffic lights, solar powered traffic lights' components are frailer and thus easier to damage.

4. CONCLUSION

In our research we analysed the current state of traffic light systems in the territory of the Republic of Srpska and the City of Novi Sad, as well as potential issues that could arise if solar powered traffic lights were introduced. As the availability of solar-powered traffic signalization is very limited in these regions, there is a lot of room for improvement in this area, which is in line with the European carbon neutral future. According to our research and available research results in the rest of the world, the transition to solar powered traffic lights has both environmental and economic benefits. Our region, with its continental climate that has no extreme high or low temperature, but also a sufficient number of sunshine hours and wind, is suitable for the widespread implementation of renewable energy power sources.

Currently, there are many challenges that are recognized by transportation sector officials and experts, but renewable energy technology and its availability on a global level are improving each day. Using information about all issues and challenges presented in this research paper, local communities should make an effort to overcome the initial barrier and convey the transition to renewable energy powered traffic systems. It is possible to introduce such traffic systems gradually, which would put less strain on municipal budgets and organization. Also, this would give more time to retrain current workers and hire new ones to operate solar-powered equipment, which would increase employment. Future research can be directed toward determining the exact financial benefits and greenhouse gas emission reduction when all traffic light systems use solar panels as their primary power source. Also, appropriate diversification of renewables by each region could be determined to expand the renewable energy source to wind and potentially hydropower.

5. ACKNOWLEDGMENTS

This research was funded by Provincial Secretariat for Higher Education and Scientific Research, Autonomous Province of Vojvodina (142- 451-277/2022-01/1)

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