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INDEPENDENT ELECTRICITY SUPPLY SYSTEMS FOR TOURISM IN HARD-ACCESSIBLE AREAS IN THE FUNCTION OF SUSTAINABLE SPATIAL PLANNING

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Abstract:

Ecotourism is becoming dominant, especially after global disturbances such as the pandemic. In addition to the health segment, it must include the cognitive and educational segments, so attractions are an important element in creating eco-products in tourism. Whether they are natural or artificial attractions, they are often located in hard-to-reach areas and their function cannot be maximally valorized without basic infrastructure. The development and implementation of a system for the production of electricity from unlimited solar energy are important for the development of sustainable tourism. The paper aims to point out the importance of setting up independent electricity supply systems, including off-grid and hybrid setups, and to offer practical solutions for achieving energy self-sufficiency. Hybrid power systems (HPS) are especially important to rationalize costs. Fully autonomous power systems in inaccessible areas where access to the public network is difficult or completely disabled are crucial.

Key Words: *independent supply systems, attractions, eco-tourism, spatial planning*
JEL classification: *Z32, O20*

Introduction

Spatial planning is a crucial tool for establishing long-term, sustainable frameworks for social, spatial, and economic development at the national,

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regional, and local levels. Spatial planning is defined as „methods used largely by the public sector to influence the future distribution of activities in space“ (European Commission, 1997, p. 24), and is supplemented to „ coordinate the spatial impact on other sectoral policies, to achieve a more even distribution of economic development between regions than would otherwise be created by market forces, and to regulate the conversion of land and property uses“ (European Commission, 1997, p. 24). Its main role is to ensure the integration of various sectors (such as housing, transportation, energy, tourism, etc.) and enhance national and local systems of urban and rural development, taking into account environmental issues (Economic Commission for Europe, 2008). Spatial planning in tourism is a purposeful, scientifically grounded, and continuous societal activity that seeks the effective and optimal direction of the spatial arrangement of appropriate structures in which tourist traffic will occur in the best possible way within a specific area (Stanković, 2008). Planning the spatial structure must align with the requirements for achieving positive economic effects as an element of tourism policy. The role of spatial planning in tourism, among other things, is to fulfill three basic tasks: space organization, space arrangement, and space equipment. These elements impact the tourist valorization of space, the selection of locations for suitable purposes, and provide a detailed insight into existing and potential demand in the domestic and international tourism market. This also influences the choice and placement of certain forms of tourist accommodation and hospitality facilities while respecting the principles of environmental preservation and the green transition of the tourism sector.

Tourism development in a destination is conditioned by several factors, primarily the tourist's geographical location, followed by natural and cultural factors, as well as economic and sociological factors. Preserved natural resources are the basis for the development of eco-tourism, adventure, mountain, rural tourism, and water sports, as well as wine tourism, spa, and cultural tourism. Tourism development strategies precisely sculpt these forms of tourism as the main potentials for the development of sustainable forms of tourism and sustainable development in general (Ministry of Trade and Tourism of the Republic of Srpska, 2021). Providing energy for tourism in remote regions presents unique challenges that demand innovative solutions. Independent electricity supply systems, in tandem with sustainable spatial planning, play a vital role in meeting these challenges and fostering responsible tourism development. Tourist destinations in isolated regions often face

difficulties in securing reliable access to traditional power grids, necessitating exploration into alternative energy solutions. By utilizing renewable sources like solar, wind, and hydroelectric power, these systems ensure a sustainable approach to electricity generation. Implementing independent electricity supply systems aligns seamlessly with sustainable spatial planning principles. Through the use of renewable energy sources, these systems contribute to a reduction in carbon emissions, minimize ecological impact, and play a crucial role in overall conservation efforts.

The perceived problem is that these attractions, whether they are natural wonders or human-made landmarks, are frequently situated in hard-to-reach areas, requiring basic infrastructure for their optimal utilization. One of the aspects of solving this problem when advancing sustainable tourism is the development and implementation of solar energy systems for electricity production. The paper subjectspoint out the increase in demand for ecotourism, particularly in the wake of global disruptions like the pandemic, emphasizing the need for a comprehensive approach that goes beyond health considerations. In areas where accessibility to the public power grid is challenging or non-existent, fully autonomous power systems become crucial. The paper aims to point out the importance of setting up independent electricity supply systems, including off-grid and hybrid setups, and to offer practical solutions for achieving energy self-sufficiency. Given their unlimited and environmentally friendly nature, solar energy systems contribute significantly to reducing the ecological footprint of tourist attractions. HPS combining solar with other renewable sources or conventional power, play a pivotal role in cost rationalization, ensuring efficiency and reliability in energy production. These systems, powered by renewable sources like solar energy, provide a sustainable solution to meet the energy demands of remote tourist attractions.

Harmony of nature and energy

The allure of natural landscapes has long been a driving force behind tourist movements, with nature serving as a primary attraction and motivating factor for travelers seeking authentic and rejuvenating experiences. Within the realm of tourism, a significant subset that has gained prominence is ecotourism. The aesthetic appeal of natural landscapes plays a pivotal role in attracting tourists. In an era dominated by urbanization and technological advancements, the desire to escape the hustle and bustle of city life is a powerful motivator for tourists.

Ecotourism destinations, often situated in remote and pristine locations, provide an ideal setting for escape to natural environments, fostering a sense of peace and harmony. The increasing global awareness of environmental issues has led to a growing preference for sustainable and responsible travel practices. Ecotourism aligns with this trend, as it emphasizes minimizing the ecological footprint of tourism activities and contributing to the well-being of local communities. Nature serves as a compelling attraction and motivation for tourist movement, particularly within the realm of ecotourism. Understanding these motivations is crucial for destination managers and policymakers to develop strategies that not only attract tourists but also ensure the long-term preservation of the natural environments that draw them. By the beginning of the 21st century, it became more than clear that the functioning of economic systems depends on the functioning of the natural system in which it operates. The impact of the economic system is more dominant compared to the natural system, and its growth determines the dynamics of both. In the early days of human civilization, people were concerned about protecting themselves from the elements, whereas today, the concern is about protecting areas where nature still prevails (Ljешević, 2010). According to Ciglič and Perko (2013), „areas characterized by landscape diversity may have an advantage when it comes to economic growth, especially tourism“ (p. 119). It is undisputed that the natural and anthropogenic potentials of tourist destinations represent a crucial component of their resource base. Preserving natural potentials and making them accessible to tourists in protected areas are of great importance for the development of tourism. Tourism has a significant impact on the natural and built environment, leading to conflicts, especially between nature conservation and tourism development, particularly in cases of construction booms in inaccessible natural areas lacking development plans and where tourism is unregulated (Špulerova et al., 2016).

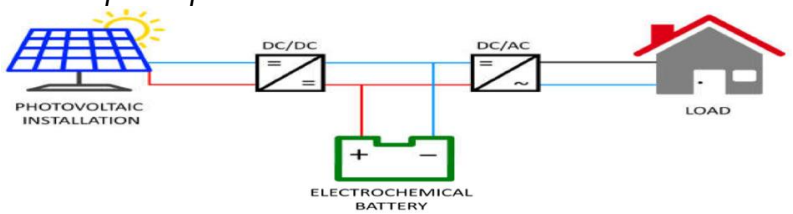
As a consequence of the high increase in the installed capacity of grid-connected PV plants in recent years, it is quite difficult to plan the growing amount of energy from renewable sources fed into the grid, which is up to now non-programmable. This factor cannot be ignored any longer in the management and control of the load in the transmission network and distribution (Ogliari et al., 2013). The development of fully autonomous power systems in such areas not only ensures a reliable and uninterrupted energy supply but also reduces dependence on external resources. This autonomy is crucial for preserving the pristine nature of

these destinations, preventing the negative environmental effects associated with extensive infrastructure development. The combination of renewable energy systems, HP solutions, and advanced technologies for lighting control represents a holistic approach to fostering sustainable tourism. As ecotourism continues to thrive, embracing innovative energy solutions will be essential for preserving the natural and cultural richness of hard-to-access areas.

Harnessing solar panels for independent power supply systems

The utilization of solar panels (SPs) as a primary source of energy has gained significant traction in recent years, particularly in the context of creating independent power supply systems. This approach, driven by the desire for sustainability and energy autonomy, is being increasingly adopted across various sectors.

Figure 1: *Illustrative diagram of the independent power generation system considered, consisting of a photovoltaic installation and energy storage in the form of electrochemical batteries*



Source: *Mielcarek et al. (2023)*

Community and Economic Development

Beyond powering tourist attractions, SPs support local communities by providing electricity for basic needs. This dual functionality fosters community development, aligning with broader sustainability goals and positively impacting the socio-economic landscape. Solar power systems (SPS) significantly reduce carbon emissions compared to conventional energy sources. By harnessing the sun's energy, these systems contribute to mitigating climate change and preserving the environmental integrity of the areas they serve. The cost-effectiveness and low maintenance aspects of SPS contribute significantly to their appeal and widespread adoption. While the initial installation costs of SP may seem substantial, it's crucial to view this as a long-term investment. Over the lifespan of SPs, which typically ranges from 25 to 30 years or more (Glover & Tynan, 2023), the cost per unit of electricity generated becomes

significantly lower compared to conventional energy sources. This long-term perspective makes SPS economically advantageous. Solar panels have relatively low operational and maintenance costs once they are installed. Routine maintenance primarily involves cleaning the panels to ensure optimal sunlight absorption and occasional checks on the system's electrical components. These factors contribute to lower ongoing operational expenditures. Ongoing advancements in solar technology contribute to increased efficiency and reduced maintenance requirements. Innovations in panel durability, weather resistance, and self-cleaning technologies further minimize the need for manual interventions, ensuring that SPS remain reliable and cost-effective over time. Many governments and local authorities offer incentives and subsidies to encourage the adoption of solar power. These financial support mechanisms can significantly offset the initial investment, making solar installations more accessible and attractive for businesses, communities, and individuals. This resilience contributes to the long-term cost-effectiveness of SPS. By establishing independent SPS, businesses and communities can reduce their dependence on centralized power grids. This not only enhances energy resilience but also mitigates the impact of grid-related power outages or fluctuations, further underlining the cost-effectiveness of solar solutions. When conducting a comprehensive lifecycle analysis, taking into account manufacturing, installation, operation, and decommissioning, SP consistently demonstrates a favorable environmental and economic profile.

Solar Photovoltaic Panels, Characteristics and Applications

Tourist attractions in hard-to-access areas serve as essential elements in creating eco-products that not only entertain but also educate and raise awareness about environmental conservation. The integration of solar energy systems not only addresses the energy needs of these remote attractions but also exemplifies a commitment to renewable energy practices. By minimizing reliance on non-renewable resources, such systems contribute to the overall resilience of tourist destinations, especially in areas where the traditional power grid is impractical or unavailable. In addition to powering attractions, these solar energy systems can support local communities by providing electricity for basic amenities, fostering a more sustainable and inclusive approach to tourism development. The positive socio-economic impact further solidifies the case for investing in renewable energy infrastructure in hard-to-reach areas. To dispel preconceived notions about the complexity of introducing these systems, it is necessary to briefly refer to their technical

specifications, characteristics, and applications. SPs have the added benefit of minimal ongoing operating expenses, making it feasible financially for small and medium-sized tourism businesses.Looking ahead, improvements in solar technology will further reduce adoption hurdles and make it available to a wider spectrum of ecotourism operators. Solar photovoltaic (PV) modules, also known as solar electric panels, vary in size, cell count, and electrical connectivity, and are influenced by environmental conditions. These panels come in diverse shapes and sizes, constructed from different materials. The most commonly used module is the „glass sandwich," comprising 36 PV cells connected in series to generate sufficient voltage for a 12-volt battery. Modules may have an individual metal frame or be protected with a rubber seal, intended for installation within a larger mounting system designed to accommodate multiple modules. PV panels produce direct current (DC) electricity, akin to the power generated by a car battery or other rechargeable batteries. This contrasts with the alternating current (AC) used in household appliances. To power typical household appliances using solar energy, a solar inverter is necessary to convert DC to AC. Small battery charging systems or powering small electronic devices (like mobile phones and personal music devices) may not require an inverter but necessitate proper adapters and, if needed, voltage converters or limiters. High-efficiency solar cells ensure high performance of the 12V solar panel and generate more energy in peak hours. Here we list the basic components for a residential off-grid system that is widely used in marinas, dry camping, garden watering, and other off-grid applications. They are designed to maintain 12-volt batteries in recreational vehicles, cabins, boats, battery doors, backup power, and remote power use. They are resistant to strong wind (2400pa) and snow load (5400pa). Class A solar cells ensure all SPs have a positive power tolerance.

Voltage and Solar Panels

PV modules have three different voltage values that are important to understand (Li, 2021, p. 1). Nominal Voltage: Also known as „conversion voltage," this nominal voltage refers to the battery voltage that the module is best suited to charge. It is a historical term originating from the days when SP were primarily used for battery charging. The actual output voltage varies with light and temperature conditions), 2. Maximum Power Voltage (Vmp): This is the highest voltage a panel can produce when connected to a system for peak efficiency, and 3. Open Circuit Voltage (Voc): The maximum voltage a panel can produce when not connected to

an electrical circuit or system. Voc can be measured directly using a meter connected to the panel terminals or the ends of built-in cables.

Location and Orientation of Solar Arrays

The location of PV panels is critical for energy production. Panels installed in locations closer to the equator receive more sunlight throughout the year than those further north or south. South-facing exposure yields optimal results, capturing maximum exposure as the sun moves from east to west. Adjustments should be made for magnetic declination when determining the south direction using a compass. The array's tilt also affects output, with an angle equal to your geographic latitude providing the best production throughout the year. Adjustments, such as a tilt angle equal to your latitude minus 15 degrees for summer production and 15 degrees for winter, can further optimize output in different seasons.

Power independence of individual facilities

What enables the independent and continuous supply of individual guest accommodation units today are high-quality and cost-effective batteries in which the generated electrical energy is stored. As an example for this study, we mention Absorbent Glass Mats, Deep Cycle batteries with a low self-discharge rate (2% per month), and a warranty period ranging from 5 to 10 years, depending on the type of battery and usage. They are among the most efficient and cost-effective battery types available. AGM technology allows the battery to be mounted in any position without the risk of leakage.

Table 1: *Characteristics of the listed batteries by model*

Model	Voltage	C100*4 Ahr	C10*5 Ahr	CCA / 20°C	Lenght (mm)	Width (mm)	Height (mm)	Height above (mm)
C12V71	12V	71	55	250	229	138	208	227
C12V104	12V	104	80	400	350	167	179	184
C12V104 D	12V	104	80	400	260	169	210	220
C12V130	12V	130	100	500	328	171	214	229

[4] C100 = total amp hours you can draw from the battery over a 100 hour period (deep cycle, using a home battery)

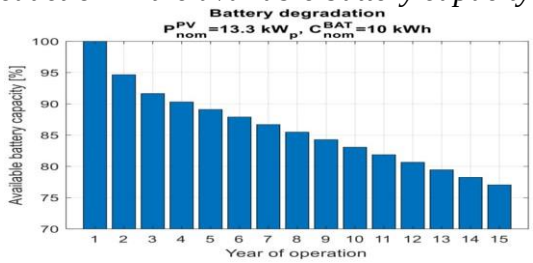
[5] C10 = total amp hours you can draw from the battery over a 10 hour period (initial battery usage)

C12V156	12V	156	120	600	407	174	231	233
C12V195	12V	195	150	750	485	172	242	247
C12V260	12V	260	200	1000	520	238	218	233
C12V325	12V	325	250	1250	520	268	220	235

Source: *AA Solar, 2024*

The batteries emit extremely low corrosive gas with lower self-discharge rates than other comparable batteries. These batteries last three to five times longer than lead acid batteries. The economic benefits for the user are reduced fuel consumption of the generator, shorter operating time of the generator as well as greater efficiency of the solar investment. Modern batteries are designed and manufactured to provide the longest possible lifespan. In float applications (such as backup power supplies) NP series batteries (6 and 12 volts) will achieve a service life of 3 to 5 years. The expected lifetime is based on 20% capacity loss and 80% remaining capacity at the end of a stated lifetime. After 15 years of operation, the available capacity drops to approximately 78% of the initial capacity. A battery exhibiting such progressive degradation over the years of operation requires replacement.

Figure 2: *Illustrates the progressive degradation of the battery over time, expressed as a reduction in the available battery capacity.*



Source: *Mielcarek et al. (2023)*

Conclusion

The growing prominence of ecotourism, particularly in the aftermath of global disruptions like the pandemic, underscores the need for a comprehensive approach that encompasses not only health aspects but also energy dimensions. It was pointed out in the paper that solar photovoltaic panels help to significantly preserve the environment and, at the same time, significantly reduce electricity costs. In addition, solar energy is clean, and does not release pollutants during use. The advantage of solar systems is that they can fit into the surrounding natural landscape,

protecting the aesthetic integrity of ecotourism destinations. A higher level of energy independence is also made possible by the flexibility and adaptability of the SPS, which is particularly beneficial for rural areas that would otherwise be dependent on diesel generators or remote power lines. Often situated in remote and challenging terrains, these attractions require essential infrastructure for their optimal utilization. The focus on sustainable spatial planning emerges as a key factor in ensuring the harmonious integration of independent electricity supply systems for tourism in hard-to-access areas. Independent systems for electricity production and storage in batteries enable the autonomous operation of accommodation facilities in remote areas, which are becoming increasingly attractive. The emphasis on developing and implementing systems harnessing unlimited solar energy holds significant promise for advancing sustainable tourism practices. Ecotourism, like all other branches of tourism, also rests on the principle of economic sustainability. Building a solar energy system requires certain financial investments, but an increasing number of government subsidies, tax rebates, and other incentives are available to reduce these costs. Over time, SPshavebecome a financially smart investment due to their low operating costs and excellent reliability. In essence, the interplay between independent electricity supply systems, attractions, and spatial planning is a dynamic nexus that holds the potential to redefine the landscape of sustainable tourism. Through this paper, service providers in tourism are introduced to independent power supply systems, with a particular emphasis on the application of photovoltaic panels and batteries. This is aimed at advancing sustainable development and preserving natural attractions. In the future, the role of such systems in creating a sustainable energy ecosystem, reducing harmful gas emissions, and preserving the natural environment will become increasingly important. Independent systems, such as photovoltaic panels and batteries, provide a reliable source of clean energy, directly contributing to reducing dependence on fossil fuels. The significance of spatial planning in achieving sustainability is particularly emphasized. Through effective planning, it is possible to optimize the placement of photovoltaic panels and batteries, considering geographical characteristics and the needs of the local community. This integration of spatial planning is not just a technological requirement but a social imperative, enabling better adaptation of infrastructure to communal needs and promoting common interests in preserving natural resources. Based on the above, it can be concluded that the implementation of independent power supply systems is crucial for a sustainable future, and the role of spatial planning is essential in

achieving a harmonious balance between technological progress and environmental protection. This approach provides a lasting solution that supports economic, ecological, and social sustainability, taking a step towards sustainable development and responsible tourism.

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