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Original scientific papers

TECHNO-ECONOMIC ANALYSIS AND COST-EFFECTIVENESS OF PHOTOVOLTAIC SYSTEMS FOR RESTAURANTS IN MACEDONIA

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Abstract

Advances in photovoltaic technology have improved efficiency and reduced costs, helping mitigate energy price volatility and fossil fuel dependence. These systems play a critical role in environmental protection by minimizing carbon emissions compared to fossil fuel-based power plants of similar capacity.

This paper presents a techno-economic analysis for the installation of a photovoltaic (PV) system on an average restaurant in Macedonia. The objective is to determine the feasibility of a photovoltaic system for an average restaurant that procures electricity from the open market, with the goal of reducing the energy dependence of restaurants and encouraging investments in PV systems by these commercial entities. Such investments can significantly contribute to increasing domestic electricity production from renewable energy sources while reducing CO_2 emissions. The analysis is based on the electricity consumption of an average restaurant and electricity production from a PV system with a capacity of 40 kWp. By comparing the hourly electricity production from the photovoltaic system, obtained through PV*SOL premium, with the hourly electricity consumption of the restaurant, derived from the standard load curve for restaurants, a techno-economic analysis was conducted in accordance with the forecasted electricity prices taken from the HUDX electricity exchange.

Additionally, annual CO_2 emission reductions were calculated using PV*SOL premium, considering the system's lifetime and factoring in the 1% annual efficiency degradation of PV modules based on manufacturer specifications. Investments in PV systems for restaurants not only enhance energy efficiency and economic feasibility but also contribute significantly to sustainable development and reduced environmental impact.

Keywords: *electricity consumption, electricity production, PV*SOL premium, environmental impact, CO_2 emissions.*

INTRODUCTION

The high electricity prices that overwhelmed energy markets across Europe in 2021 and 2022 caused chaos for both households and the business sector. This situation forced many business owners to shut down their companies as they could not withstand the energy crisis. However, companies that installed photovoltaic (PV) systems on their rooftops for self-consumption at the onset of the crisis proved successful, as they protected themselves from the soaring market prices and managed to remain competitive [1].

On the other hand, the energy transition and the European climate agreement are progressing at a rapid pace. The transition to green energy, a process of shifting from fossil fuels to renewable energy sources such as solar energy, is crucial for limiting global warming to the 1.5 °C target outlined in the 2015 Paris Agreement [1]. Beyond addressing the energy crisis, investments in renewable energy sources, such as photovoltaic systems, significantly contribute to reducing greenhouse gas emissions, combating climate change, and improving air quality, particularly in regions with high pollution levels.

In line with the above, a techno-economic analysis was conducted for the installation of a photovoltaic system with an installed capacity of 40 kW on an average restaurant in Macedonia. The analysis assumes a power purchase agreement (PPA) with a licensed supplier operating on the open market, with the objective of demonstrating the profitability of such investments. By doing so, the analysis aims to encourage further investment in rooftop photovoltaic systems on restaurants in Macedonia, contributing not only to energy independence but also to sustainable development and environmental protection.

MATERIAL AND METHODS

Methodological Approach

For the purposes of the techno-economic analyses, the electricity consumption on both hourly and monthly levels of an average restaurant in Macedonia, with a surface area of approximately 270 m², was first examined. The electricity consumption data for the restaurant was obtained from the owner of a restaurant of this size in Stip on a monthly basis, while the hourly distribution was derived using the standard restaurant load curve available on the EVN Macedonia website.

Subsequently, a simulation of a photovoltaic system with an installed capacity of 40 kW was performed using PV*SOL premium software. This provided a visual representation of the projected photovoltaic system, the hourly electricity generation from the system, and the avoided CO_2 emissions. The calculation of avoided CO_2 emissions was performed using the licensed software PV*SOL premium, which estimates annual CO_2 emissions reduction based on the PV system's energy production and country-specific emission factors. The initial annual energy generation was determined using the software, while the long-term estimation over 25 years accounted for a 1% annual degradation rate of the PV modules, as specified by the manufacturer. The avoided CO_2 emissions for each year were calculated based on the adjusted energy production, and the total emissions reduction over 25 years was obtained by summing the yearly values. This approach ensures a realistic assessment of the environmental benefits while considering the gradual decline in PV system efficiency.

The techno-economic analysis was conducted in Excel using relevant parameters for financial analyses and electricity prices for 2025, 2026, and 2027, taken from the reference electricity exchange in Macedonia – HUDX. Accordingly, the charts and tables presented in this study were developed in Excel, based on the data obtained from the analyses.

Electricity consumption

In order to determine the cost-effectiveness of a photovoltaic system for an average restaurant in Macedonia, it is first necessary to analyze the consumption of electricity in the restaurant. Research has shown that most of the electricity consumed by restaurants is used for cooling and heating, hence the peaks in monthly electricity consumption, as can be seen from the graph in Figure 1, are in the winter and summer months, and in autumn and spring there is a slight decrease in electricity consumption [1]. For this reason, a restaurant with an area of about 270 m^2 with adequate electricity consumption, about 321.91 MWh per year, was taken as a benchmark for an average restaurant.

In North Macedonia, the energy mix is heavily reliant on fossil fuels, with coal being the dominant energy source. More than half of the electricity generated in the country comes from coal-fired power plants, which significantly contributes to greenhouse gas emissions and environmental pollution. Consequently, restaurants and other commercial entities that rely on grid electricity indirectly support this carbon-intensive energy production. This reliance highlights the importance of transitioning to renewable energy sources, such as photovoltaic systems, which not only reduces dependence on grid electricity but also helps mitigate environmental impacts by lowering carbon emissions.

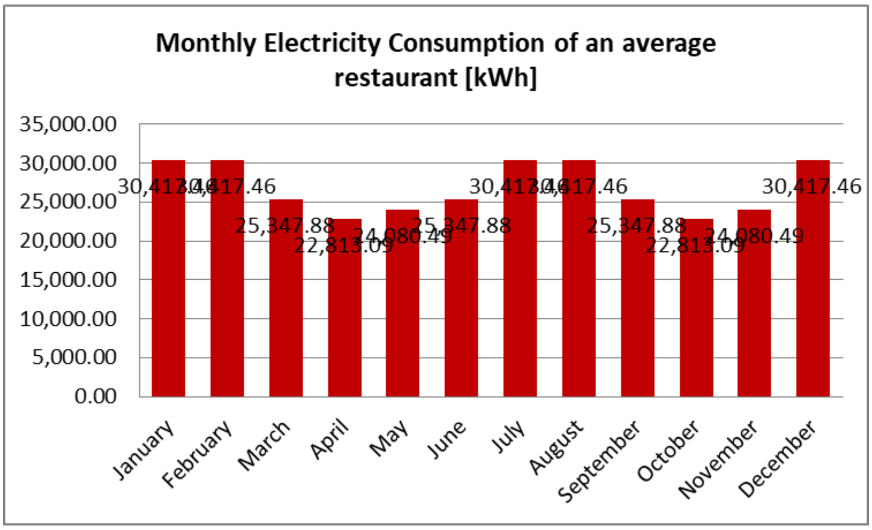

Figure 1. Graphical presentation of the restaurant's monthly electricity consumption

Electricity production

According to the new amendments in the Regulation of Renewable Energy Sources in Macedonia from June 2021, the maximum installed power of a photovoltaic system on a roof for a legal entity that wants to acquire prosumers status is 40 kW. Therefore, in these analyses, a 40 kW photovoltaic system was simulated in the PV*SOL premium software, which resulted in hourly electricity production, a visual presentation of the designed photovoltaic system and avoided CO_2 emissions [2].

The following parameters are obtained from the simulation of the photovoltaic system with an installed power of 40 kW in the PV*SOL premium software:

- Number of PV modules: 86;
- Photovoltaic module peak power: 540 Wp;
- Total installed DC power: 46.44 kWp;
- Number of inverters: 1;
- Total installed AC power: 40 kW;
- DC/AC ratio: 1.161;
- Annual electricity production: 62.62 MWh;
- Avoided CO_2 emissions: 30 t/year.

Figure 2. Visual presentation of the designed photovoltaic system

Table 1. Tabular presentation of the analysis of electricity consumption and production

Month	Monthly Electricity Consumption without 40kW PV System [kWh]	Monthly Electricity Production from 40 kW PV System [kWh]	Monthly Electricity Consumption with 40kW PV System [kWh]	Surplus electricity from the PV System [kWh]
January	30 417.46	2 317.27	28 100.19	0.00
February	30 417.46	3 382.65	27 034.81	0.00
March	25 347.88	5 060.28	20 289.99	2.39
April	22 813.09	6 040.11	16 832.92	59.94
May	24 080.49	7 609.74	16 606.98	136.23
June	25 347.88	8 196.73	17 259.98	108.82
July	30 417.46	8 108.42	22 321.18	12.14
August	30 417.46	7 549.89	22 867.57	0.00
September	25 347.88	5 596.91	19 750.97	0.00
October	22 813.09	4 236.61	18 576.79	0.31
November	24 080.49	2 530.32	21 550.16	0.00
December	30 417.46	1 986.74	28 430.71	0.00
Total	321 918.08	62 615.66	259 622.24	319.83

Table 1 shows the monthly electricity production from the photovoltaic system, then the electricity consumption of the example of our average restaurant, the excess electricity from the photovoltaic system and the electricity consumption that the restaurant will have after installing the photovoltaic system. It can be noted that the electricity production is about 63 MWh on an annual basis and is about 5 times lower than the electricity consumption of the restaurant. According to the hourly analysis, the electricity production from the photovoltaic system will be used completely in the restaurant for almost half of the year, and in the summer months there are also surpluses of electricity that will be delivered to the electricity distribution network and for which an appropriate compensation will be obtained by selling to the universal supplier or on the free market. Figure 3 presents a comparative view of the monthly electricity consumption of the restaurant with and without a photovoltaic (PV) system. The figure clearly shows the reduction in grid electricity consumption after the PV system is installed, which directly contributes to lower electricity bills.

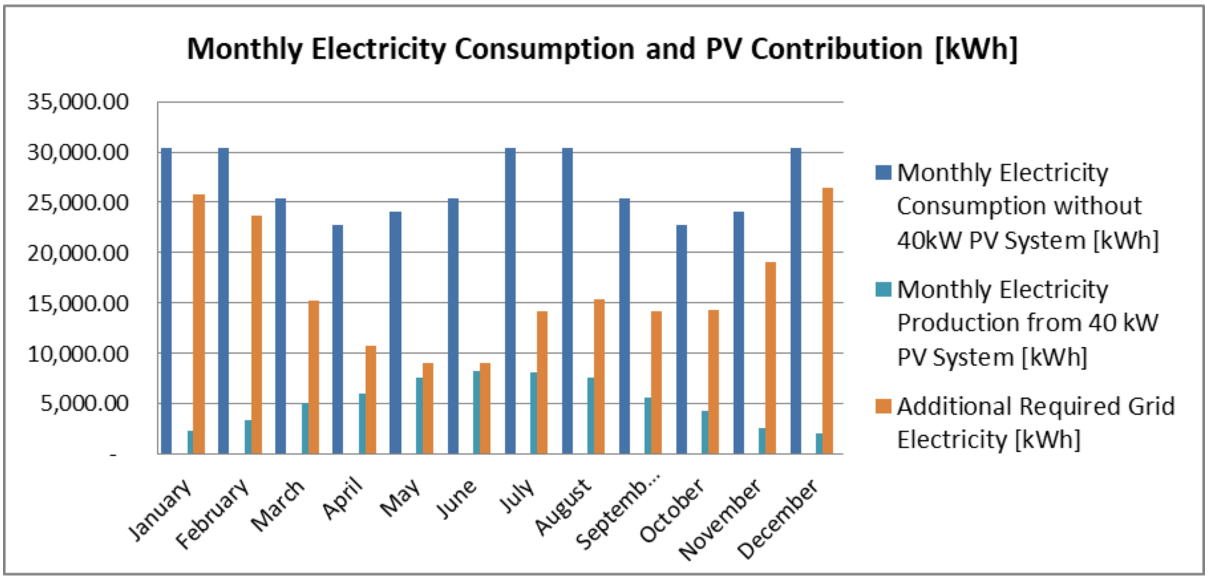

Figure 3. Monthly Electricity Consumption of the restaurant and PV Contribution

The photovoltaic (PV) system analysis conducted in this study includes not only the generation of electrical energy but also an estimation of the avoided CO_2 emissions as a direct environmental benefit. Using the PV*SOL premium simulation software, the system's annual electricity production was modeled, and the corresponding reduction in CO_2 emissions was calculated. Over a 25-year lifespan of the PV system, approximately 666.54 metric tons of CO_2 emissions are expected to be avoided, with an annual reduction of around 30 metric tons in the initial year [3].

To account for the natural degradation of PV panel efficiency, the simulations incorporated a 1% annual decline in electricity generation, which reflects the standard performance degradation rate of photovoltaic modules over time [3,4]. As a result, the yearly avoided CO_2 emissions decrease proportionally to the reduction in electricity production. The detailed data on annual electricity generation and avoided CO_2 emissions are presented in Table 2 of this study. For the first year of operation (2025), the system is estimated to produce 62 615.66 kWh, avoiding 30 000 kg of CO_2 emissions, while in the final year (2049), the production is projected at 49 195.75 kWh, avoiding 23 570.34 kg of CO_2 emissions.

The calculation of avoided CO_2 emissions is based on the carbon intensity of the current energy mix in North Macedonia, where a significant portion of electricity is generated from coal-fired power plants. By replacing grid electricity with clean solar energy, the PV system effectively reduces the reliance on fossil fuels, contributing to the decarbonization of the energy sector.

Table 2. Avoided CO_2 emissions over the entire lifetime of the PV system

Year	Yearly Electricity Production [kWh]	Avoided CO_2 emissions [kg/kWh]
2025	62 616	30 000
2026	61 990	29 700
2027	61 370	29 403
2028	60 756	29 109
2029	60 148	28 818
2030	59 547	28 530
2031	58 951	28 244
2032	58 362	27 962
2033	57 778	27 682
2034	57 200	27 406
2035	56 628	27 131
2036	56 062	26 860
2037	55 502	26 592
2038	54 947	26 326
2039	54 397	26 062
2040	53 853	25 802
2041	53 315	25 544
2042	52 781	25 288
2043	52 254	25 035
2044	51 731	24 785
2045	51 214	24 537
2046	50 702	24 292
2047	50 195	24 049
2048	49 693	23 808
2049	49 196	23 570
Total	1 391 186	666 536

Techno-economic analysis

As mentioned, two techno-economic analyses were made for an average restaurant, i.e. two cases were considered: a restaurant supplied with electricity on the free market and a restaurant supplied with electricity through the universal supplier.

In the techno-economic analyses we used the obtained data on electricity consumption of the average restaurant, the electricity production from the designed photovoltaic system with an installed power of 40 kW obtained at an hourly level with the simulation in the PV*SOL premium and the total investment cost of the photovoltaic system.

When considering the profitability of a project for installing a photovoltaic system, it is necessary to consider the costs of its maintenance [5]. In these analyses, several items were taken as key in considering the costs of maintaining photovoltaic systems of this size, namely: Inverter cost: €5/kWp; Insurance costs: €1.0/kWp; Spare parts and maintenance materials: €3.0/kWp; Equipment and PV modules cleaning costs: €1.5/kWp; and other unforeseen costs: €500.

When we map these parameters to the designed photovoltaic system, we get that the total annual costs for maintenance and operation of the PV system are €762. These costs also include the annual amount for replacing the inverter after the 12th year. Regularly, the inverter is replaced on the 13th year due to its service life, which is at most (depending on the product) around 15 years, but also due to its reduced efficiency [6]. Therefore, for the first 12 years of operation of the photovoltaic system, these costs will be €762, and for the remaining 13 years, the costs for operating and maintaining the photovoltaic system will be €746.

When preparing the cost-effectiveness analysis, the prices of the Hungarian Derivative Energy Exchange (HUDEX), as a reference electricity exchange in Macedonia, were taken as reference prices for the purchase of electricity to cover consumption and for selling surplus electricity produced by the photovoltaic system. On this electricity exchange, there are predicted peak load and base load electricity prices for the next three years. The reference prices were taken on 10.12.2024 for 2025, 2026 and 2027 year. This means that the prices for the next 22 years, i.e. until the photovoltaic system is fully depreciated, need to be predicted. Of course, this does not mean that the predicted prices will be the same as the real ones, since it is a question of predicting prices for a longer period of time, and of course the variation in electricity prices can be unpredictable. In accordance with this, and according to the expectations that electricity prices will decline after their huge increase in the recent period, the financial analyses assume that for the period from 2028 to 2049, the price will decrease by 5% annually from the previous year [7].

On the other hand, in order to calculate the annual savings on electricity bills of the restaurant, as well as the annual income from the sale of surplus electricity produced by the photovoltaic systems, it is necessary to determine the prices at which these amounts will be calculated. According to the current situation on the electricity market, the prices for the purchase of electricity to cover consumption are 15% higher than the prices on the HUDEX electricity exchange, while the prices for selling surplus electricity produced by photovoltaic systems of this size are 15% lower than the prices on the HUDEX exchange. At the same time, it is necessary to make a prediction of the price of the distribution fee because it is unknown for the upcoming period. According to European practices, an increase in the price of the distribution fee by 2.5% per year can be expected, therefore this type of constant growth was taken into account when making the financial analysis [7].

Results and Discussion

The deployment of the PV system provides substantial benefits for environmental protection and climate change mitigation. Over its lifetime, the system will:

1. Reduce greenhouse gas (GHG) emissions by approximately 665 metric tons, which is equivalent to the emissions generated by burning over 330 000 liters of diesel fuel or the annual carbon sequestration of 870 mature trees.
2. Improve air quality by decreasing emissions of harmful pollutants associated with coal and gas combustion, such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM).
3. Promote sustainability by utilizing a renewable energy source, thereby reducing the environmental footprint of electricity consumption in the analyzed facility.

Table 4 shows the analysis of the electricity consumption of the restaurant before and after the installation of the photovoltaic system, the electricity production from the 40 kW photovoltaic system and the surplus electricity, for the entire life of the PV system. The results shown for 25 years predict a reduction in the electricity production from the PV system by 1% each year, according to the specifications of the manufacturer of the PV modules used in the analyses.

Accordingly, for these parameters, the income from electricity savings after installing the photovoltaic system and the income from the sale of surplus electricity for the entire operating life of the photovoltaic system have been calculated according to the predicted electricity prices [8].

Table 3. Analysis of the electricity consumption of the restaurant with and without the PV system, electricity production from the PV system and surplus electricity from the PV system for the entire lifetime of the PV system

Year	Electricity consumption (kWh)	Electricity production (kWh)	Electricity consumption with PV System (kWh)	Surplus Electricity from the PV System (kWh)
2025	321 918.08	62 615.66	259 622.24	319.83
2026	321 918.08	61 989.50	259 881.87	316.63
2027	321 918.08	61 369.61	260 141.75	313.46
2028	321 918.08	60 755.91	260 401.89	310.33
2029	321 918.08	60 148.35	260 662.29	307.23
2030	321 918.08	59 546.87	260 922.95	304.15
2031	321 918.08	58 951.40	261 183.88	301.11
2032	321 918.08	58 361.89	261 445.06	298.10
2033	321 918.08	57 778.27	261 706.51	295.12
2034	321 918.08	57 200.48	261 968.21	292.17
2035	321 918.08	56 628.48	262 230.18	289.25
2036	321 918.08	56 062.19	262 492.41	286.35
2037	321 918.08	55 501.57	262 754.90	283.49
2038	321 918.08	54 946.56	263 017.66	280.66
2039	321 918.08	54 397.09	263 280.68	277.85
2040	321 918.08	53 853.12	263 543.96	275.07
2041	321 918.08	53 314.59	263 807.50	272.32
2042	321 918.08	52 781.44	264 071.31	269.60
2043	321 918.08	52 253.63	264 335.38	266.90
2044	321 918.08	51 731.09	264 599.71	264.23
2045	321 918.08	51 213.78	264 864.31	261.59
2046	321 918.08	50 701.64	265 129.18	258.97
2047	321 918.08	50 194.63	265 394.31	256.38
2048	321 918.08	49 692.68	265 659.70	253.82
2049	321 918.08	49 195.75	265 925.36	251.28

According to the analyses presented in Table 3, the implementation of the photovoltaic (PV) system will lead to a significant reduction in annual electricity consumption during the first year of operation. Specifically, the total electricity consumption will decrease from the current value of 321 918.08 kWh to 259 622.24 kWh, representing a notable improvement in energy efficiency. This reduction in electricity usage corresponds to annual savings in electricity costs of approximately €10 991.

Furthermore, the cost of electricity consumption for the first year of operation, after the installation of the PV system, will be significantly reduced compared to the current expenses. Before the installation, the annual electricity costs amount to approximately €56 799.03. However, with the PV system in place, these costs are expected to decrease to approximately €45 807.59 [8].

This reduction in electricity expenses demonstrates the substantial financial benefit provided by the PV system, as it effectively lowers the reliance on purchased electricity from the grid. The difference of nearly €11 000 in annual savings not only improves the economic sustainability of the operation but also contributes to long-term cost reductions for the restaurant.

Table 4. Total revenues from savings and sales of surplus electricity

Year	Total Revenues (Savings + Surplus Electricity)
2025	11 024 €
2026	10 268 €
2027	9 479 €
2028	9 148 €
2029	8 839 €
2030	8 551 €
2031	8 281 €
2032	8 030 €
2033	7 797 €
2034	7 580 €
2035	7 379 €
2036	7 192 €
2037	7 021 €
2038	6 862 €
2039	6 717 €
2040	6 584 €
2041	6 463 €
2042	6 353 €
2043	6 254 €
2044	6 165 €
2045	6 086 €
2046	6 016 €
2047	5 955 €
2048	5 903 €
2049	5 859 €

To fully understand the investment cycle, as well as the method and investment payback period, it is essential to analyze the proposed methods of financing the photovoltaic (PV) system installation. This financial analysis considers two types of investment approaches for the project.

The first investment method involves financing the PV system through a combination of 70% credit and 30% own funds contributed by the restaurant. For this scenario, a loan interest rate of 6% is applied, with a loan repayment period of 10 years. This financing method reduces the immediate financial burden on the restaurant by leveraging external capital, which is gradually repaid over the defined period.

The second investment method assumes that the restaurant will finance the entire project using 100% of its own funds, thereby avoiding any loan or associated interest payments. While this approach eliminates debt-related costs, it requires a larger upfront capital investment from the restaurant.

For both investment methods, a detailed financial analysis was conducted to determine and compare their respective financial impacts, including the return on the investment period. The results of these analyses, as presented in Table 5 and Table 6, reveal notable differences in the payback periods for each financing scenario.

The findings show that the choice of investment method significantly influences the overall financial performance and return timeline of the PV system project. By comparing the outcomes of both approaches, it becomes clear that the selection of financing strategy depends on the restaurant's available capital, risk preference, and long-term financial goals.

Table 5. Investment cycle with 70% credit and 30% own funds

Year	Personal funds	ANNUAL REVENUES	Maintenance costs and other expenses	Annual annuity for the loan	Depreciation	Income tax 10%	Net Cash Flow
-1	8 437 €	- €	- €	- €	- €	- €	- 8 437 €
1	- €	11 024 €	762 €	2 675 €	1 125 €	764 €	6 823 €
2	- €	10 268 €	762 €	2 675 €	1 125 €	680 €	6 151 €
3	- €	9 479 €	762 €	2 675 €	1 125 €	591 €	5 451 €
4	- €	9 148 €	762.€	2 675 €	1 125 €	548 €	5 163 €
5	- €	8 839 €	762 €	2 675 €	1 125 €	507€	4 896 €
6	- €	8 551 €	762 €	2 675 €	1 125 €	466 €	4 647 €
7	- €	8 281 €	762 €	2 675 €	1 125 €	428 €	4 417 €
8	- €	8 030 €	762 €	2 675 €	1 125 €	390 €	4 204 €
9	- €	7 797€	762 €	2 675 €	1 125 €	353 €	4 007 €
10	- €	7 580 €	762 €	2 675 €	1 125 €	317 €	3 826 €
11	- €	7 379 €	762 €	- €	1 125 €	549 €	6 067 €
12	- €	7 192 €	762 €	- €	1 125 €	531 €	5 900 €
13	- €	7 021 €	746 €	- €	1 125 €	515 €	5 760 €
14	- €	6 862 €	746 €	- €	1 125 €	499 €	5 618 €
15	- €	6 717 €	746 €	- €	1 125 €	485 €	5 487 €
16	- €	6 584 €	746 €	- €	1 125 €	471 €	5 367 €
17	- €	6 463 €	746 €	- €	1 125 €	459 €	5 258 €
18	- €	6 353 €	746 €	- €	1 125 €	448 €	5 159 €
19	- €	6 254 €	746 €	- €	1 125 €	438 €	5 070 €
20	- €	6 165 €	746 €	- €	1 125 €	429 €	4 990 €
21	- €	6 086 €	746 €	- €	1 125 €	422 €	4 919 €
22	- €	6 016 €	746 €	- €	1 125 €	415 €	4 856 €
23	- €	5 955€	746 €	- €	1 125 €	408 €	4 801 €
24	- €	5 903 €	746 €	- €	1 125 €	403 €	4 754 €
25	- €	5 859 €	746 €	- €	1 125 €	399 €	4 714 €
NPV							61 732 €
Investment payback period [years]							5.48

According to the results presented in Table 5 and Table 6, it can be observed that the return on the investment period varies depending on the selected investment method. Specifically, for a restaurant that is supplied with electricity purchased on the free market, the first investment method demonstrates an average return on an investment period of 5.48 years, which translates to approximately 5 years and 6 months. This period is calculated based on the cash flow and savings achieved through the reduction in electricity expenses as a result of the implemented investment.

On the other hand, when analyzing the second investment method, as shown in Table 5, the return on the investment period is notably shorter. The calculations indicate that this period amounts to 4.53 years, or approximately 4 years and 6 months. This shorter payback period suggests that the second method is more economically advantageous in terms of achieving a faster return on the initial investment.

Table 6. Investment cycle with 100% own funds

Year	Personal funds	ANNUAL REVENUES	Maintenance costs and other expenses	Depreciation	Income tax 10%	Net Cash Flow
-1	28 123 €	- €	- €	- €	- €	- 28,123 €
1	- €	11 024 €	762 €	1 125 €	764 €	9 498 €
2	- €	10 268 €	762 €	1 125 €	680 €	8 826 €
3	- €	9 479 €	762 €	1 125 €	591 €	8 125 €
4	- €	9 148 €	762 €	1 125 €	548 €	7 838 €
5	- €	8 839 €	762 €	1 125 €	507 €	7 570 €
6	- €	8 551 €	762 €	1 125 €	466 €	7 322 €
7	- €	8 281 €	762 €	1 125 €	428 €	7 091 €
8	- €	8 030 €	762 €	1 125 €	390 €	6 878 €
9	- €	7 797 €	762 €	1 125 €	353 €	6 682 €
10	- €	7 580 €	762 €	1 125 €	317 €	6 501 €
11	- €	7 379 €	762 €	1 125 €	549 €	6 067 €
12	- €	7 192 €	762 €	1 125 €	531 €	5 900 €
13	- €	7 021 €	746 €	1 125 €	515 €	5 760 €
14	- €	6 862 €	746 €	1 125 €	499 €	5 618 €
15	- €	6 717 €	746 €	1 125 €	485 €	5 487 €
16	- €	6 584 €	746 €	1 125 €	471 €	5 367 €
17	- €	6 463 €	746 €	1 125 €	459 €	5 258 €
18	- €	6 353 €	746 €	1 125 €	448 €	5 159 €
19	- €	6 254 €	746 €	1 125 €	438 €	5 070 €
20	- €	6 165 €	746 €	1 125 €	429 €	4 990 €
21	- €	6 086 €	746 €	1 125 €	4225 €	4 919 €
22	- €	6 016 €	746 €	1 125 €	415 €	4 856 €
23	- €	5 955 €	746 €	1 125 €	408 €	4 801 €
24	- €	5 903 €	746 €	1 125 €	403 €	4 754 €
25	- €	5 859 €	746 €	1 125 €	3993 €	4 714 €
NPV						62 653 €
Investment payback period [years]						4.53

CONCLUSION

In this analysis, a simulation was made for installing a photovoltaic system on the roof of an average restaurant in Macedonia in the PV*SOL premium software, which determined that the electricity production from the designed photovoltaic system is around 62 615 MWh/year, while the total investment with current prices for the construction of photovoltaic systems of this size is around €28 120.

By comparing the electricity consumption and electricity production on an hourly basis, it was concluded that the costs of electricity consumption would be reduced from the current costs on an annual basis, which are approximately €56 799.03 to €45 807.59. These savings result from a reduction in the restaurant's electricity consumption, since part of it is covered by the production of electricity from the photovoltaic system, and the income from selling the surplus on the free market at HUPX –

15% prices would be around €33 in the first year [8]. The small income from surplus electricity is a result of the fact that the restaurant uses most of the electricity produced for its own needs.

Electricity production is about 5 times lower than electricity consumption, but based on the cost-effectiveness analyses, it has been shown that by installing a 40 kW photovoltaic system, an average restaurant in Macedonia will have significant savings on electricity bills with a return on investment of less than 6 years for investing with credit and a return on investment of less than 5 years for investing in own funds, which means that this investment is cost-effective in both cases.

According to the results obtained, it is concluded that the investment of a 40 kW photovoltaic system for an average restaurant in Macedonia is cost-effective and sustainable, i.e. the restaurant will provide savings on electricity bills. On the other hand, it is also noted that if the restaurant wants to generate greater income from the sale of surplus electricity, it is necessary to install a photovoltaic system with a higher installed capacity, which will also provide an additional reduction in the costs of purchasing additional electricity and greater energy independence for the restaurant.

By producing its own electricity from a photovoltaic system, in addition to saving on electricity bills, restaurants will also protect themselves from possible future increases in the price of electricity by remaining competitive in the market because the prices of their services and products will not be completely dependent on the price of electricity. Beyond these advantages, the adoption of PV systems also contributes immensely to environmental protection and the reduction of greenhouse gas emissions, which are critical in the fight against climate change.

By generating electricity from PV systems, restaurants can reduce their reliance on fossil fuels, which are a primary source of CO_2 emissions. In this specific case, the modeled restaurant's PV system avoids emissions of approximately 30 metric tons of CO_2 annually, translating to 750 metric tons of CO_2 avoided over a 25-year operational period. Scaling this impact to Macedonia's restaurant sector, which includes over 700 restaurants as per the 2021 census, the potential environmental benefits are profound [9]. If every restaurant were to install a similar 40 kW PV system, the annual avoided CO_2 emissions would amount to approximately 21 000 metric tons, and over 25 years, this figure would reach an astounding 525 000 metric tons. The avoided emissions are equivalent to the carbon sequestered by over 690 000 mature trees annually or the emissions generated by burning more than 10 million liters of diesel fuel. This shift to renewable energy also reduces the emission of harmful air pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter (PM), which contribute to respiratory and cardiovascular diseases. By reducing the carbon intensity of electricity generation, restaurants collectively contribute to improving air quality and public health in urban and rural areas.

Furthermore, the widespread adoption of PV systems would support Macedonia's national and international commitments to mitigating climate change, including the goals set under the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) [10].

The integration of photovoltaic systems into the hospitality sector aligns with a global trend toward sustainability and environmental responsibility. Restaurants equipped with PV systems will not only reduce their operational costs and achieve greater energy independence but will also establish themselves as environmentally conscious businesses. This shift enhances their reputation and marketability, particularly among environmentally aware consumers who increasingly prioritize supporting businesses that take concrete actions to reduce their carbon footprint.

In conclusion, the investment in PV systems for restaurants in Macedonia is not only economically viable but also environmentally transformative. By embracing renewable energy, the restaurant sector can play a pivotal role in reducing the country's greenhouse gas emissions, enhancing energy security and contributing to a cleaner, more sustainable future. These measures will protect both the environment and the financial stability of restaurants, making them more resilient to future energy price fluctuations while positioning them as leaders in the transition to a low-carbon economy [10].

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