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ГОДИШЕН ЗБОРНИК НА ФАКУЛТЕТ ЗА ТУРИЗАМ И БИЗНИС ЛОГИСТИКА

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ГОДИНА 1

VOLUME I

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SUSTAINABILITY IN HOTEL INDUSTRY: THE ROLE OF ROOFTOP PV PLANTS

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Abstract

Rooftop photovoltaic (PV) power plants, which have grown in popularity in recent years, might soon generate over 25% of Europe's renewable energy. They might substantially contribute to sustainable electricity generation on small family structures, as well as medium and large-scale commercial buildings, due to several advantageous preconditions. This study looks at the feasibility of installing and operating a middle-scale rooftop PV power plant at a small-scale private hotel in Skopje, the capital city of North Macedonia. Using available solar irradiation statistics at the location, market pricing for the equipment, and valid power rates, a brief techno-economic analysis was conducted. The results are further used to investigate several features of rooftop PVs. Moreover, the research aims to present the potential and advantages of installing small rooftop PVs in terms of investment cost, securing steady energy supplies, and reducing the hotel industry's and tourism's overall environmental imprint. The findings demonstrate that rooftop PV power plants should not be considered as a passing fad, but rather as a realistic future trend when it comes to sustainable energy generation.

Key words: Tourism; Green hotels; Photovoltaics; Energy; Operating costs; Environment.

1. Introduction

As common conventional energy supplies, particularly fossil-based fuels such as coal, oil, and natural gas, became increasingly depleted, the focus of energy generation changed to various so-called alternative or renewable energy sources. The phrase "alternative energy sources" has practically become outdated, since more and more these energy sources are making a substantial contribution to the global energy portfolio daily. As a result, renewable energy sources including wind, sun, and marine energy, among others, have become inescapable energy sources [8, 9, 15].

Any energy used on Earth has a direct or indirect connection to the Sun, which is the planet's only source of energy and a giant energy-packed star that gives it life. Hopefully, we as humans have figured out how to harness this energy and adapt it to our daily requirements. The electromagnetic induction, discovered in 1831 by English physicist Michael Faraday, and the photovoltaic effect, discovered in 1839 by French physicist Edmond Becquerel, are the two main ways for generating electric energy. With the development of commercially accessible semiconductor materials in the second part of the twentieth century, practical and commercial uses of the photovoltaic effect in energy generation became possible. The use of the photovoltaic (PV) effect for electricity generation using so-called photovoltaics (PVs) has become a popular and appealing method for electric power generation [5, 11].

PVs, often known as solar cells, are one of the cleanest, most broadly applicable, and promising renewable energy generating technologies that use unlimited sunlight as a raw energy source [9]. PVs represent the direct conversion of sunlight energy, i.e. the energy of the photons emitted by the Sun, into electrical energy without any other energy transformation from a physical standpoint. They are designed to be tough, simple and require very little maintenance [11]. Opposite to any fossil-based fuel, PVs do not emit CO_2 or other pollutants, and so have no negative impact on human health or the environment.

The authors of this study examined certain aspects related to the use of PVs in so-called rooftop facilities. They are small and medium-sized electric power plants that employ PVs located on the rooftops of existing industrial and/or commercial buildings, hence the term “rooftop PVs”. They became particularly appealing after 1990, when two major state-sponsored programs, the German "100,000 Solar Roofs" program in 1990 and the Japanese "70,000 Solar Roofs" program in 1994, were implemented. Both initiatives resulted in massive commercial PV output, and they were quickly followed by similar schemes in other nations across the world [4].

Rooftop PVs provide several benefits, including: (i) It does not necessitate the buying or leasing of extra space; (ii) They make use of roof space that could not be used for any other commercial use; (iii) They can be swiftly set up and put into operation with low operational costs and a long operational life; (iv) They are flexible, nearly maintenance-free, and readily link and function in parallel with existing power grids, etc.

This study explores the potentials of employing rooftop PVs for electric power production in the hotel business, bearing in mind that the tourism industry, particularly the hotel industry, is and rapidly becomes a very energy-demanding consumer [1]. Furthermore, the research contributes to the literature by suggesting that installing a PV power plant in hotels will improve the hotel's environmental friendliness, attracting a greater number of environmentally aware guests [12]. Following the introduction, Section 2 provides a background material on the current and future developments in PV power plants, along with a brief overview on the concept of rooftop PV plants. Section 3 encompasses research data and methodology, while section 4 presents the main results and discussion. Conclusion is noted in the last section.

2. Background Material

2.1. Current and future developments in PV power plants

The photovoltaic phenomena, depicted schematically in Figure 1, serves as the operational foundation for PVs. Thin N-type and P-type silicon films are stacked on top of each other to form the PV cell. The electrons are segregated in the crystal lattice of the silicon atom due to the action of solar energy (photons), and a potential difference emerges at the cell's ends, resulting in an electric voltage. Electric currents might flow through the conductors and the load releasing a given quantity of electricity and power if both ends, positive and negative electrodes, are linked to conductors to which a specific external load is attached.

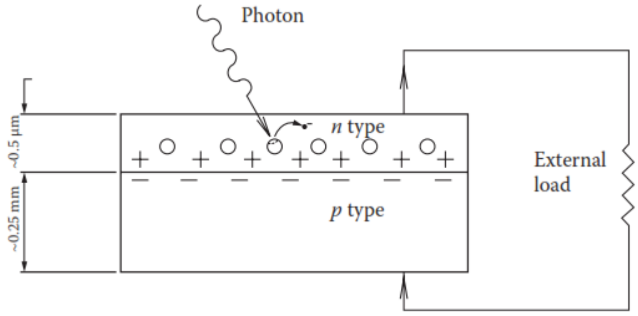

Figure 1. Schematic representation of the photovoltaic effect
Слика 1. Шематски приказ на фотоволтаичен ефект
Source: [6, p. 223]

The quantity of energy created by a single solar cell is very small and has no practical significance. As a result, actual PVs are typically made up of several individual PVs that are linked in parallel and/or serial connection to form so-called PV panels. The value of the generated power may vary depending on the number of individual PV cells and the manner of their connections, for example, current PV panels typically have a nominal output power of 250-400 W. Even if this amount of electricity is insufficient for commercial use in any home or business structure, more PV panel assembly is required. Today, commercially accessible PV generators can range from 1-10 kWs, even MWs, depending on the user's demands. Their installed capacity is only determined by the amount of space available for installation, the demand of users, and, in the case of grid-connected facilities, the quantity of energy that can be easily absorbed by the existing electrical system.

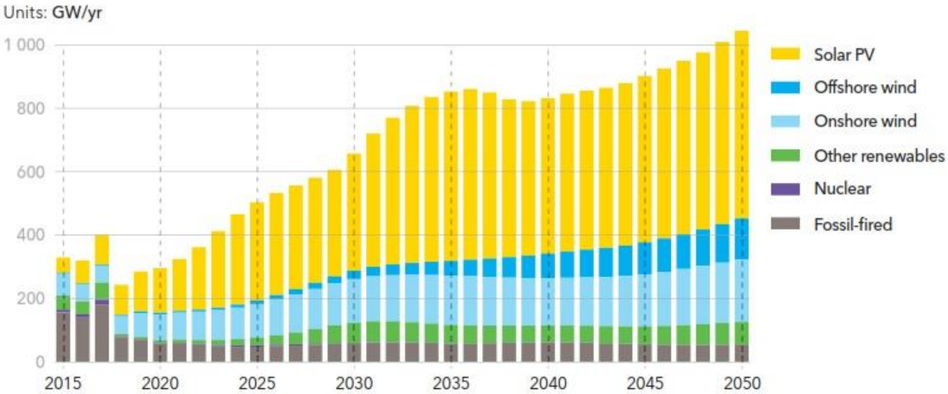

Figure 2. Electricity generation capacity in the world by power station type
Слика 2. Капацитет за производство на електрична енергија во светот по тип на електрани
Source: [2, p.156]

According to recent research [3, 4, 6], solar energy usage has a promising future. The demand for new PV energy production facilities might skyrocket, having a major influence on global energy generation (Figure 2) [2].

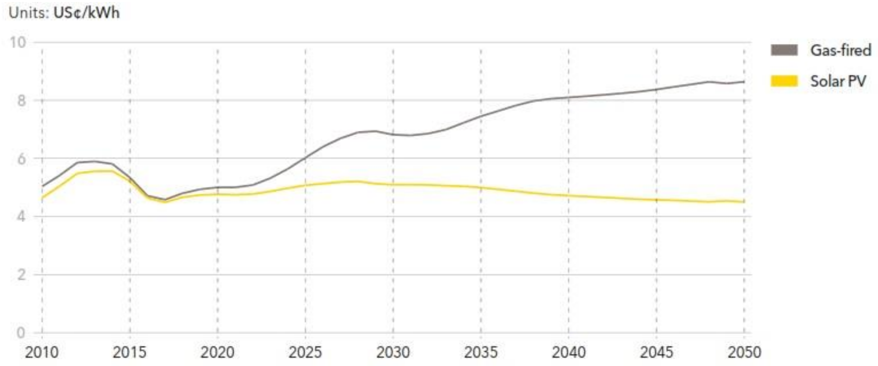

Figure 3. Energy price comparison between solar PV and gas-fired power plants
Слика 3. Споредба во цени помеѓу соларни фотоволтаици и електрани на гас
Source: [2, p. 155]

Furthermore, as shown in Figure 3, another positive assumption is that, as the number of newly installed PV generators grows, the price of generated energy would stay steady and cheap in the long run. As a result, it's clear that solar PV has a lot of potential and might play a big part in the future of electric power generation.

2.2. Rooftop PV plants

PV plants that might be built on the rooftops of existing structures, such as private and/or communal residential buildings, administrative buildings, and/or industrial and commercial buildings, are referred to as rooftop PV plants. They might have varied installation capacities and connections, such as standalone PV plants or grid-connected PV plants, depending on the available space.

In the hotel sector, the installed capacity of a rooftop PV power generator is obviously limited by the amount of available installation space and money that someone is willing to invest in such a facility. Knowing that hotels are either located at sea-side sites as summer resorts or at high-altitude locations as winter ski resorts, one may deduce that both places have a substantial number of sunny days, making them appropriate for PV power generating facilities, particularly rooftop PV generators.

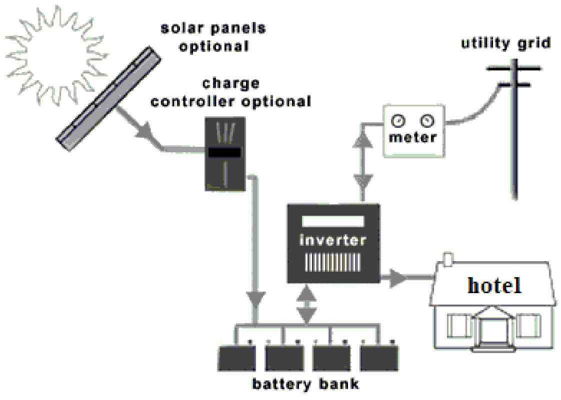

Figure 4. Typical electric connection diagram of a PV generator with the electric grid
Слика 4. Типичен дијаграм за електрично поврзување на фотоволтаичен генератор со електрична мрежа
Source: [10]

With regards to the connection types, virtually all these renewable power generators must be grid-connected, since hotels require a consistent and uninterrupted electricity supply. Thus, when it comes to PV generators, additional attention must be made to ensuring the security of energy supply by utilizing strong and dependable rooftop PV generators. Because PVs can only create energy when there is sunlight, they must be properly built with a steady electrical grid connection and, preferably, extra electric storage facilities such as batteries. Figure 4 depicts the overall configuration of a grid-connected PV generator with a battery system attached.

3. Data and Methodology

A small-scale hotel was explored as a pilot project for the installation of a rooftop PV generator located in Skopje, the capital city of North Macedonia. The hotel, which is highlighted by a white square box on the bird-eye view in Figure 5, is surrounded by tiny buildings and vegetation, indicating that it has a high potential for solar power generation using rooftop PV generator. The hotel features a square form with an interior atrium with 1,000 m^2 of accessible roof space ideal for PV generator installation.

Figure 5. The bird-eye view of the hotel location and its surroundings
Слика 5. Поглед од птичја перспектива на локацијата на хотелот и околината
Source: Google Earth

We need to establish the average seasonal solar irradiation at the hotel site before we can calculate the power potential of this accessible roof area. According to the national map of average solar irradiations [14], North Macedonia has a high solar irradiation coefficient in general, with an annual value between 1,450-1,600 kWh/m2 (Figure 6).

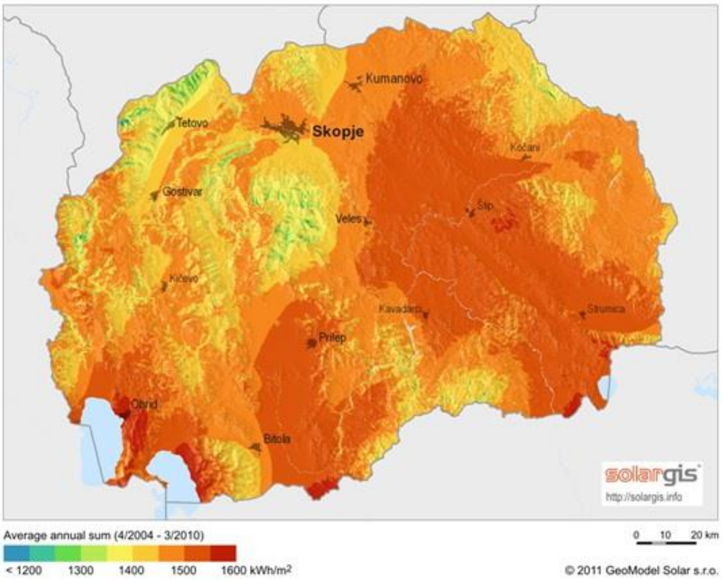

Figure 6. Global solar irradiation for North Macedonia
Слика 6. Глобално сончево зрачење за Северна Македонија
Source: [14]

Additionally, to optimize the generated power at a specific location, some additional and location-dependent parameters must be considered, such as the geographical position of the site in relation to the Sun's movement, daily and seasonal changes in solar declination, local placement of PV panels on the roof, and so on. The best results might be obtained if the PV panels' surface area is aligned perpendicularly to the Sun.

However, depending on the time of day and season, the angle of the sunlight changes continually. When calculating the potential energy generation for the hotel location per m^2 used roof space, we have used the lower value for solar irradiation coefficient of 1,450 kWh/m^2. So, according to [13], the expected electricity generation at our hotel location per month and for the whole year for each available m^2 of the roof area are calculated (Table 1).

Table 1. Calculated potential energy generation at the hotel location per m^2 used roof space

Табела 1. Пресметано производство на потенцијална енергија на локацијата на хотелот по м^2 искористен покривен простор

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Days	31	28	31	30	31	30	31	31	30	31	30	31	365
Electricity production [kWh/m^2]													
Summer (63º)	79.7	91.6	126.2	133.2	157.2	174.3	188.5	177.3	140.4	110.1	72.0	62.0	1,512
Winter (33º)	93.9	99.7	124.6	117.9	128.6	136.5	149.4	151.6	134.4	115.9	81.6	76.3	1,410
Optimal tilt (fixed 48º)	89.3	98.3	128.6	128.4	146.3	159.0	173.0	168.6	140.7	115.9	78.9	71.9	1,499
Optimal tilt (flexible)	93.9	99.7	128.6	133.2	157.2	183.9	188.5	178.3	140.7	116.9	81.6	76.6	1,579

The investor can choose between two installation options:

- First, with three fixed PV panel locations, 63° in summer, 33° in winter, and optimal fixed tilt of 48° for spring and autumn, or
- Second, a variable tilt for each month.

The investor might also request the installation of a special tracking system that would watch the Sun's position online, throughout the day and seasonally, and determine the ideal tilt of PV panels appropriately, always assuring maximum power output. Due to high maintenance costs and the requirement for additional power for its operation, this tracking device would obviously raise the PV generator's investment and operational expenses. The trade-off is a higher amount of generated electricity, which needs to be explored further.

4. Results and Discussion

We recommend using the southern and western parts of the roof as the best PVs installation sites because the entire available rooftop surface could not be utilized. According to [7], 333 solar panels, each with a 300 W installed capacity, could be readily put on a selected portion of the hotel's roof. This may result in a total installed capacity of around 100 kW and an estimated yearly produced power of 150,000 kWh. As a result, the same amount of power may be scraped off the hotel's electrical bill every year. Given that the average power price per kWh for industrial users under the current tariff structure is 0.14 euro/kWh, the total annual electricity bill savings may be calculated at 21,000 euro.

On the other hand, depending on the kind of equipment utilized, the total expenditure for the construction and operation of a rooftop PV generator with a total installed capacity of 100 kW is projected to cost between 100,000-150,000 euro. This estimate provides a pay-back period of 5-7 years, which is appealing given that the project's life expectancy is between 20-25 years. Finally, in terms of environmental advantages, even though this is a small PV generator with an installed capacity of only 100 kW, it has a very low environmental impact, saving roughly 126t of CO_2 emissions each year, or more than 400 trees [7].

5. Conclusion

Using existing rooftops of diverse residential, commercial, or industrial buildings, provides a new front for cheaper solar energy usage through so-called rooftop PV plants. Solar energy harvesting using PVs offers several advantages, including being a free energy source, producing clean energy, being simple to install and maintain, and having a broad application range. The main obstacle, aside from the necessity for a large installation area, might simply be the higher upfront investment cost as compared to other conventional energy sources.

The research investigated a simple solution for using a rooftop PV plant as a grid energy substitute in the hotel business. The study found that the construction of small and/or medium-sized rooftop PVs electric production plants might be useful and could significantly contribute to lowering the operational costs of such hotels due to the good location and many sunny days. Such power plants are more than just a modern trend but should be considered as a substantial and important source of electric power in future.

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