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An Analysis on YEKDEM Program Implemented in Turkey

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Abstract: This study examines the Renewable Energy Resources Support Mechanism (YEKDEM) implemented in Turkey for solar energy. Within this context, the appropriateness of the incentive amounts provided through the YEKDEM application was analyzed. For this purpose, the current formulation calculated the effects of changing the coefficients of the Exchange Rate, PPI, and CPI values in the mathematical equation, as well as the total incentive amounts for certain years. In the study, it was assumed that the weather was entirely sunny when calculating solar radiation. The effects of the incentive amounts, profit-loss scenarios, and the payback period for plant investors were presented. The formula that offers the highest incentive amount for investors is the one with coefficients of 30%-30%-20%-20%. Annual earnings vary between US$ 15,928 and US$ 146,176. Payback periods range from 5.9 to 54 years, depending on the use of credit and equity.

Key words: YEKDEM, Solar energy, Energy economics, Energy policy, Solar power plants.

Türkiye'de Uygulanan YEKDEM Programına İlişkin Bir Analiz

Öz: Bu çalışmada, Türkiye'de güneş enerjisi için uygulanan Yenilenebilir Enerji Kaynakları Destekleme Mekanizması (YEKDEM) incelenmiştir. Bu bağlamda, YEKDEM uygulamasıyla sağlanan teşvik miktarlarının uygunluğu analiz edilmiştir. Bu amaçla, mevcut formülasyon ile matematiksel denklemde Döviz Kuru, ÜFE ve TÜFE değerlerinin katsayılarının değiştirilmesinin etkileri ve belirli yıllar için toplam teşvik miktarları hesaplanmıştır. Çalışmada, güneş radyasyonu hesaplanırken havanın tamamen güneşli olduğu varsayılmıştır. Teşvik miktarlarının etkileri, kar-zarar senaryoları ve santral yatırımcıları için geri ödeme süresi ortaya konulmuştur. Yatırımcılar için en yüksek teşvik miktarını sunan formül, %30-%30-%20-%20 katsayılı olandır. Yıllık kazançlar 15.928 ABD doları ile 146.176 ABD doları arasında değişmektedir. Geri ödeme süreleri, kredi ve öz sermaye kullanımına bağlı olarak 5,9 ila 54 yıl arasında değişmektedir.

Anahtar kelimeler: YEKDEM, Güneş enerjisi, Enerji ekonomisi, Enerji politikası, Güneş enerji santralleri.

1. Introduction

Today, almost all countries still largely use fossil fuels to produce electricity. Using renewable energy instead of fossil fuels is extremely important in terms of leaving a cleaner environment for the future by reducing dependence on fossil fuels. One of these is solar energy, which has drawn significant interest from various sectors and application areas [1–6]. The main areas of focus for researchers are as follows: a) increasing the efficiency of solar thermal collectors or PV/T systems [7], b) producing electricity using solar power using single or hybrid energy systems [8–12], c) producing hydrogen powered by solar energy [12,13], d) using solar energy in zero-energy or sustainable-energy buildings [14,15]. The design and analysis of solar energy systems require an understanding of the distribution of solar radiation worldwide. The energy, energy, and conversion efficiencies as well as the collectors operating circumstances are influenced by numerous factors. The solar irradiation intensity is one of the most crucial factors. It has a direct impact on both the solar irradiance intensity and the thermal collector efficiency. In general calculations, average solar radiation and system efficiency are employed. Nonetheless, it is evident that this approach is unable to forecast results with accuracy. To ensure precise estimations of solar energy, the monthly distribution of solar radiation worldwide should be forecast [1]. Some incentive programs for Renewable Energy Resources are implemented around the World. These are supports such as feed-in tariffs, tax reductions, and discounts based on the power plants institutional capacity and quota. The incentive method used by some countries around the World is given in Table 1.

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Table 1. Renewable energy resource incentive programs implemented in some countries.

Country	Incentive program
USA [16]	Tax deduction, Financial support for installation
China [17]	Tax deduction
Germany [18, 19]	Tariff guarantees and financial aid instruments
Spain [19]	Inflation-based control of wages and premium
France [20]	Tariff guarantees
Canada [21]	Incentives for solar energy systems, especially for rooftop PV systems
India [22]	Financial aid for maximum 2MW power plants
Malaysia [23,24]	Energy policy supports under the renewable energy program
Ireland [25]	Quota obligation schemes, feed-in-tariff and competitive tendering schemes
Pakistan [26]	Exemption from payment of income tax, exemption from import duties on electricity generation equipment and protection against foreign exchange risks

As mentioned above, Turkey launched an incentive program similar to some of the above countries with a 10-year fixed price guarantee in 2011. However, the program was changed in 2021 and a different application was introduced. According to the program in 2021 [27], a dynamic mathematical formula that changes depending on PPI-CPI-US$-EURO movements was declared, but since the formula did not pose a very positive situation for the investor, this formula was updated again in 2023 by changing the coefficients of the variables in the formula [28, 29]. Today, YEKDEM incentive amount and local contribution amounts are determined with this formula.

The aim of this study is to examine the effects of the YEKDEM program currently implemented by Turkey for certain years and by changing the coefficients in the formula.

2. Material and Methods

The Materials and Methods section is presented under the subheadings of calculations and application conditions of the incentive program and Solar radiation and cost calculations.

2.1. Calculations and application conditions of the incentive program

In the study, analyses of YEKDEM (Renewable Energy Resources Support Mechanism), solar radiation, and GES (Greenhouse Gas Emissions) were conducted. Typically, these analyses are performed independently. However, the critical aspect lies in determining the point at which these separately calculated analyses are integrated. After calculating the YEKDEM rate in Turkish Lira (TL) per kilowatt-hour (kWh), it is converted to US cents (US$/kWh). This value represents the type of monetary incentive that the investor will receive. During the GES analysis, the most recent daily capital cost flow is computed. This value is subsequently utilized to derive the net income for the solar radiation analysis. Similarly, once the YEKDEM calculation is completed independently, the electricity purchase price is determined by multiplying the US$/kWh value by the power output obtained from the photovoltaic (PV) system. The primary objective is to provide guidance to the investor by determining the most up-to-date annual profit and loss scenario. This integrated approach ensures a comprehensive evaluation of the financial and environmental aspects, enabling informed decision-making for potential investors in renewable energy projects.

The initial YEKDEM values to be used in the formula are 32 TL kuruş/kWh and 106 TL kuruş/kWh for 2021 (old YEKDEM) and 2023 (last YEKDEM), respectively [27,28]. The domestic contribution pricing and application prices for the renewable energy sources support mechanism are revised by Equation 1 for YEK-certified production facilities that go into operation between July 1, 2021, and December 31, 2030.

$$\frac{YEKDEM_{GD}}{YKF_{GD}} = \frac{YEKDEM_{OGD}}{YKF_{GD}} x[\left(\frac{25}{100} x \frac{PPI_{A-2}}{PPI_{A-3}}\right) + \left(\frac{15}{100} x \frac{CPI_{A-2}}{CPI_{A-3}}\right) + \left(\frac{30}{100} x \frac{EXC.RATE_{D-1}}{EXC.RATE_{D-2}}\right) + \left(\frac{30}{100} x \frac{EXC.RATE_{E-1}}{EXC.RATE_{E-2}}\right)] \quad (1)$$

For what these variables mean, please see the following references Refs. [5,29].

2.2. Solar radiation and cost calculations

The methodology for the solar energy estimates utilized in the analysis is summarized below. Further information about the process can be found in the articles listed below [5].
Using Equation 2, the calculation determines the amount of solar radiation at the surface of the PV module at the optimal angle [30].

$$I_s = I \cdot R_B \quad (2)$$

Researchers frequently employ Levelized Cost Analysis (LCOA) as a method in the literature. Consequently, a brief version of the important equations is provided here. For more precise information, please see the Refs. (19,29)

$\dot{Z}$is the cost flow of capital and is calculated by Equation 3, [19,29].

$$\dot{Z} = \dot{Z}^{CI} + \dot{Z}^{OM} \quad (3)$$

Here, $\dot{Z}^{CI}$,the levelized hourly cost of the capital investment is presented. $\dot{Z}^{OM}$, the levelized hourly maintenance and service costs for the solar power facility are displayed.

The current value (PW) of the studied photovoltaic SPP is calculated by Equation 4, [25,32,33].

$$PW = TCI - S \cdot PWF_{(i_{eff},N)} \quad (4)$$

Total capital investment (TCI) is expressed in US$ in Equation 4, and The letter "S" stands for the solar power plants salvage value (Equation 5) [18,30,31].

$$S = TCI \cdot J \quad (5)$$

Here, J; the salvage value ratio, Equation 6 is used to get the SPPs present value factor (PWF) [18,32].

$$PWF = \frac{1}{(1+i_{eff}{}^{N})} \quad (6)$$

The PWF stands for the single payment present-worth factor [24], N, the systems lifetime, is determined to be 25 years, the effective discount rate is i_{eff} and is calculated by Equation 7, [23,33].

$$i_{eff} = (1 + \frac{i}{p})^p - 1 \tag{7}$$

The compound annual interest rate, or P, is a measure of how much money costs. The total credit amount from all sources plus the interest rates set by each source is added to find the cost of money. The cost of money is equal to the interest rate because this approach considers only one source of funding. These are the annual capital expenses of the studies interest rate analysis, which came under the heading of economic data about PV-module-based solar power facilities. This value is obtained through Equation 8 [37].

$$AC = PW \cdot CRF_{i_{eff},N} \tag{8}$$

Recoverability of capital factor, Equation (9) is used to determine CRF [38].

$$CRF = \frac{\mathrm{i}_{eff}(1+\mathrm{i}_{eff})^N}{(1+\mathrm{i}_{eff})^N - 1} \tag{9}$$

For solar power plants $\dot{Z}^T$, the equipment's annualized cost is calculated as in Equation 10, [38,39].

$$\dot{Z}^T = \frac{\emptyset\, AC}{3600\ (s/h)\ \tau\ (h/year)} \tag{10}$$

Where τ, the estimated number of running system hours per year is found. The SPP based on PV modules has maintenance and operation costs of ϕ. The hourly levelized capital investment $\dot{Z}^{CI}$ cost for the SPP is calculated by Equation 11.

$$\dot{Z}^{CI} = \frac{A\,C}{\tau} \tag{11}$$

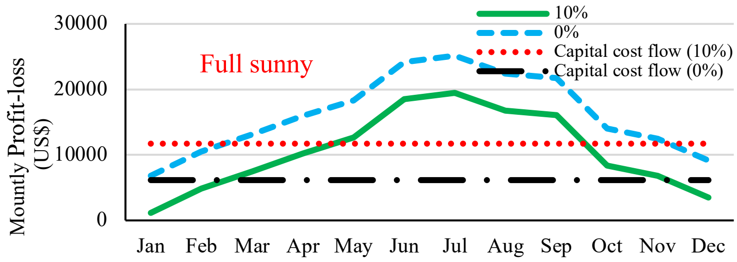
Equation 1, taking into account the operating and maintenance economic aspects, it is applied in the estimation process.

$$\dot{Z}^{OM} = \frac{OM}{\tau} \tag{12}$$

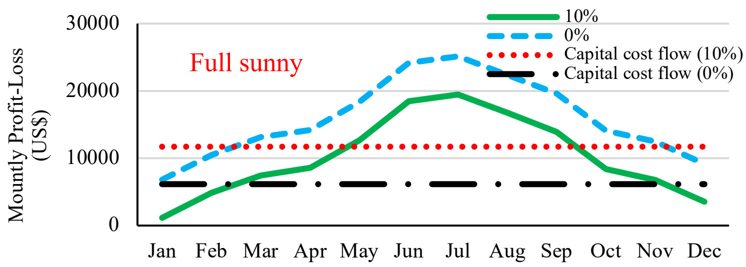
3. Results and Discussion

In present study, the incentive amounts given to solar power plant investors by the Republic of Turkey within the scope of the YEKDEM program year 2022 were analyzed. In the literature, the cost of a 1 MW solar power plant varies between US$ 864,517 - US$ 1,158,040 [34,35]. In this study, the cost value of US$ 864,517 was used for the plant cost. Here, the effects obtained by changing the coefficients and the values calculated with the current coefficient are discussed. In the analysis, the year 2022 was chosen because the inflation values in 2022 were very high. Here, domestic contribution amounts and lower and upper limits of the incentive amount were not taken into account. The calculations show the amounts that the investor should receive according to the current calculation through a direct formula. If the investor exceeds the upper limit of the amount given, a fixed monthly fee of 6.05 cents US$/kWh is applied. This shows that the money he will receive will be much lower than this calculation. However, if the GES materials used are preferred domestically, the incentive amount will increase a little more, which will be in favor of the investor.

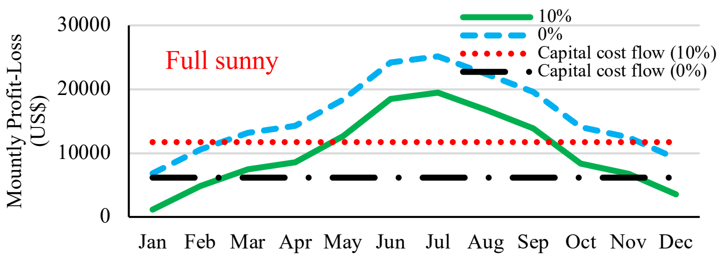
Economic values according to net profit-loss and capital cost flow are given in Figure 1. Figure 1(a) displays the calculated results based on the applied YEKDEM coefficients. Figures 1(b), 1(c), 1(d), and 1(e) present the results obtained under the conditions where the PPI, CPI, US$, and EURO coefficients are set to 20%, 20%, 30%, and 30%; 15%, 25%, 30%, and 30%; 25%, 25%, 25%, and 25%; and 30%, 30%, 20%, and 20%, respectively.



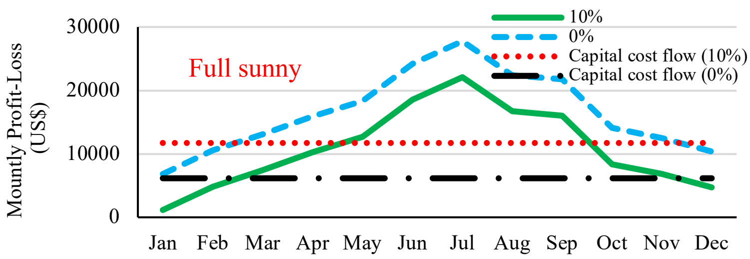
a) PPI, CPI, US$, and EURO coefficient in the valid YEKDEM formula (25, 15, 30, 30%)



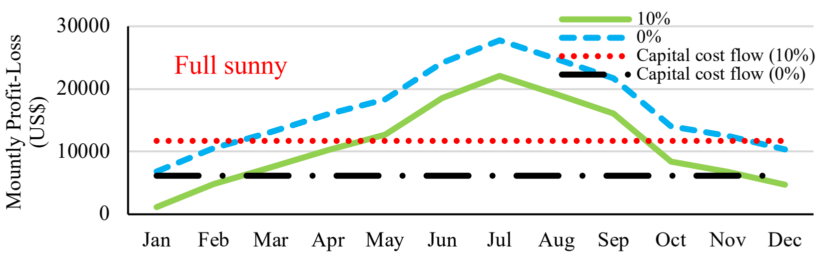
b) PPI, CPI, US$, and EURO coefficient in the YEKDEM formula (20, 20, 30, 30%)



c) PPI, CPI, US$, and EURO coefficient in the YEKDEM formula (15, 25, 30, 30%)



d) PPI, CPI, US$, and EURO coefficient in the YEKDEM formula (25, 25, 25, 25%)



e) PPI, CPI, US$, and EURO coefficient in the YEKDEM formula (30, 30, 20, 20%)

Figure 1. The net profit-loss situation in the coefficient changes for the year 2022.

In Figure 1, calculations were obtained according to capital cost flow, net profit-loss situation and equity and interest rates (10%). If the curve (purchase price) is below the capital cost flow, it shows that the solar power plant investor is losing money, while if it is above it, it shows that the investor is making a profit. Here, it is clear that a power plant established using trade credit costs more to the investor. In other words, the payback period of a power plant established by the investor with his own means is completed in a shorter period of time. It is noticeable from the curves that the investors profit rate is very high in the summer months when solar radiation is high (especially in June, July and August). When a loan is not used, an average profit of almost 10 months is made, while when a loan is used, a profit of only 4-5 months is made. In addition, these profit-loss rates vary according to changes in PPI, CPI, US$, and EURO. The formula that provides the highest total incentive amount to investors is the one with PPI, CPI, US$, and EURO coefficients set at 30%, 30%, 20%, and 20%, respectively (Figure 1(e)).

YEKDEM incentive amounts given between 2018-2023 are given in Fig. 2. The initial application price of YEKDEM was determined by the authorized institution as 106 Turkish lira kuruş/kWh. The incentive amounts to be given without any lower-upper limits (4.95-6.05 cents US$/kWh) are 316.32, 317.57, 302.05, 307.81, 310.59 and 330.83 cents US$/kWh for the years 2018-2023, respectively. The incentive amount given, except for 2020, has increased regularly. This is an expected situation when the formulation variables are taken into account. However, depending on the currency to be given to investors (cents US$/kWh), there may be different reasons for the decrease in 2020. For example, if the incentive was given in TL, this decrease would not have occurred, but the decrease in TL/US$ values together with the sudden increase in the dollar reveals this result. The total incentive amount to be given between these years was found to be 1,885.17 cents US$/kWh. Within the scope of formulation coefficients, the formula that offers the highest incentive amount for investors on a US$/kWh basis is the formula with a coefficient of 30%-30%-20%-20%, while the lowest incentive amount is the formula with a coefficient of 15%-25%-30%-30%. When the lower-upper limit is applied and the incentives are paid in another currency such as TL, there will be some changes in the incentives given with these coefficients. For example, when given in TL, the lowest incentive given is the equation with a coefficient of 20%-20%-30%-30%, while the coefficients giving the highest incentive remain the same as US$. This means that the exchange rate is more dominant than PPI-CPI values. YEKDEM incentive amounts between 2018 and 2023 are given in Figure 2.

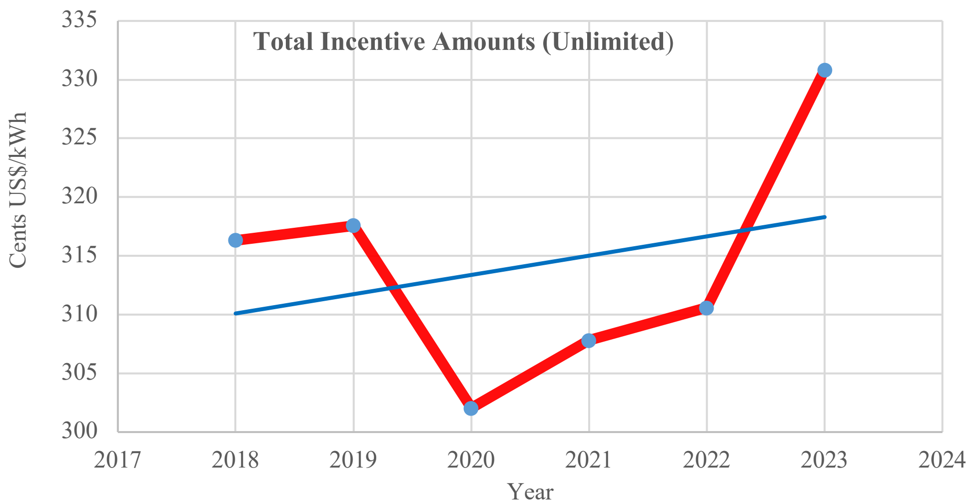


Figure 2. YEKDEM incentive amounts given between 2018-2023.

The total incentive amount to be given between these years (for example, until June 2023) was found to be 1,723.90 cents US$/kWh. This amount is very high compared to the repealed YEKDEM of 2021. According to the YEKDEM of 2021, the total incentive amount to be given between these dates is 180.64 cents US$/kWh. This result shows how correct the removal of the old YEKDEM of 2021 was. In addition, the result of this comparison is shown more clearly in Figure 3 for a better understanding. The reason for such a significant difference between the old YEKDEM and new YEKDEM incentive amounts lies in the effects of the PPI, CPI, Euro, and Dollar coefficients, as well as the differences in YEKDEM application starting prices and payment periods. Investors are now in a more advantageous position compared to the previous YEKDEM.

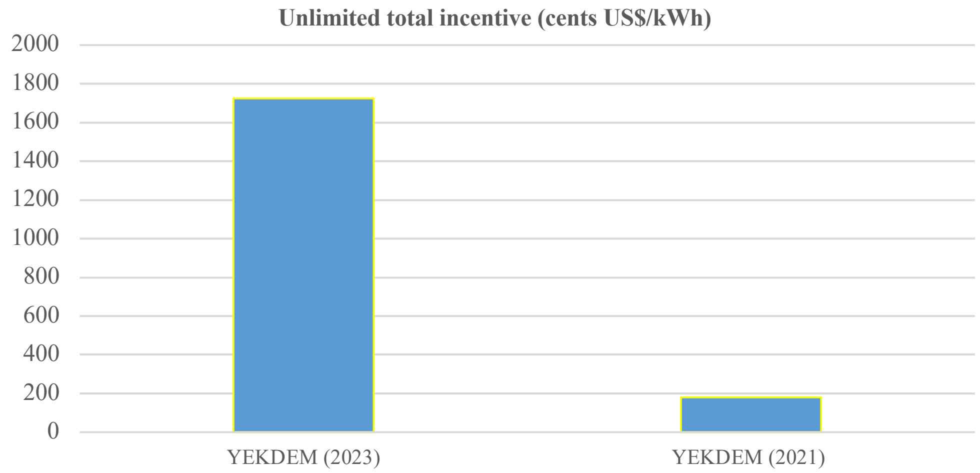


Figure 3. Total incentive amounts to be given between January 2018 and June 2023.

The results of incentive amounts according to the old and new YEKDEM are also reflected in Table 2 data for 2022 (without any lower or upper limits and full sunny).

Table 2. Investment payback period, annual profit-loss situation and total support amounts for 2022.

	YEKDEM (2021)	**YEKDEM (2023)**
Payback period (10%)	54 years	11 years
Payback period (0%)	22.5 years	5.9 years
Yearly profit-loss (10%)	US$ 15,928	US$ 78,229
Yearly profit-loss (0%)	US$ 38,285	US$ 146,176

The difference between the incentive amounts between the two YEKDEMs is striking. It has been understood that the investment payback period is much longer compared to the dated-2021 YEKDEM [27]. For example, the payback periods between the old and last YEKDEM in the non-credit case are 22 years and 6 years. It is seen that the payback period is much longer in credit cases. The payback periods, which are 22.5 and 5.9 years in the credit case, increase to 54 and 11 years. Similarly, the net profit amount in credit and non-credit cases is much higher compared to the last YEKDEM. These rates for credit and non-credit are calculated as US$ 15,928 and US$ 38,285 for YEKDEM dated 2021, and US$ 78,229 and US$ 146,176 for YEKDEM dated 2023, respectively.

4. Conclusions

In this study, a research was conducted on the YEKDEM program currently implemented in Turkey. It was assumed that the weather was completely sunny (cloudless) throughout the year. The data obtained on the implementation of the review program under current conditions in the years 2018-2023, the change of the PPI-CPI-EURO-US$ coefficients in the correlation and the determination of the payback periods of the solar power plant investment were presented. The findings are presented in the form of items.

- Annual earnings vary between US$ 15,928 and US$ 146,176 depending on credit/equity use. But, these values may also change depending on climate and inflation.
- Payback periods are between 5.9 - 54 years depending on credit and equity use. These figures may vary depending on cost and climate conditions.
- The formula that offers the highest incentive amount for investors (the most advantageous to the investor) is the formula with a coefficient of 30%-30%-20%-20%. An update in this direction may be made in the future.

As a result, since the use of commercial credit, the fact that the weather will not be completely sunny, and the negativities caused by inflation will put the investor in a difficult situation, it is recommended to develop a better formula that protects both the investor and the government institutions.

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