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Research Article

Usage and efficiency analysis of electricity generated by PV power plant in a marina or industrial facility

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Abstract: In this study, the analysis of the usage efficiency and the time allocation to cover the initial investment cost of a PV power plant to be installed in an industrial facility having constant electricity consumption monthly and a yacht marina having fluctuating electricity consumption in a year (equal yearly electricity in each in total) within the installation assumption of same conditions of PV plant has been done. The PV power plant data with 680 kWp power and located at the same latitude as the yacht marina in the center of Mediterranean were used. For this purpose, it has been calculated that the PV power plant installed power required for the annual electricity need of the yacht marina will be 1357 kWp. With this power, 2,141,117 kWh of electricity has been produced annually and the yacht marina/industrial facility need has been supplied. In addition, the Net Present Value (NPV) was used to calculate the coverage period for the initial investment cost of the PV plant. In the calculations, it has been determined that the time to cover the initial investment cost is 4.31 years in the yacht marina and 4.37 years in the industrial facility. This result showed that installing PV power plants in marinas would be 1.5% more advantageous than other industrial facilities.

Keywords: *Energy efficiency, PV plant, Solar energy, Yacht marina*

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1. INTRODUCTION

Most of the electricity produced in the world is obtained from fossil fuels. Fossil fuels increase both environmental pollution and costs. In Turkey, a series of supportive policies are implemented for minimizing these costs, efficient use of energy, and environmentally friendly technology investments. Foremost among them are PV applications, which form the basic structure of solar energy systems. For example; some supportive subsidies, such as Value Added Tax (VAT) exemption, customs duty exemption, minimum 30% tax reduction and 6 years insurance premium support for employees, etc., have been provided to the facilities that install the PV systems for their own needs [1]. In addition, according to the Regulation on Unlicensed Electricity Generation in the Electricity Market, the supply company provides a ten-year purchase guarantee for the surplus electricity produced in the PV systems installed for their own needs [2].

PV plants convert solar energy into electrical energy. The main element in PV systems is PV panels. PV panels consist of PV cells. Depending on the cell structure, solar energy can produce electricity with an efficiency between 5% and 30% [3]. PV plants are of two types, with and without storage. Storage plants store the generated electricity in the battery. If needed, electricity is used from the battery. No batteries are needed in non-storage systems. The electricity produced in these systems is used directly. Excess electricity is sold to the grid. In cases where the PV plant does not meet the need, electricity is purchased from the grid. Also, PV panels produce direct current (DC). Its network is loaded with alternating current (AC). Inverter converters that will convert DC to AC are used for network adaptation [4].

In the literature, there are many studies on PV applications [5-7]. Kandasamy et al. examined PV efficiency and other cost parameters on 1000 kWp grid-connected photovoltaic system performance in detail for Tuticorin, Sivakasi, Sivagangai and Madhurai with PVsyst software for four geographic conditions in Tamil Nadu [8]. Sharma and Chandel found PV's performance by examining a grid-connected PV plant with an installed power of 190 kWp in India [9]. In research conducted in Gujarat by Ramoliya, it was estimated that 1,416,980 kWh of energy could be produced annually in a grid-connected 1 MW PV plant [10]. Charfi et al., in their experimental study in Tunisia, PV system maximum performance at an angle of 30 degrees obtained by adjusting the PV panel inclination angle [11]. Boboker, created the most appropriate investment system by modeling in their study conducted in different regions in Libya [12]. In the modeling of Dal and Yılmaz, it has been determined that a marina's electricity needs can be met by producing 2,462,118 kWh of electricity per year with a PV system with an installed power of 1,500 kWp [13]. El-Shimy, in his study with PV system in 29 different regions in Egypt, found that the shortest time to cover the initial investment cost of the system was in the Wahat Kharga region with 4.9 years [14]. Sulukan, stated that in the PV system modeling on the roof in Istanbul, at the end of 4 years, it has reached a positive cash flow by meeting the initial investment cost [15].

Turkey's installed PV power plant power is 6,964 MW [16]. It is essential to popularize PV applications as a factor reducing Turkey's dependence on foreign energy. In addition, the most important parameter in determining the solar energy potential is solar radiation. The solar radiation falling on the 30º inclined panel surface on the Mediterranean coast is 1,850 kWh/m^2 [17]. In the Atlas as mentioned earlier, it has been shown that the high potential of the Mediterranean Region makes it the optimum area for PV power plant investment. Electricity is not yet produced by using PV applications in marinas clustered in the Mediterranean Region of in Turkey [13]. In the region mentioned above, electricity consumption increases due to the increase in tourism during the summer months. Likewise, solar radiation reaches its highest level in summer. Electricity consumption of marinas varies according to yacht mooring capacity. The annual electricity consumption in marinas varies between 1,000,000 and 6,000,000 kWh depending on the yacht mooring capacity. A marina, which was examined in a study, consumes 2.141.117 kWh of electricity per year, and 34% of this consumption takes place in the summer months with the highest solar radiation. In this study; both the scenarios of establishing power plant in the marina and in an industrial facility which is at the same location in the Mediterranean Region have been examined.

2. MATERIAL AND METHOD

In this study, the situation of meeting the electricity need of an industrial facility in the same location as a marina in the Mediterranean from a PV plant has been analyzed. In this analysis, an industrial facility, which its electricity consumption is equivalent to the annual consumption of the marina but assumed to consume equal electricity each month, and makes mass/serial production is foreseen. In this context, the data of an operating PV power plant located at the same latitude and close to the marina area were used to meet the electricity needs of the marina/industrial facility. Within this frame, the electricity consumption data of the marina for 2019 are given in Table 1.

Table 1. Electricity consumption of yacht marina / industrial facility in 2019 (kWh).

Months	Electricity consumption of Marina(E_{mc})	Electricity consumption of industrial facility (E_{me})
January	152162	178426
February	130.623	178426
March	148877	178426
April	162653	178427
May	171637	178427
June	212273	178427
July	256395	178427
August	263298	178427
September	200356	178426
October	143941	178426
November	124323	178426
December	174579	178426
Total	2141117	2141117

The analyzed marina consumes 2,141,117 kWh of electricity annually. In addition, it has been accepted that the industrial facility will consume 2,141,117 kWh of electricity annually, equally each month.

The amount of energy obtained from PV panels varies according to the latitude and the tilt angle of the panel with the horizontal ground [18]. Also, the panels should be orientated to the southward, and the azimuth angle should be taken as 0° [19]. For the location, azimuth angle and panel tilt angle that will be used for the marina/industrial facility; the data of an operating PV plant, which is close to the marina, was used. The technical data of the operating PV power plant are given in Table 2.

Table 2. Technical characteristics of the PV plant in operation.

		Technical Specifications
PV plant	Plant connection type	On-grid
	Plant power	680 kWp
	Quantity	2430
	Plant lifetime	25 years
PV panel	Model	Polycrystalline
	Power	280 Wp/panel
	Cell Quantity	60 pieces
	Cell Size	157x157 mm
	Efficiency	0,17
	Panel tilt angle	30º
	Azimuth angle	0º
	Performance	10th year %90, 25th year%80
Inverter	Quantity	16 pieces
	Power	40 kW

In the study, the installed power of the PV power plant, which continues to operate, is 680 kWp, and the monthly/annual electricity generation amount in 2020 is given in Table 3. The PV plant generates 1,072,925 kWh of electrical energy annually.

Table 3. The monthly electricity generation amount of the current PV plant (kWh).

Months	January	February	March	April	May	June
Generation (E_m)	57351	58269	91196	103693	106338	100808
Months	July	August	September	October	November	December
Generation (E_m)	119946	112874	105939	96647	67457	52409

The electrical energy produced by the operating power plant and to be produced from the PV power plant to be installed in the marina/industrial facility is calculated with Equation (1) and Equation (2).

$$E_y = \sum_{i=1}^{12} G_i A_{pva} \eta_{pv} \eta_s \quad (1)$$

$$E_{yp} = \sum_{i=1}^{12} G_i A_{pvp} \eta_{pv} \eta_s \quad (2)$$

In equations, i stands for month. E_m and E_y refer to the monthly and annual electrical energy (kWh) produced by the PV plant in operation, respectively. E_{yp} refers to the annual electrical energy (kWh) to be produced by the marina/industrial facility. G_i refers to the monthly solar radiation falling on the PV panel (kWh/m^2). A_{pva} refers to PV plant's panel area, A_{pvp} refers to the panel area (m^2) to be installed in the marina/industrial facility. η_{pv} and η_s refer to the panel and system efficiency of the PV plant (unitless), respectively. In this study, the panel and system efficiencies of the power plants in operation and to be established are considered equal. As seen in Equation (3) and Equation (4), when Equation (1) and Equation (2) are proportional to each other, the panel area ratios of the existing PV plant and the PV plant to be installed in the marina/industrial facility are equal. With this ratio, the installed power of the system to be installed and the amount of electrical energy to be produced monthly/yearly are calculated. The annual electricity consumption amount of the marina is 2,141,117 kWh, and this consumption amount has been accepted as the generation amount of the power plant to be installed in the marina/industrial facility. The proportion of the consumption amount which is 2,141,117 kWh and the electricity production amount of the existing power plant which is 1,072,925 kWh in 2020 were calculated. The said proportion was found to be ($\delta = 1.996$).

$$\delta = \frac{E_{yp}}{E_y} \quad (3)$$

$$\delta = \frac{G_i A_{pva} \eta_{pv} \eta_s}{G_i A_{pvp} \eta_{pv} \eta_s} \quad (4)$$

Using this ratio, Equation (5) and Equation (6), the installed power of the PV power plant to be installed in the marina/industrial facility and the electrical energy it will generate monthly are calculated.

$$\delta = \frac{P_{ys}}{P} \quad (5)$$

$$\delta = \frac{E_{mp}}{E_m} \quad (6)$$

In Eqs. 5 and 6, P_{ys} refers to the installed power (kWp) of the power plant to be installed in the marina/industrial facility. P refers to installed power (kWp) of the PV plant in operation. E_{mp} refers to the monthly electricity amount (kWh) to be produced by the power plant to be installed in the marina/industrial facility. E_m refers to the monthly electricity amount (kWh) produced by the power plant in operation.

For PV panels, manufacturers guarantee 80% panel power up to 25 years. Most manufacturers state that this decrease in panel power is linear (-0.7%/year) [20]. In this study, it is predicted that the panel power performance will decrease linearly. However, the data of 2020 has been used instead of the decrease in panel performance for the first 10 years because the existing power plant started operating earlier. Therefore, the data of 2020 has been assumed as the average production of the plant for the first 10 years. For the next 15 years, the calculation is made by predicting that the panel power will decrease linearly (-0.7%) every year.

The PV plant that will be installed is designed to be connected to the grid. After the PV plant starts operating, it is envisaged that the marina/industrial facility will produce the electricity it needs, the excess production will be sold to the grid, and in case the generation cannot be met, the electricity will be purchased from the grid. Calculations were made taking into account this envisage. The unit price tariff published by the Energy Market Regulatory Authority (EMRA) has been applied in the calculations.

In addition, the initial investment cost of the PV power plant to be installed in the marina/industrial facility has been calculated. Subsequently, the NPV method was used for calculation of the cash flow of the PV plant during its 25 years life cycle. For cash flow calculation, the weighted average of the Central Bank of the Republic of Turkey (CBRT) inflation and discount rates between 2011 and 2020 is used. As a result of these calculations, the payback period of the initial investment cost and the cash flow are obtained separately for both the marina and the industrial facility.

It has been presumed that the PV power plant will be installed on the roofs, docks and breakwaters that are not used for other purposes in the marinas, there is no building that will create a shadow on the PV panels around the installation area, and the area where the power plant will be installed is the company's own assets. The specific locations of both marina and existing power plant are not specified in this study due to commercial concerns.

3. RESULTS AND DISCUSSIONS

The power plant installed power required to produce the electricity needed by the marina/industrial facility has been calculated as 1357 kWp using Equation (5). Both the scenarios of establishing the power of 1357 kWp in the marina and in an industrial facility which is at the same location have been examined. The monthly electricity amount to be produced by the PV power plant, which has 1357 kWp installed power, to be installed in the marina/industrial facility is calculated separately for each month using Equation (6) and given in Table 4.

Table 4. Monthly electricity generation of the PV plant to be installed in the marina / industrial facility (kWh).

Months	January	February	March	April	May	June
Generation (E_{mp})	114448	116281	181990	206929	212206	201171
Months	July	August	September	October	November	December
Generation (E_{mp})	239362	225250	211410	192868	134616	104586

Moreover, the consumption of 2,141,117 kWh of electricity to be produced annually at the marina and the consumption of the same production in the industrial facility are examined separately and given in Table 5.

Table 5. Monthly range of the electricity generation of the PV power plant to be installed and the consumption of the marina and the industrial facility (kWh).

Months	Electricity generation of the PV plant (E_{mp})	Consumption of the marina (E_{mc})	Consumption of the industrial facility (E_{ec})
January	114448	152162	178426
February	116281	130623	178426
March	181990	148877	178426
April	206929	162653	178427
May	212206	171637	178427
June	201171	212273	178427
July	239362	256395	178427
August	225250	263298	178427
September	211410	200356	178426
October	192868	143941	178426
November	134616	124323	178426
December	104586	174579	178426
Total	2141117	2141117	2141117

3.1. Relative Shortage/Excess Energy

Relative shortage/excess energy is the difference between the actual value and the calculated value. The low difference is related to the closeness of the result to the real value. The monthly difference between the marina/industrial facility estimation and the PV plant production (kWh) is calculated by using Equation (7) and Equation (8).

$$E_{fi} = E_{mp}\text{-}E_{mc} \tag{7}$$

$$E_{fi} = E_{mp}\text{-}E_{ec} \tag{8}$$

In equations, E_{fi} refers to the monthly difference (kWh) between the consumption in the marina/industrial facility, and the production of the PV power plant. E_{mc} refers to the consumption in the marina (kWh). E_{ec} refers to the consumption in the industrial facility (kWh).

The relative shortage/excess energy percentage is the percentage expression of the difference between the real value and the calculated value to the real value. The relative shortage/excess energy percentage between the marina/industrial facility estimation and the PV plant production ($\%\varepsilon$) is calculated by using Equation (9).

$$\%\varepsilon = \frac{E_{fi}}{E_{mp}} 100 \tag{9}$$

In order to understand that the electricity produced in the PV plant meets the needs of the marina/industrial facility, the absolute value is not used in the formulas given in Equation (7) and Equation (8).

In case the electricity to be produced by the PV power plant is used in the marina/industrial facility, the difference and the relative energy surplus/insufficiency percentage resulting from the interaction of the enterprises with the grid are given in Table 6.

When Table 6 is examined, it has been determined that 1,952,885 kWh of the electricity produced by the PV plant will be used directly by the marina and 1,897,344 kWh will be used directly by the industrial facility.

Also, it has been determined that the electricity produced for the marina will not be enough for the marina's need in January, February, June, July, August and December and 188,232 kWh of electricity will be purchased from the grid. In the remaining six months, the production is more than the marina's need and that 188,232 kWh of electricity will be sold to the grid. It has been calculated that the generation will not be enough for the industrial facility in January, February, November and December and 243,773 kWh of electricity will be purchased from the grid, while the electricity produced by the PV plant in the other eight months is too much for the industrial facility and 243,773 kWh of electricity will be sold to the grid. Therefore, it has been determined that the industrial facility receives and sells 55,541 kWh more electricity from the grid compared to the marina.

The high electricity consumption of the marina's electricity demand in June, July, August and September and the high electricity production in the PV plant decreased the relative shortage/excess energy rate. Moreover, the relative shortage/excess energy percentage for the marina is lower in 8 months of the year compared to the industrial facility. The reason for this is that the increase and decrease in the consumption amount of the marina is similarly seen in the production at the PV power plant.

Table 6. Gap and relative shortage/excess energy percentage between electricity generation and consumption in the PV plant.

Months	Electricity consumption in marina and generation of PV plant		Electricity consumption in industrial facility and generation of PV plant	
Months	Gap (kWh)	Relative shortage/excess energy (%)	Gap (kWh)	Relative Shortage/Excess energy (%)
January	-37714	-33	-63978	-56
February	-14342	-12	-62145	-53
March	33113	18	3564	2
April	44276	21	28502	14
May	40569	19	33779	16
June	-11102	-6	22744	11
July	-17033	-7	60935	25
August	-38048	-17	46823	21
September	11054	5	32984	16
October	48927	25	14442	7
November	10293	8	-43810	-33
December	-69993	-67	-73840	-71

Various test methods can be used to determine the relationship between PV plant production and consumption. In this study, Spearman rank difference correlation coefficient method has been preferred. This method has been preferred because the kurtosis test result (-2.41) of the yacht port was lower than 1.96 [21]. This method is used to measure the linear relationship between two ordinal variables that do not have a normal distribution. A Spearman rank difference correlation coefficient approaching 1 in absolute value increases the strength of the relationship, while approaching zero decreases the strength of the relationship. The mentioned coefficient is calculated with the following equation:

$$r_s = 1 - \frac{6\sum_{i=1}^{12} F}{12(12^2 - 1)} \tag{10}$$

Here, r_s is the Spearman rank difference correlation coefficient, and F is the difference between marina/industrial facility consumption and PV plant production. As seen from Table 7, the Spearman rank difference correlation coefficient value is calculated as 0.783, and the correlation between the marina and the PV plant is concluded as high.

Table 7. PV plant production and consumption correlation results.

Results	Spearman corr.
Yacht port-PV plant	0.783
Industrial facility-PV plant	0.643

In Figure 1, the increase and decrease between PV plant production and marina consumption are parallel to each other. It has been analyzed that since there is a constant consumption in the industrial facility, there is no relationship between the production and the consumption. It shows that the electricity consumption in marinas increases in the summer season, while the consumption decreases relatively in the winter season and follows a fluctuating course. The fact that the PV plant produces more electricity due to the high amount of solar radiation in the summer season means that the electricity production of the plant decreases due to its low level in the winter season. This shows that PV power plants to be established in marinas are more advantageous than other industrial facilities.

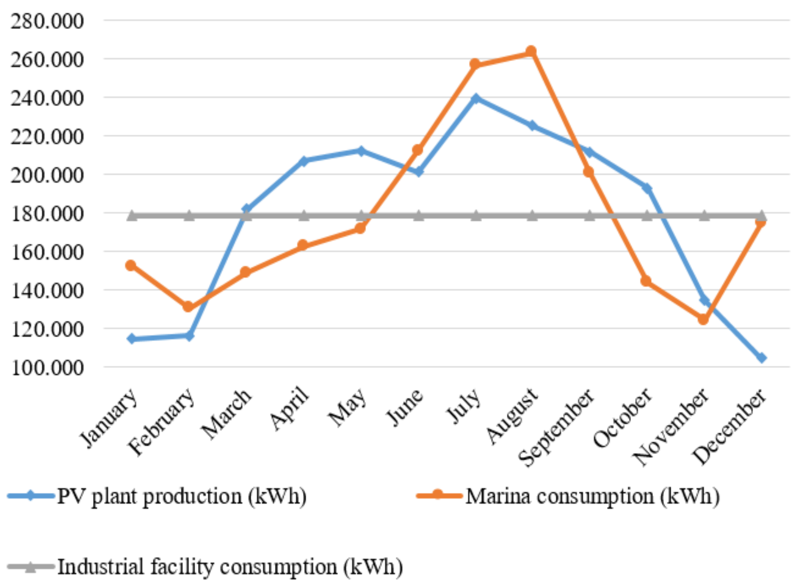

Figure 1. PV power plant production, marina and industrial facility consumption distribution.

3.2. PV Plant Cost Calculation

In the study, it is envisaged that the enterprises will use their own assets for the financing of PV plant installation. The PV power plant installed power for both businesses is 1357 kW. For this installation, the cost was calculated as 4846 polycrystalline solar panels with a power capacity of 280 W, 32 inverters with a power of 40 kW, energy cables sufficient for the installation, labor, engineering and process management as a set and given in Table 8, data of which was obtained from the market. Calculations in the study were made in Turkish Lira (TRY). (1 USD = 8 TRY) was accepted.

Table 8. Panel and equipment cost calculation for PV plant installation.

Product name	Quantity	Unit price (TRY)	Total Price (TRY)	Percentage (%)
PV panel (Poly 280 W)	4846	650	3149900	46.45
Inverter (40 KW)	32	54000	1728000	25.48
Carrier system (Aluminum-set)	4846	110	533060	7.86
Cable, panel, and equipment installation	1	1300000	1300000	19.17
Engineering and process management	1	70000	70000	1.03
Total cost (VAT Excluded)			6780960	
Total cost (%18 VAT Included)			8001533	

The initial investment cost of the PV power plant, which is envisaged to be built in the marina/industrial facility, has been calculated as 8001533 TRY. The biggest shares in the total cost belong to PV panel with 46.45%, inverter with 25.48% and materials and installation with 19.17%.

The unit price tariff published by EMRA has been applied in the income and expense calculations of the PV plant and is given in Table 9. Taxes, funds and distribution cost expenses are added to the purchase price of grid stated in Table 9. The electricity sales price of the power plant is calculated directly over the consumption price.

Table 9. Turkey Energy Market Regulatory Authority Price Tariff [22].

	Unit price (VAT Included)	Unit
Electricity sale price	0.594796	TRY/kWh
Electricity distribution price	0.211497	TRY/kWh
Taxes and funds	0.201280	TRY/kWh
Purchase price from the grid	1.007573	TRY/kWh

3.3. Generation of PV Power Plants and Marina Consumption

As can be seen in Table 10, under normal conditions, the marina's electricity requirement of 2,141,117 kWh/year is currently supplied from the grid, and 2,157,332 TRY is paid annually in return. In case a PV power plant is installed in the marina, 1,952,885 kWh/year electricity to be produced will be used directly by the marina, and the amount of electricity to be purchased from the grid will decrease to 188,232 kWh/year. In addition, 188,232 kWh/year part of the electricity produced by the PV plant will be sold to the grid and an additional 111,960 TRY will be earned in return.

Table 10. Electricity generation of PV power plants and yacht marina consumption account.

	Electricity production/ consumption (kWh/year)	Unit price (TRY/kWh) (VAT included)	Annual consumption price (TRY/year)
Purchased before the installation	2141117	1.007573	-2157332
Purchased after the installation	188232	1.007573	-1896657
Annual energy saving	1952885	1.007573	+1853842
Sold after the installation	188.232	0.594796	+111960
Annual electricity saving			+2079634
Net annual electricity expense (out of calculation)			-77698
Annual maintenance and repair			-30000
Worker and insurance charges			-60000
Net annual saving			+1989634

As a result, the total annual savings of the marina will be 2,079,634 TRY. When annual maintenance, repair and labor are deducted, the net saving amount for the pre-production (base (0)) year was found to be 1,989,634 TRY (the situation before the businesses started operating). According to this production, the marina will have to pay an additional 77,698 TRY (out of calculation) electricity price for the base (0) year as a result of the netting by buying and selling from the grid. The calculations in Table 11 were similarly made for the industrial facility.

Table 11. Electricity generation of PV power plants and industrial facility consumption account.

	Electricity production/ consumption (kWh/year)	Unit price (TRY/kWh) (VAT included)	Annual consumption price (TRY/year)
Purchased before the installation	2141117	1.007573	-2157332
Purchased after the installation	243773	1.007573	-245619
Annual energy saving	1952885	1.007573	+1911713
Sold after the installation	243773	0.594796	+144995
Annual electricity saving			+2056708
Net annual electricity expense (out of calculation)			-100624
Annual maintenance and repair			-30000
Worker and insurance charges			-60000
Net annual saving			+1966708

As a result, the annual total savings of the industrial facility will be 2,056,708 TRY. Net savings for the base (0) year were found to be 1,966,708 TRY when annual maintenance, repair and labor expenses are deducted. The industrial facility will have to pay an additional 100,624 TRY (out of calculation) electricity fee for the base (0) year as a result of netting by buying and selling from the grid.

It has been determined that the net electricity expense of the marina for the base (0) year will be 22,926 TRY less than that of the industrial facility. The low electricity costs means that marinas will use the electricity to be produced in the PV plant more efficiently than industrial facilities. It has been understood that marinas are 1.2% more efficient for the base (0) year than industrial facilities.

3.4. Payback Period Calculation of PV Power Plant

The cash flow and payback period of the investment in PV plant installation in the marina and industrial facility are calculated using NPV (Equation (10) [23].

$$NPV = \sum_{t=1}^{m} \frac{I_t}{(1+k)^t} - C_o \qquad (11)$$

In the equation, t refers to time period (year), I_t refers to the net cash flow in t year, m refers to the economic life of the investment, k refers to the discount rate. Lastly, C_o refers to the initial investment cost.

In Table 12, the initial investment cost of the PV plant and the cumulative cash flow table according to NPV for the marina are given. In this study, it is predicted that the power plant income will change depending on the inflation rate. Within this frame, the weighted average of the discount rate and inflation rate for the last ten years by the Central Bank were accepted to be 13.1% and 10.15%, respectively [24]. In the study, it was predicted that the installation of the power plant would be completed within one year. Moreover, the cumulative net flow calculation over NPV was made and the payback period of the power plant was calculated separately for both the marina and the industrial facility.

In calculations; If the PV power plant is installed in a marina in the Mediterranean, the payback period of the investment has been determined as 4.31 years.

Table 12. Investment cash flow table of the PV plant for the marina (TRY)

	Inflation effected income	Discounted cash flow	Cumulative net flow	Payback amount	Payback period (year)
Base year (0)	1.989.634	1989634	0	-8001533	
1st year	2.191.582	1937738	1937738	-6063795	
2nd year	2.414.027	1887196	3824934	-4176599	
3rd year	2.659.051	1837972	5662906	-2338627	
4th year	2.928.945	1790032	7452938	-548595	4,31

Similarly, if the PV power plant is installed in an industrial facility in the Mediterranean, the payback period of the investment is calculated as 4.37 years.

When the investment to be made in both businesses is evaluated in terms of initial investment cost and payback period, it is seen that it will reach positive cash flow in less than 5 years. It has been determined that the investment in the marina will turn into profit approximately 22 days earlier than the industrial facility. The results obtained were found to be compatible with the literature [15].

In addition, the profit and loss situation for the marina and industrial facility is given in Figure 2.

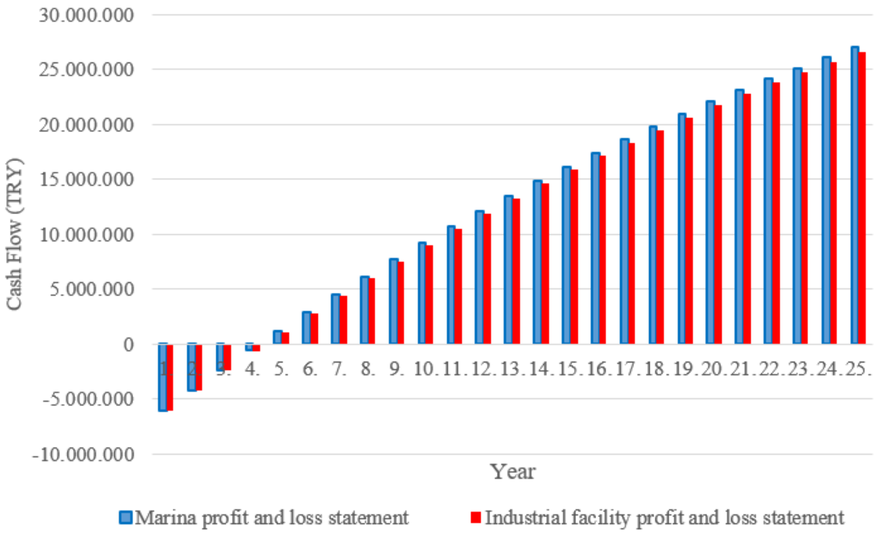

Figure 2. Marina / Industrial facility profit and loss situation

In the proposed PV power plant installation, a total income of 27,054,363 TRY from the marina and 26,650,423 TRY from the industrial facility will be provided, excluding the initial investment cost, at the end of the 25-year period. Moreover, although there is 1.2% efficient use of marinas for the basic (0) year than industrial facilities, 403,940 TRY more income will be obtained as a result of the annual power reduction of the PV panel (-0.7%) in 25 years. This shows that the electricity produced in marinas will be used 1.5% more efficiently than in industrial facilities. These results determined in the study showed that it is more advantageous to install PV power plants in marinas.

4. CONCLUSIONS

In this study, the availability of electricity produced in a PV plant in the Mediterranean Sea for the electricity requirement of a marina or industrial facility was investigated. In the study, calculations were made using the data of the current PV plant for the year 2020. As a result of the calculations, with the installation of a 1357 kW PV power plant in a marina or industrial facility, 2.141.117 kWh of electricity can be produced annually. The important results obtained are summarized below.

Due to the fact that the increase and decrease depending on the months between PV plant production and marina consumption are parallel to each other, the relative shortage/excess energy percentage of the marina in 8 months within a year was lower than that of the industrial facility.

In the calculations made in the PV plant installation, it has been determined that the payback period for the marina is 4.31 years and 4.37 years for the industrial facility. In addition, PV power plant installation will provide 403,940 TRY more income than the first investment cost for the marina in 25 years compared to the industrial facility. It has been observed that positive cash flow continues at the end of 25 years in both businesses.

It has been understood that marinas are 1.5% more advantageous than industrial facilities in the duration of 25 years. In parallel with the increase in electricity consumption due to tourism in marinas during the summer months, electricity production in the PV plant also increases. On the other hand, in parallel with the relative decrease in consumption in marinas in other seasons, the production of PV power plants also decreases. The fact that industrial facilities have constant electricity consumption every month throughout the year makes marinas more advantageous compared to the mentioned facilities.

The use of breakwater and dock areas, which are not used for any other purpose in marinas, for PV power plants will contribute to electricity generation. In addition, this study will contribute positively to the literature and the feasibility studies before the PV plant installation.

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