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RESEARCH ARTICLE

Techno-Economic Assessment of Grid Sales Constraints on Solar Power Plants Through Capacity Sizing: A Case Study of Türkiye

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ABSTRACT The integration of solar power plants into the electrical grid poses significant challenges, particularly with regard to the sale of excess energy. Inadequately defined tariffs and regulatory scopes can lead to either excessive investment profitability or technical issues affecting grid security. Regulatory frameworks play a crucial role in shaping the feasibility and profitability of solar projects. Until recently, the high purchase guarantees under Türkiye's feed-in tariffs have led to excessive profitability for many producers with low consumption, making solar power plants a highly lucrative investment. To address this issue, a significant regulatory change has been introduced, linking the amount of electricity sold to the amount consumed. As a result, a substantial decline in revenues is expected for numerous power plants. This article examines how the regulatory and technical constraints limiting the sale of excess energy to the grid in Türkiye will impact solar power plants and alter the feasibility of new projects. It explores how restrictions imposed by regulatory authorities influence the optimal sizing of solar investments using technical and financial metrics. Various scenarios are analyzed, including capacity limits, demand profiles, net metering periods, and grid sales constraints, to assess their impact on solar plant design. The findings of this study demonstrate that sales restrictions significantly affect the economic viability and technical configuration of solar projects. Compliance with these regulations often requires adjusting plant size to align generation capacity with permissible sales volumes. The study first establishes that the regulatory change has resulted in substantial revenue losses for existing solar power plants and subsequently provides a framework for structuring future investments. The research concludes with recommendations for optimizing the size of solar power plants under electricity sales-constrained conditions across different scenarios to maximize economic benefits. The results demonstrate that with proper sizing, investment returns can be nearly as high as those in unconstrained sales conditions.

INDEX TERMS Energy policies, feed-in tariffs, electricity sales constraints, PV power plant capacity sizing, economic evaluation.

I. INTRODUCTION

In order to prevent global warming, it was accepted with the approval of 185 countries in the Paris climate agreement to reduce net carbon emissions to zero by 2050 [1]. Solar power plants, a prevalent method of carbon-free clean energy production, are predicted to assume the most significant role in achieving this target. Indeed, over the past decade, the installed power capacity of solar power plants worldwide has increased by 729%, reaching 843.1 GW, thus demonstrating considerable growth. This growth rate is projected to increase by a factor of 20 over the next 25 years [2]. Similarly, in 2022, electricity generated from PV plants reached 1300 TWh with a record increase of 270 TWh (26% increase), surpassing wind for the first time in history and showing the most significant absolute generation increase among all renewable technologies. This generation growth rate matches the level projected from 2023 to 2030 in the Net Zero Carbon

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Emissions scenario. It would require annual capacity additions by 2030 that are close to three times the level in 2022 to maintain a consistent generation growth rate [3].

The energy policies of countries have been a big part of the fast growth of solar PV [4]. But to meet future targets, the public and private sectors will need to work together to deal with the problems of adding solar energy to the grid, including policy, regulation and finance.

Systems that incentivize electricity generation from renewable sources play a critical role in energy policies. Practices such as Feed in Tariffs (FITs), which guarantees renewable energy producers fixed payments per unit of energy supplied to the grid for a certain period, and net energy metering, which reduces the billing burden of users by giving the grid the electricity produced more than their needs, have been adopted as a standard and successful policy tool in many countries [5]. Undoubtedly, the implementation and conditions of these mechanisms (guaranteed purchase period, system limits and tariff prices, etc.) vary according to the type of renewable energy source and the relevant energy legislation of the country. As of 2023, FITs, implemented at national and state/provincial levels, remain the most widely accepted policy to incentivize renewable energy generation. Ninety-two countries and 52 states/provinces have adopted some form of FITs policies [6]. The main reason for the widespread adoption of FITs is the significant investment security offered by their long-term guarantees. However, the rapid increase in installed capacity, especially in solar PV, with these investment incentives causes technical problems such as excessive increase in daytime electricity supplied to the grid and disruption of the grid balance.

On the other hand, incentive mechanisms such as FITs may result in overcompensation and low efficiency if the system is not well regulated and adapted to cost reduction in renewable energy technologies [7]. Especially in the first periods of implementing the policies, the high purchase guarantees combined with falling installation costs led to a rapid increase in investments, and the excessive profitability of these facilities returned to the countries' economy as a financial burden [8]. Therefore, countries try to regulate the system with legal regulations to find a market balance and control the situation by preventing technical problems [9]. Some of these regulations can be listed as reducing tariff prices, limiting installed power, and paying a limited amount of electricity sold to the grid. Each Regulation affects existing system participants and potential investments and requires good feasibility [10].

Similar arrangements have been valid for Türkiye's FITs system called YEKDEM. The system, introduced in 2011 to increase the use of renewable energy resources in electricity generation, has undergone many changes until today. Participation in the system, which is implemented as a mix of net metering and FITs under the name of unlicensed (exempt from obtaining an electricity generation license) electricity generation activities, especially for the benefit of individual users and small investors, has reached 9000 MW as of 2024 [11]. Initially, the installed power capacity was determined to be up to 500 kWp in the system with a purchase guarantee of 13.3 cents/kWh. In the following years, the installed power limit was increased first up to 1 MWp and then up to 5 MWp, and in 2019, the tariff price was equalized with the grid prices. Despite this, the system, which remains a good investment, has been abused, especially by consumers with low electricity consumption to make money [12].

For this reason, the relevant authority in Türkiye, the Energy Market Regulatory Authority (EMRA), limited the electricity sold to the grid and implemented a sell-as-you-consume model. Accordingly, prosumers can pay their bills by netting the electricity they produce and consume monthly. In contrast, the excess electricity will be sold to the grid in a limited way. This is determined as the total electricity consumed by the user in the previous year. If the consumption amount of the previous year is exceeded in the current year, the electricity sale limit will be adjusted by the difference, effective from that month onward. This limitation, which was implemented at the beginning of 2023, will affect the profitability of many solar investors as it applies to all users who joined the system after 2019. Investors with low consumption who installed solar PV at maximum capacity (1 MWp) for maximum profit before the limitation will incur significant losses [13].

In this study, how the grid energy sales restriction introduced by the relevant regulation will affect PV power plants is measured with financial and technical parameters. After that, it has been carried out for the optimal capacity sizing of solar PV plant. In addition, the effect of changes in consumption profiles on the relevant parameters has been analyzed. In another scenario, the monthly and annual netting of generated and consumed electricity are analyzed. Finally, the optimal PV capacity is determined according to consumption needs only in the case of total sales constraint.

The contributions of the paper are as follows:

- This study provides a comprehensive evaluation of the impact of new energy market regulations on solar PV investments, offering valuable insights for policymakers, investors and other market participants.
- By highlighting the financial risks faced by low-consumption investors who installed systems at maximum capacity before the restrictions, it serves as a guide for optimizing future investment decisions.
- The results prove that an optimally sized PV power plant investment can achieve strong performance and profitability, even under sales and capacity constraints.

II. LITERATURE REVIEW

FITs have been introduced in many countries worldwide to encourage interest in renewable energy sources. These incentive mechanisms need to be well calculated. Some FITs mechanisms can lead to excessive profitability, which can destabilize the market and, at the same time, cause technical problems due to excess supply to the grid. In some cases, tariffs may be insufficient [14]. In a study conducted in Serbia, the government's offset and 12-year purchase

guarantee prices were found to be unprofitable for a solar PV investment, and the same result could be reached from the grid prices. In this case, it was suggested that the purchase periods be extended or the guaranteed tariff prices increased at a rate similar to the annual increase in grid prices [15]. In another study, the fact that solar energy FITs prices are based on global weighted average levelized energy costs and local factors are not taken into account has led to an excessive increase in investments, and at the same time, the incentive mechanism is not well defined in terms of capacity, project region, technology type has created an imbalance in system supply [16]. A study examining the FITs policy applied to domestic rooftop solar power plants in Australia suggested that it should be applied differently regionally instead of the tariff being the same throughout the country. Incentive prices should be more attractive in regions with low investments, and relatively lower prices should be given in regions with high investments [17]. It was also argued that to achieve solar penetration targets, higher FITs prices should be offered at the beginning, and then these prices should be gradually reduced to reduce the financial burden of the states. However, an analysis was made in the UK based on a similar scenario. The government, which had been offering reasonable prices for domestic users until recently, lowered the prices with its decision. It was concluded that this would slow down solar growth and increase the tendency towards battery storage PV systems and self-consumption in the long term, thus reducing the electricity drawn from the grid and negatively affecting distribution companies [18]. In another study conducted across Europe, it was observed that the PV market grew rapidly with the attractive FITs system with low tax and high tariff prices since 2008. However, in the following period, this situation collapsed the FITs system as in the case of Spain and was reflected as a net cost to the system. In the post-2014 period, it was observed that additional taxes and the reduction of guarantee prices led to a stagnation in Europe and a decrease in investments. Despite this, it was emphasized that there is still a high potential in the region, and a balance in the market can be achieved with well-thought-out FITs policies [9]. Another critical factor in the constant change and instability of FITs policies has been the decrease in the costs of PV technology over the years. When the high purchase guarantees given in the early periods were combined with the decreasing installation costs, investments rapidly increased, and the excessive profitability of these facilities returned to the countries' economies as a financial burden [19].

Net metering and net billing are other standard incentive methods besides the FITs mechanism [20]. In the early stages of the transition to renewable energy, in order to accelerate this transition, the purchase guarantees given above the FITs system's market prices increased the states' financial burden and disrupted the market balance [21]. Instead, net metering policies enable producers to earn credits by giving their excess electricity to the grid and to pay their electricity consumption bills with this credit. In net billing, the producer receives money from the grid operator for the excess electricity it feeds into the grid. In this method, the kWh value of the electricity given is usually kept at a low level compared to the kWh value of the electricity received, so it is not preferred. Nevertheless, it may be more profitable for a producer with low consumption [22]. The net metering system is in practice in many states, especially in the USA, for household producers who want to reduce their bills. However, there are differences in practice according to the states [23].

Delaware requires all electric utility companies to offer net metering for solar power producers. There are some limitations on how much electricity can be produced with a grid-connected system. Accordingly, the electricity produced by the producer cannot exceed 110% of its 12-month historical energy consumption. In addition, after collecting and using net metering credits for one year, unused credits can be transferred to the next year or sold at a specific price. However, this price is below the one-to-one retail rate associated with net metering [24].

Similarly, for grid-connected solar systems in Maryland, there is a restriction that the owner cannot exceed 200% of the annual electricity use. In other words, if 10000 kWh is used per year, the annual generation capacity of the solar system can be 20000 kWh [25]. In New Jersey and Ohio, this restriction is determined as 100% production equal to consumption. Since users who produce more than consumption are removed from the system, a 95% sizing is preferred in these regions [26]. In Virginia, users must comply with the state's system capacity limit to connect to the grid and benefit from the net metering program. There is an upper limit of 20 kW for residential and 1 MW for non-residential systems. Again, there is a restriction in the Regulation that the capacity of no solar power plant can exceed 100% of the annual electricity use [27].

It is common for the grid operator to impose restrictions on generated power when the nominal power of a solar power plant exceeds the maximum allowed due to grid capacity limitations. Therefore, integrating battery energy storage systems is recommended to minimize power outages in solar power plants [28]. This configuration has been extensively studied in the existing literature, and optimization studies have been performed where battery systems can avoid power constraints [29]. However, although the power constraints can be solved with the battery model, the energy constraints cannot be solved this way because the maximum amount of energy supplied to the grid is determined. Moreover, it has been observed that there is no similar application worldwide regarding the application of a continuously varying limit on the sale of monthly excess energy according to consumption, which constitutes the analysis in this study, and no study has been conducted on the energy constraint of grid-connected PV power plants without battery storage.

III. METHODOLOGY

In this study, a 1 MWp solar PV plant will be designed to meet the electricity demand of a consumption facility, with monthly consumption data provided in Table 1, and to benefit from the feed-in tariff by exporting excess electricity to the grid. Subsequently, the changes in the financial metrics of the investment are compared through an economic analysis, considering both the case where the sale of excess energy is unrestricted and the case with restrictions on grid electricity sales, in accordance with Türkiye's new FITs regulation. After determining the differences between the two scenarios, the objective is to identify the optimal solar power generation capacity that can be installed for the relevant consumption facility, based on the grid energy sales constraints. In the following sections, the analysis is extended to account for changes in consumption profiles and different scenarios.

A. PERFORMANCE CRITERIA

The performance of a grid-connected PV power plant is evaluated by parameters that measure its design and performance efficiency. Such parameters include levelized cost of energy (LCOE), sizing ratio (Rs), and performance ratio (PR). Additionally, economic criteria such as net present value (NPV), internal rate of return (IRR), payback period, and rate of return on investment (ROI) are employed to assess the feasibility of the investment and facilitate comparisons between projects [30].

1) LEVELIZED COST OF ENERGY

LCOE represents the cost per kilowatt-hour of electricity produced by an electricity generation plant. It is often used to compare the costs of different energy sources [31]. Although there are different methods, LCOE is generally calculated by dividing the total cost of a given power generation facility by the amount of electricity generated over the facility's lifetime, as given in equation (1).

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \tag{1}$$

I_t : *Investment expenditures of year t*
M_t : *Operation and maintenance expenses of year t*
E_t : *Amount of energy produced in year t*
r:Discount rate
n:Project lifetime

2) PERFORMANCE RATIO

The performance ratio is a critical metric used to evaluate the efficiency of a solar PV system by comparing the actual energy output to the theoretical energy output under ideal conditions. It is defined as the ratio of the actual energy produced by a solar PV system (Y_f) to the theoretical or reference energy output (Y_r) that would be produced under standard test conditions (STC), assuming no losses. This ratio indicates how efficiently the system can utilize solar energy. A high-performance ratio indicates that the system can utilize solar energy with maximum efficiency. The performance ratio compares solar PV systems regardless of nominal rated power capacity, geographical location, PV module tilt angle, and orientation [32], [33].

$$PR = \frac{Y_f}{Y_r} \tag{2}$$

Actual yield (Y_f) is the real energy output of the system during a given period.

$$Y_f = \frac{Actual\ energy\ produced\ (kWh)}{Installed\ capacity\ (kWp\ or\ m^2)} \tag{3}$$

Reference yield (Y_r) is the theoretical energy output of the system based on the location's solar irradiance, the panel's capacity, and optimal operational conditions.

$$Y_r = \frac{Reference\ energy\ produced\ (kWh)}{Installed\ capacity\ (kWp\ or\ m^2)} \tag{4}$$

3) SIZING RATIO

PV array rated power $P_{PV(rated)}$ over inverter rated power $P_{i(rated)}$ under standard test conditions is commonly used to define the PV system sizing ratio (R_s). The sizing ratio can be calculated according to the following equation (5);

$$R_s = \frac{P_{PV(rated)}}{P_{i(rated)}} \tag{5}$$

The rated power of the PV array, $P_{PV(rated)}$, can be obtained using the following equation [30].

$$P_{PV(rated)} = P_{mpp,stc}.N_S.N_P \tag{6}$$

$P_{mpp,stc}$: *Nominal power of a PV panel under STC*
N_S : *Number of PV panels in series*
N_P :*Number of PV panels in parallel*

4) NET PRESENT VALUE

The net present value of a solar PV investment is the present value of all energy revenues generated over the project's life minus the present value of all costs associated with installation and operation.

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+r)^t} \tag{7}$$

R_t : *Cash flow for year t*
r : *Discount rate*
n : *Project lifetime*

5) INTERNAL RATE OF RETURN

Internal rate of return (IRR) is an essential financial measure used to evaluate an investment's expected return and profitability and helps make investment decisions [34]. When choosing between investments, decisions are made by comparing the internal rate of return of projects. Projects with higher IRR are generally more profitable. The discount rate equals the net present value of the investment to zero.

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+IRR)^t} = 0 \tag{8}$$

R_t : *Cash flow for year t*
IRR : *Internal rate of return*
n : *Project lifetime*
NPV : *Net present value*

6) PAYBACK PERIOD

A payback period is a method of financial analysis that compares the cost of an investment and the return or gain on that investment. It measures how long it takes for an investment to recover its initial cost. In short, it shows the balance point between the cost of the investment and the return achieved. It is a metric frequently used in solar PV projects [35]. The payback period of an investment can be calculated in years from equation (9).

$$\text{Payback Period} = t^* + \frac{\text{Installation cost} - \text{Profit up to year } t^*}{\text{Profit in year } (t^* + 1)} \tag{9}$$

7) RETURN ON INVESTMENT

Return on investment (ROI) is a financial metric that measures a project's profitability. It simply refers to the return on investment compared to the initial cost. It assesses an investment's profitability and compares different investment opportunities. The ROI of a project can be calculated using the formula in equation (10).

$$ROI = \frac{\text{Net profit over the project lifetime} - \text{Initial cost}}{\text{Initial cost}} \times 100 \tag{10}$$

B. DEMAND PROFILE

In this study, it is aimed to meet all the electricity needs of the Electrical and Electronics faculty building in Yildiz Technical University Davutpasha Campus and to sell the maximum amount of excess electricity produced to the grid. In Table 1, the monthly electricity consumption values of the faculty building in kWh are given for the years 2018-2022. Accordingly, while the average electricity consumption in 2018, 2019, and 2022 was 424354.3 kWh, the average in 2020 and 2021 decreased to 320589.9 kWh. In 2020 and 2021, the closure due to the pandemic and the transition to online education caused a decrease in electricity consumption. Figure 1 visualizes the changes in the monthly electricity consumption of the building over the years. Although the total consumption amounts decreased during the pandemic period, it is seen that the consumption profiles are similar throughout the years. During cold months like December, January, and March, the heating demand is high, leading to increased electricity consumption. The coincidence with the semester break explains the decrease in February. With the warming weather in April, electricity consumption decreases, reaching its lowest levels in May. After June, extreme heat in the region increases air conditioner usage, leading to a rise in electricity consumption during the summer months. In July electricity consumption reaches its seasonal peak. Since it is a faculty building, it is not expected that there will be significant changes in the electricity demand of the building over the years.

TABLE 1. Five-year electricity consumption data.

kWh	2018	2019	2020	2021	2022
January	40505.1	42902.0	38529.3	28360.6	41236.9
February	36635.0	38289.2	37510.1	24095.6	34353.7
March	36059.0	38863.0	30270.9	28917.1	45462.2
April	30737.1	34227.9	19973.8	22238.4	31567.5
May	26835.0	31946.7	15209.5	17619.0	28674.5
June	29439.5	34946.6	18917.3	20631.3	34722.2
July	35966.3	41097.0	20050.3	32094.1	31721.5
August	34035.9	35618.1	21934.5	38806.7	37058.5
September	34583.9	35254.6	20859.8	27307.4	29678.9
October	33203.6	31584.9	20351.4	28280.3	29236.7
November	37024.8	30683.2	24281.1	34998.7	34420.8
December	45977.2	37710.4	29209.7	40732.6	40803.8
Total	421002.4	433123.5	297097.7	344082.0	418937.0

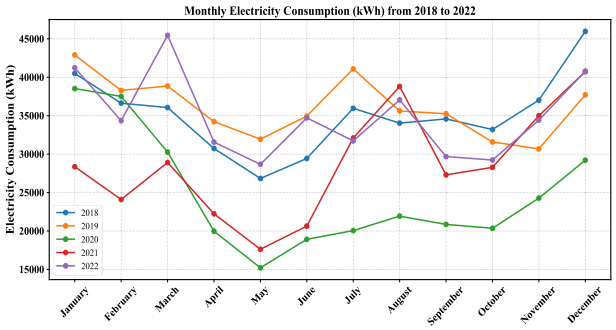


FIGURE 1. Monthly electricity consumption profiles by years.

C. INSTALLATION AREA

The coordinates of the solar PV plant planned to be installed on the land within Yildiz Technical University Davutpasa Campus is located at the coordinates 41°01'14.02'' N latitude and 28°53'43.78'' E longitude [36]. The satellite image of the area, shown in Figure 2, reveals that the location is open land and free from any obstructions in the southern direction that could cause shading.



FIGURE 2. PV system installation area.

The solar irradiance reaching the panel surface throughout the year data of the installation area obtained from

the national solar energy potential data center is presented in Figure 3. Accordingly, the highest radiation in July is 208.8 kWh/m^2. Additionally, the region experiences the highest average sunshine hours in July, with an average of 10.89 hours per day [37].

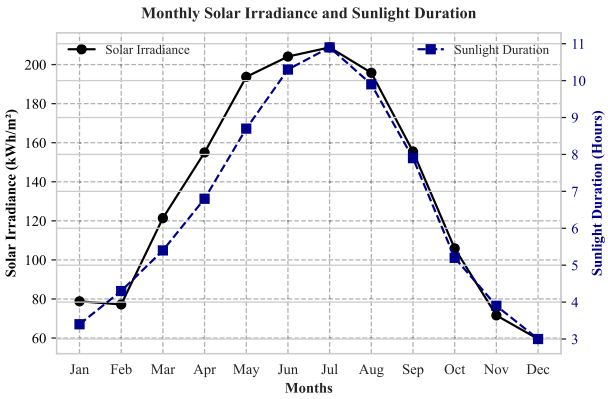


FIGURE 3. Irradiance values incident on the panel surface at 30° tilt and 0° azimuth angles and monthly average sunshine hours of the region.

D. PV PLANT MODELING

The PVsyst 7.4 program is used for the design and simulation of the solar PV plant [38]. The energy produced from this PV system will meet the electricity needs of the faculty building and the excess electricity will be sold to the grid in accordance with the regulations.

The decision to start the design with an installed capacity of 1 MWp is based on the fact that it is the maximum capacity allowed to be installed in the incentive system and also 1 MWp is the most common capacity for solar PV plants in Türkiye. It is also considered to be the most profitable capacity, as the guaranteed tariff applies to all electricity produced within this limit until the new regulations are adopted.

E. PANEL AND INVERTER SELECTION AND SYSTEM DESIGN

In the design of the 1 MWp solar PV plant, 140 strings are formed, each consisting of 21 series modules oriented at 30° tilt and 0° azimuth, connected in parallel. A total of 2940 modules and 7 inverters are used in the design. The technical information of Trina Solar 340 Wp monocrystalline PV panel and Huawei 125 kW inverter model used in the PV system designs in this study are given in Table 2. Thermal losses are assumed to be 29 W/m^{2}K for a ground-mounted PV system equipped with all-weather modules. The DC voltage drop is determined to be 1.5%, while the AC voltage drop is 0.5%. Module mismatch losses are defined as 2% and dust losses are assumed to be 1%. Aging loss is not specified in this section, but it is projected to decrease linearly with a −0.8% reduction compared to first year production in the economic analysis section. For shading losses, the horizon shading of the plant area is obtained from the PVGIS database for far shading analysis. Near shading analysis is not performed, as there are no objects in close proximity to the installation area.

TABLE 2. PV panel and inverter specifications.

PV Panel		Inverter	
Trina Solar DE14A-(II)-340		Huawei SUN2000-125KTL-M0	
Pmax	340 Wp	Vmin MPP	200 V
Vmpp	38.2 V	Vmax MPP	1000 V
Impp	8.9 A	Vmax Array	1100 V
Voc	46.2 V	Efficiency η	98.8%
Isc	9.5 A	Grid Voltage	400 V
Efficiency η	19.44%	Grid Frequency	50 Hz
Cell Type	Si-mono	Pnom AC	125 kWac
Module Area	1.77 m2	Pmax AC	138 kWac

F. ECONOMIC ANALYSIS AND FINANCIAL PARAMETERS

In this study, it is first assumed that the 1 MWp power plant operates without any sales restrictions under the previous regulation, allowing all excess electricity generated after monthly netting to be sold to the grid at the guaranteed tariff. Once the electricity production and consumption values have been subtracted and the amount of electricity that can be sold due to monthly net metering has been determined, a financial analysis of the power plant investment will be conducted, and the previously mentioned metrics will be evaluated. For a grid-connected, ground mounted solar PV plant, the installation cost is assumed to be 1.06 $/Watt, while the operation and maintenance costs are estimated at 13 $/kWdc-year [39], [40]. It is assumed that the electricity demand of the faculty building, which has electricity consumption data for the last five years presented in Table 1, will repeat the same values every five years, with the generation plant commissioned in January 2023. The monthly electricity generation amounts for the power plant in the first year are projected to decrease linearly with an annual aging factor of 0.8% throughout the solar PV plant's lifetime.

As of January 1, 2023, Energy Market Regulatory Authority in Türkiye published a single-time middle voltage public and private sector tariff of 3.6308 TL/kWh, with the dollar exchange rate on the same date being 18.70 TL/$. It is assumed that license-exempt electricity sales will continue at the same tariff rate at the end of the ten-year YEKDEM FITs period [41]. The PV panels and inverters used in the power plant are assumed to be depreciated on a 25-year straight-line basis, with their scrap value set at zero. A financial analysis will be conducted in USD, and an inflation rate of 3% will be considered. Electricity tariff prices are assumed to increase at the same rate as annual inflation in dollar terms. The parameters to be used in the financial analysis, including project life, discount rate, tax rate, panel and inverter prices,

and electricity tariff prices in dollars, are summarized in Table 3 [42].

TABLE 3. Tariffs and financial parameters.

Project Lifetime	25 years
Installation Cost	1.06 $/Watt
Operation and Maintenance Cost	13 $/kWdc-year
Discount Rate	3%
Inflation Rate	3%
Income Tax	20%
PV Module Price	250 $
Inverter Price	4500 $
Electricity Tariff Price	0.197 $/kWh

In the next stage, the same solar PV plant will undergo an economic analysis based on the grid electricity constraints introduced by the new regulation. According to this new rule, the user will be allowed to sell surplus electricity to the grid up to the total annual consumption from the previous year. Any electricity produced beyond this limit will be provided to the grid free of charge. Additionally, under the sales restriction regulations of the new regulation, if the total electricity consumption in any month of the current year exceeds last year's consumption, the excess amount will be added to the sales limit starting from that month. The production and consumption figures will be entered into a table created in Excel to determine the excess production amounts eligible for sale each month.

G. RESIZING

While all the excess electricity produced by a 1 MWp power plant is sold to the grid when there is no restriction, a significant portion of the energy produced by a 1 MWp power plant is given to the grid free of charge after the application of sales restrictions, as analyzed in detail in the next section. The results of the economic analysis show that the revenues of the 1 MWp solar investment are significantly reduced in case of constraint. As a result, the production capacity of the solar PV system must be sized to meet the needs of the consumer while not exceeding the limits for selling excess electricity.

Under the new regulation, the ideal capacity for a solar PV plant should satisfy the consumption needs while generating enough energy to sell to the grid. In other words, the energy transmitted to the grid after netting should equal the energy consumed. This approach ensures that the maximum amount of electricity can be sold without supplying free electricity to the grid. The average energy requirement of the consumption facility, as presented in Table 1 for the last five years, is 382848.5 kWh. Assuming no significant changes in the energy needs of the facility, which is a faculty building, over the 25-year lifespan of the power plant—and that the load profile will remain consistent—the installed capacity of the power plant should be designed to meet this demand and allow for the sale of an equivalent amount of energy. Thus, the ideal capacity is to generate an average of 2×382848.5 kWh of energy per year. Figure 4 illustrates the flow diagram for determining the plant's optimal capacity in case of grid sales constraints.

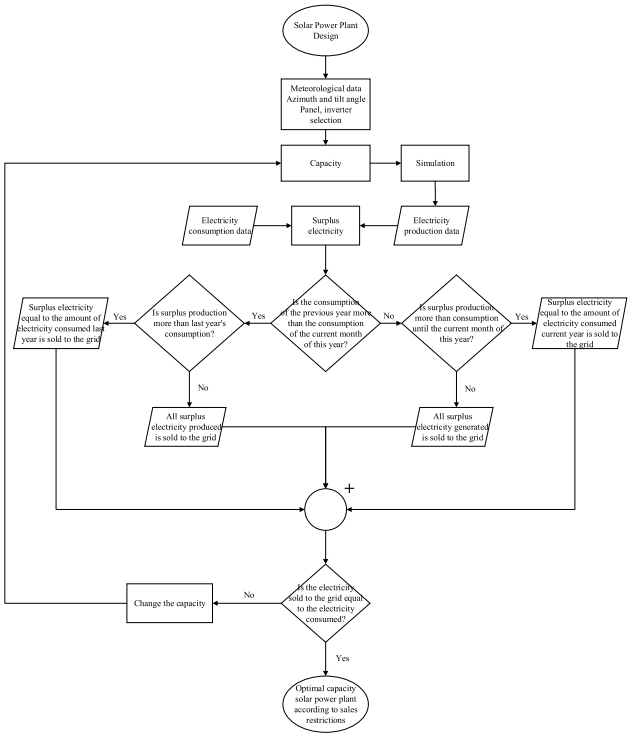


FIGURE 4. Block diagram of the optimal sizing process.

IV. ANALYSIS AND RESULTS

A. ANALYSIS OF 1 MWP PLANT WITHOUT SALES RESTRICTION

After the system design is completed, a simulation is run to obtain the production, loss, and performance outputs for the 1 MWp solar PV plant. According to the results shown in Table 4, the plant generated 1401.7 MWh of electricity in the first year, with an average performance ratio of 0.862. The highest electricity generation occurred in July.

Throughout the year, the global horizontal irradiation (GHI) is 1470 kWh/m^2. By positioning the panels with a 0° azimuth and a 30° tilt, an additional 10.7% (157.29 kWh/m^2) of irradiation is captured, resulting in a total of 1627.29 kWh/m^2 on the surface of the modules. After accounting for shading, dusting, and reflection losses, the effective irradiation reaching the panels is 1572 kWh/m^2. Multiplied by the total module area of 5716 m^2, this gives the total solar energy incident on the PV cells.

With a module electrical conversion efficiency of 17.49%, the nominal energy generated in the PV arrays amounted to 1572250 kWh. This value is further reduced by electrical losses, including temperature losses (4.5%), irradiance losses (0.7%), module mismatch losses (2.1%), light-induced

degradation (LID) losses (2%), and ohmic losses (1%), which affect the energy reaching the inverter input.

After deducting inverter losses (1.4%) and AC cable losses (0.3%), the net useful electricity generated from the system at the end of the first year is simulated to be 1401737 kWh.

TABLE 4. Simulation results of the 1 MWp solar PV plant.

Month	GlobHor (kWh/m²)	DiffHor (kWh/m²)	T_Amb (°C)	GlobInc (kWh/m²)	GlobEff (kWh/m²)	EArray (kWh)	E_Grid (kWh)	PR (ratio)
January	50.6	24.97	6.27	78.8	76.4	73223	72044	0.915
February	59.9	37.88	6.61	77.2	74.7	71616	70502	0.914
March	104.1	61.08	9.14	121.4	117.2	110795	109060	0.899
April	143.8	74.65	12.68	155.0	149.6	139194	136941	0.884
May	194.0	76.56	18.11	193.7	187.1	168573	165632	0.855
June	212.8	83.76	22.87	204.1	197.0	174531	171451	0.840
July	213.9	77.39	26.41	208.8	201.6	175309	172027	0.824
August	183.8	73.89	26.94	195.8	189.2	164708	161654	0.826
September	132.4	57.21	21.83	155.5	150.2	133588	131276	0.845
October	82.8	47.45	17.02	105.9	102.5	94302	92829	0.877
November	50.6	31.02	12.64	71.6	69.3	65115	64122	0.896
December	41.1	27.33	8.38	59.5	57.6	55029	54201	0.912
Year	**1469.9**	**673.18**	**15.77**	**1627.2**	**1572.4**	**1425983**	**1401740**	**0.862**

Figure 5 illustrates the electricity production from the 1 MWp solar PV plant, the electricity consumption of the faculty building, and the netting values over the first five years in a scenario without sales restrictions. The power plant's generation is sufficient to meet the consumption facility's energy demands each year. As a result of monthly netting, no consumption is subject to invoicing. All surplus electricity—calculated as the difference between generation and consumption on a monthly basis—is purchased by the grid operator at the guaranteed tariff under the scenario where no sales restrictions apply.

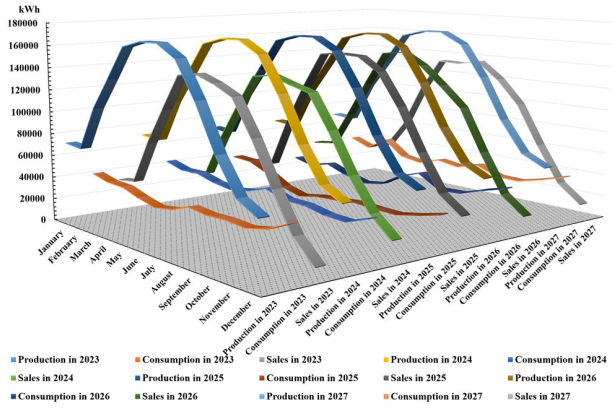


FIGURE 5. Net metering values of the 1 MWp solar plant without sales restriction.

After determining the quantities subject to sale, the investment's cost, electricity sales, depreciation, tax, bill savings, cumulative profit, and payback period over the 25-year project life are detailed in Table 5. According to these results, the net present value (NPV) of the 1 MW solar power plant, with an installation cost of 1060000 $ is calculated at 4183915 $ under the scenario without grid sales restrictions. The payback period of the investment is 4.7 years, with a return on investment (ROI) of 394.71%, an internal rate of return (IRR) of 24.5%, and a levelized cost of energy (LCOE) of 0.062 $/kWh.

TABLE 5. Financial performance of 1 MWp SPP without sales restrictions.

Installed Power	1 MWp
Performance Ratio	0.862
Sizing Ratio	1.142
Net Present Value ($)	4183915 $
LCOE ($/kWh)	0.062
Payback Period (Year)	4.7
Internal Yield Rate (%)	24.48%
Return on Investment (%)	394.71%
Production (MWh)	31876.9
Consumption (MWh)	9571.2
Sold to the Grid (MWh)	22305.6
Uncompensated Grid Supply (MWh)	0
Purchased from the Grid (MWh)	0

B. ANALYSIS OF 1 MWP PLANT IN CASE OF SALES RESTRICTION

Figure 6 shows the amount of electricity subject to monthly sales under the new Regulation's limitation on surplus electricity sold to the grid, alongside production and consumption data. To explain the restriction scenario, net metering is applied as usual until June 2023, and all surplus electricity is sold. However, in June, only 35529 kWh of the 142012 kWh surplus could be sold, while the remaining amount is supplied to the grid free of charge. This occurred because by June, the total electricity sold in 2023 had already matched the total consumption from the previous year. Consequently, no further sales to the grid are made until December. In December, since total consumption in 2023 exceeded last year's consumption, the surplus of 2065 kWh is sold to the grid.

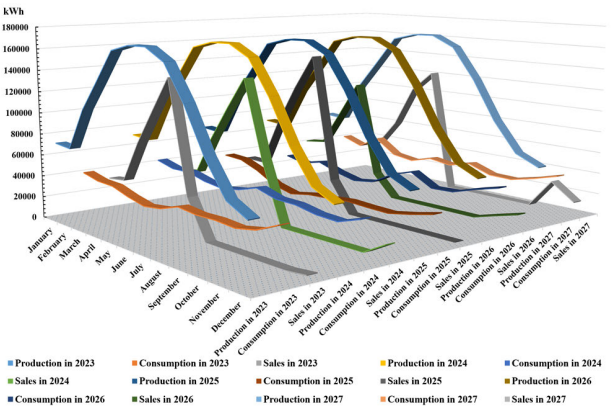


FIGURE 6. Net metering values of the 1 MWp solar plant with sales restriction.

Table 6 presents the financial performance of the 1 MWp solar PV plant under sales restriction conditions. In this case, the net present value of the 25-year investment is 2222385 $. The payback period of the investment is 7.9 years, the return

on investment is 209.66%, the internal rate of return is 15.2%, and the levelized energy cost is 0.102 $/kWh.

TABLE 6. Financial performance of 1 MWp SPP with sales restrictions.

Installed Power	1 MWp
Performance Ratio	0.862
Sizing Ratio	1.142
Net Present Value ($)	2222385 $
LCOE ($/kWh)	0.102
Payback Period (Year)	7.9
Internal Yield Rate (%)	15.16%
Return on Investment (%)	209.66%
Production (MWh)	31876.9
Consumption (MWh)	9571.2
Sold to the Grid (MWh)	9859.4
Uncompensated Grid Supply (MWh)	12446.3
Purchased from the Grid (MWh)	0

C. ECONOMIC ANALYSIS AFTER RESIZING

In the previous section, financial metrics showed that a significant portion of the energy produced by the 1 MWp solar PV plant after the sales restriction application is given to the grid free of charge, and as a result, the revenues decreased dramatically. In this case, the power plant's generation capacity is determined to be 600 kWp according to the methodology described in the methodology section based on the needs of the consumption facility.

Table 7 presents the production amounts obtained from the PVsyst simulation of the 600 kWp solar PV plant. The results indicate that the total electrical energy produced by the 600 kW power plant at the end of the first year is 841750 kWh, which is significantly higher than the average consumption of 765697 kWh. This increase is attributed to the consideration of efficiency losses due to module aging when determining the generation capacity. Assuming a production decrease of 0.8% per year over the plant's lifetime, the average production over 25 years is calculated to be 765687.3 kWh/year.

TABLE 7. Simulation results of the 600 kWp solar PV plant.

Month	GlobHor (kWh/m²)	DiffHor (kWh/m²)	T_Amb (°C)	GlobInc (kWh/m²)	GlobEff (kWh/m²)	EArray (kWh)	E_Grid (kWh)	PR (ratio)
January	50.6	24.97	6.27	78.8	76.4	43934	43261	0.916
February	59.9	37.88	6.61	77.2	74.7	42970	42332	0.915
March	104.1	61.08	9.14	121.4	117.2	66477	65488	0.900
April	143.8	74.65	12.68	155.0	149.6	83516	82236	0.885
May	194.0	76.56	18.11	193.7	187.1	101143	99472	0.856
June	212.8	83.76	22.87	204.1	197.0	104719	102961	0.844
July	213.9	77.39	26.41	208.8	201.6	105185	103308	0.825
August	183.8	73.89	26.94	195.8	189.2	98825	97076	0.827
September	132.4	57.21	21.83	155.5	150.2	80153	78833	0.845
October	82.8	47.45	17.02	109.5	102.5	56581	55740	0.877
November	50.6	31.02	12.64	71.6	69.3	39069	38500	0.897
December	41.1	27.33	8.38	59.5	57.6	33017	32542	0.912
Year	**1469.9**	**673.18**	**15.77**	**1627.2**	**1572.4**	**855589**	**841750**	**0.863**

Figure 7 shows the first five years of production of the 600 kWp resized solar power plant and the net metering values when there is sales restriction. Consequently, despite a reduction in the quantity of electricity generated due to the decline in capacity, there is no significant change in the amount of electricity sold to the grid.

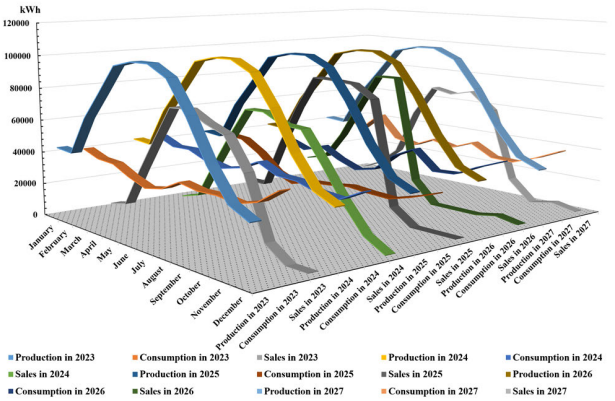


FIGURE 7. Net metering values of the 600 kWp solar plant with sales restriction.

Table 8 presents the results of the economic analysis based on the revenues generated from sellable electricity and bill savings, calculated over 25 years in relation to the electricity production of the solar power plant and the energy needs of the consumption facility. The installation cost of the 600 kWp solar power plant is 636000 $ and the operation and maintenance cost is 7800 $/year at the beginning of 2023. According to the economic analysis, the net present value of the power plant with a cost of 636000 $ is 2500631 $ at the end of 25 years. The payback period of the investment is 4.9 years, the return on investment is 393.18%, the internal rate of return is 24.1%, and the levelized energy cost is 0.065 $/kWh.

TABLE 8. Financial performance of 600 kWp SPP with sales restrictions.

Installed Power	600 kWp
Performance Ratio	0.863
Sizing Ratio	1.2
Net Present Value ($)	2500631 $
LCOE ($/kWh)	0.065
Payback Period (Year)	4.9
Internal Yield Rate (%)	24.11%
Return on Investment (%)	393.18%
Production (MWh)	19142.2
Consumption (MWh)	9571.2
Sold to the Grid (MWh)	8909.8
Uncompensated Grid Supply (MWh)	961.4
Purchased from the Grid (MWh)	300.2

Figure 8 illustrates the 25-year energy flows for the 1 MWp solar PV, comparing scenarios with and without sales restrictions, as well as for the 600 kWp PV with optimized capacity. Following the implementation of grid sales restrictions, the 1 MWp PV supplied 12446 MWh of its total 31877 MWh electricity generated to the grid free of charge, while 9859 MWh is sold. In contrast, the 600 kWp solar PV generated 19142 MWh, with only 961 MWh supplied to the grid free of charge and 8910 MWh sold.

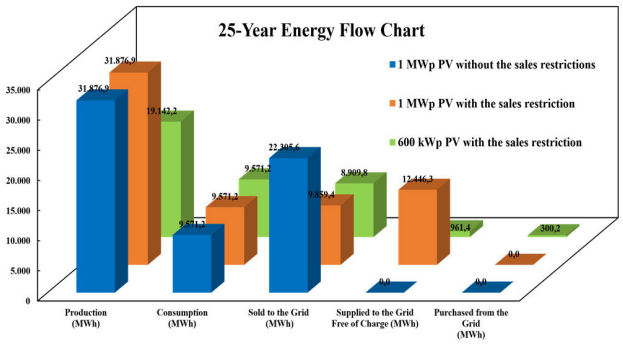


FIGURE 8. Energy flows of the 1 MWp and 600 kWp solar PV plants according to the sales restricted regulation.

Additionally, 300 MWh is withdrawn from the grid and invoiced.

Figure 9 shows the cash flow graph of the three cases. Accordingly, with the grid sales limits introduced by the new regulation, the cash flows of the 1 MWp solar power plant have decreased significantly. The 600 kWp solar power plant with optimized installed capacity is both more cost-effective and more profitable.

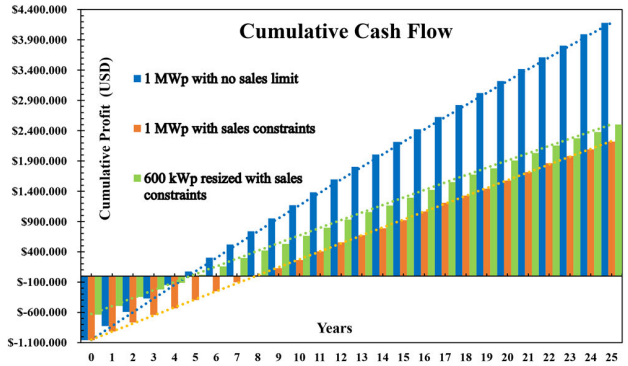


FIGURE 9. Cumulative cash flows of 1 MW and 600 kW PV power plants according to the sales restricted regulation.

Figure 10 shows the comparison of the 1 MWp and 600 kWp solar PV plants based on both performance and economic parameters under the sales restriction rules.

In summary, the design of a solar PV plant is developed to achieve the highest production return with a maximum installed capacity of 1 MWp, based on the unrestricted tariff. A financial analysis is conducted under the assumption that all surplus electricity could be sold. Subsequently, this analysis is repeated, taking into account the amount of electricity subject to sale after netting, according to the new grid sales restriction rules. Following the implementation of these restrictions, significant declines are observed in both the lost value and financial metrics of the same investment. After identifying these differences, the optimal plant capacity is determined based on the consumption facility's needs in the new context. The PV system design is thus optimized to meet consumption requirements while maximizing energy sales

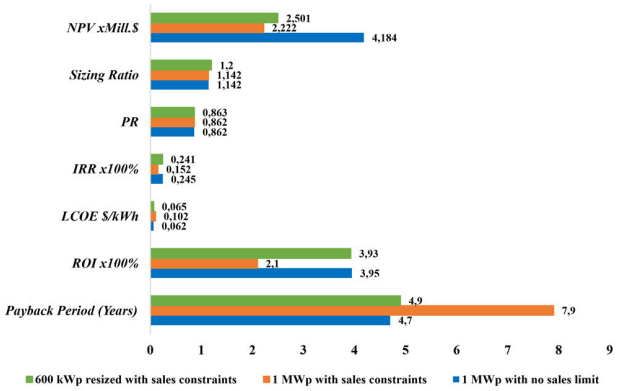


FIGURE 10. Technical and financial evaluation of 1 MWp SPP (sales restrictions vs. no sales restrictions) and 600 kWp SPP sized according to sales restrictions.

to the grid within the established sales limits. The financial analysis results and total energy flows corresponding to the resized capacity of 600 kWp are presented in Table 9.

TABLE 9. Financial metrics and energy flows of maximum capacity and optimal capacity solar power plant investments according to grid electricity sales conditions.

Parameters	No Sales Restrictions	Sales Restriction	Sales Restriction
Installed Power	1 MWp	1 MWp	600 kWp
Performance Ratio	0.862	0.862	0.863
Sizing Ratio	1.142	1.142	1.2
Net Present Value ($)	4183915 $	2222385 $	2500631 $
LCOE ($/kWh)	0.062	0.102	0.065
Payback Period (Year)	4.7	7.9	4.9
Internal Yield Rate (%)	24.48%	15.16%	24.11%
Return on Investment (%)	394.71%	209.66%	393.18%
Production (MWh)	31876.9	31876.9	19142.2
Consumption (MWh)	9571.2	9571.2	9571.2
Sold to the Grid (MWh)	22305.6	9859.4	8909.8
Free Grid Supply (MWh)	0	12446.3	961.4
Purchased from the Grid (MWh)	0	0	300.2

Despite approximately 40% less energy production due to resizing the plant capacity, the electricity sold to the grid decreased by only 9.6% compared to the 1 MWp solar PV power plant. In contrast, the electricity supplied to the grid free of charge dropped significantly from 12446.3 MWh to 961.4 kWh.

D. ECONOMIC ANALYSIS ACCORDING TO CONSTANT CONSUMPTION SCENARIO

In this section, it is assumed that the average consumption of the last five years, as given in Table 1, is consumed in equal monthly amounts, under the scenario that the electricity demand of the consumption facility is constant. In this way, if the previous year's consumption is exceeded, taking the current year's consumption values as a basis will be eliminated, and sales will be made according to the same limit every year. For that reason, the average consumption of 382848.5 kWh of electricity over the last five years, as shown in Table 1, is distributed evenly, with 31904 kWh consumed monthly, and the economic analysis is repeated. The energy

values produced, consumed and allowed to be sold for this scenario are shown in the graph in Figure 11.

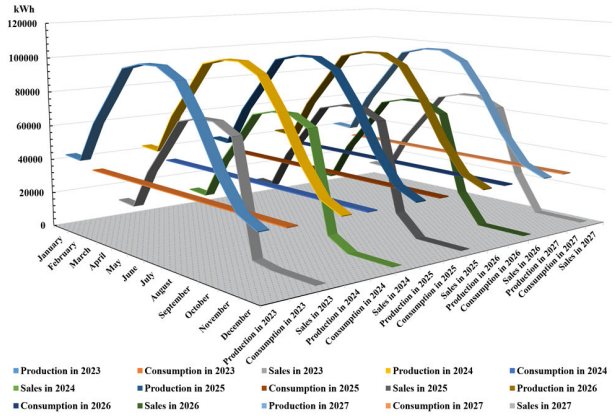


FIGURE 11. Net metering values of the 600 kWp solar PV plant according to the fixed consumption scenario with sales restriction.

According to the economic analysis results, the net present value of the 600 kWp solar PV plant at constant consumption is 2584256 $. The investment's payback period is 4.8 years, the return on investment is 406.33%, the internal rate of return is 24.2%, and the levelized cost of energy is 0.064 $/kWh.

Figure 12 shows the total energy flows for 25 years for actual consumption and average fixed consumption cases. Although the total production and consumption are the same, 229 MWh more energy is sold to the grid for monthly fixed consumption. The amount of energy given to the grid free of charge decreased by 470.3 MWh, and the amount of energy invoiced to the consumer by the grid decreased by 241.3 MWh. As a result of this, the cash flow graph, based on two different consumption patterns, is given in Figure 13.

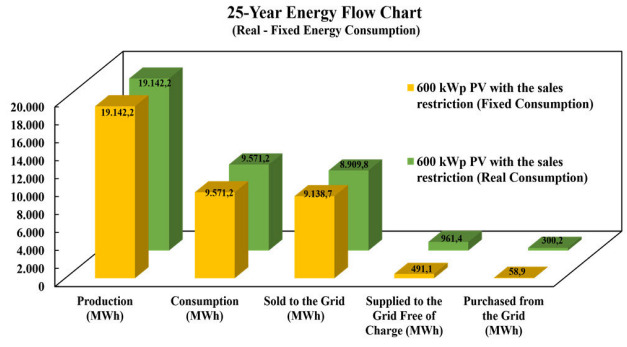


FIGURE 12. Energy flows of the 600 kWp solar PV plant under the actual electricity consumption and fixed electricity consumption scenarios.

E. ECONOMIC ANALYSIS ACCORDING TO SEASONAL CONSUMPTION SCENARIOS

In this section, the effects of grid sales restrictions on PV system investments are examined by considering seasonal scenarios. A comparison is made by focusing on two different

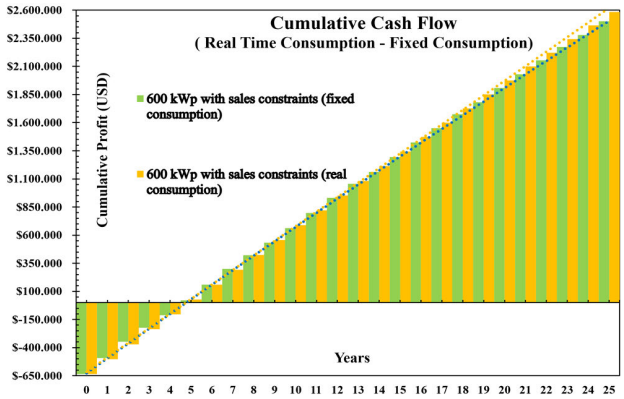


FIGURE 13. Cumulative cash flows of the 600 kWp solar PV plant according to the fixed consumption scenario with sales restriction.

scenarios as high electricity consumption in summer and high electricity consumption in winter.

1) SUMMER CONSUMPTION SCENARIO

Under the high consumption in summer scenario, a five-year consumption profile is created by rearranging the consumption data in Table 1 on a monthly basis, reflecting the highest consumption in summer and the lowest in winter. This scenario aims to measure the impact on sales revenues of increased consumption with generation in summer months under grid sales constraints. The net metering values of the 600 kWp solar power plant generation amounts using the summer consumption profile data is presented in Figure 14.

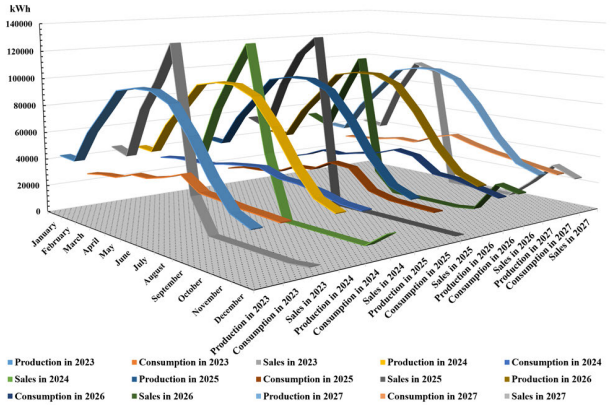


FIGURE 14. Net metering values of the 600 kWp solar PV according to the summer consumption scenario with sales restriction.

The economic analysis results indicate that the net present value of the 600 kWp solar PV plant is 2549558 $ after calculating the amount of electricity available for sale and the savings from net metering. The investment has a payback period of 4.8 years, a return on investment of 400.87%, an internal rate of return of 24.5%, and levelized energy cost of 0.064 $/kWh.

2) WI NTER CONSUMPTION SCENARIO

In contrast to the summer consumption profile, the winter consumption profile rearranges the electricity consumption data in Table 1 so that the highest consumption occurs in winter and the lowest in summer, while maintaining the same annual totals. Figure 15 shows the determination of the electricity subject to sale by netting, considering the demand of the consumption facility for the 600 kWp PV system during periods of low production and high consumption in winter, and high production and low consumption in summer.

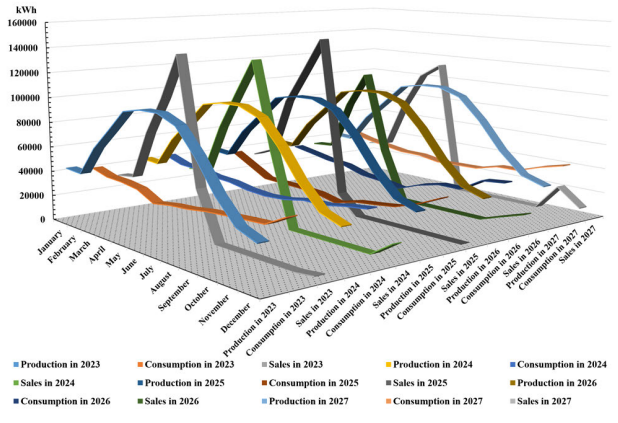


FIGURE 15. Net metering values of the 600 kWp solar PV according to the winter consumption scenario with sales restriction.

According to the economic analysis results for this scenario, the net present value of the 600 kWp SPP is 2481923 $ after determining the amount of electricity available for sale and the number of bills saved through net metering. The payback period for the investment is 4.9 years, the return on investment is 390.24%, the internal rate of return is 23.9%, and the levelized energy cost is 0.066 $/kWh.

The amounts of energy produced, consumed, sold, supplied to the grid for free, and purchased from the grid during the 25-year lifetime of the PV project, obtained according to the summer, winter, and actual consumption profile scenarios, are shown in Figure 16. It is observed that the amount of energy supplied to and purchased from the grid is the lowest in the increasing consumption profile in summer, while the amount of energy sold to the grid decreases slightly compared to the other scenarios. In the winter consumption profile, although the amount of energy sold to the grid partially increased, the amounts of energy supplied to and purchased from the grid remained higher than in the other scenarios. According to the cash flows presented in Figure 18, the most financially ideal scenario among the three cases is the summer consumption profile, while the lowest return scenario is the winter consumption profile.

Figure 17 shows the cash flows of the 600 kWp solar power plant according to the three different consumption scenarios. Figure 18 illustrates the differences in the financial metrics of the solar power plant based on various consumption profiles under the sales restrictions, including the fixed consumption

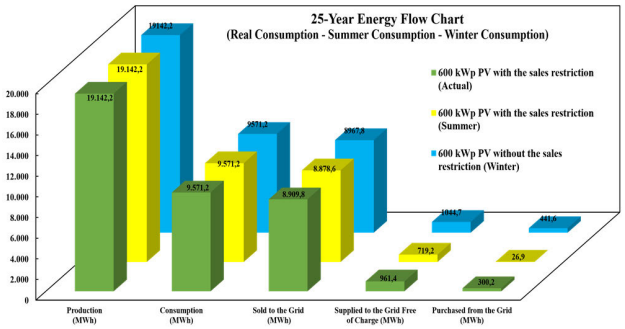


FIGURE 16. Energy flows of the 600 kWp solar PV according to the summer, winter and actual consumption scenarios.

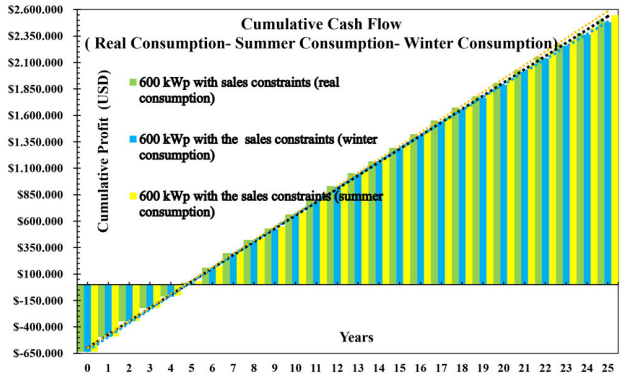


FIGURE 17. Cumulative cash flows of the 600 kWp solar PV according to the summer, winter and real consumption scenarios.

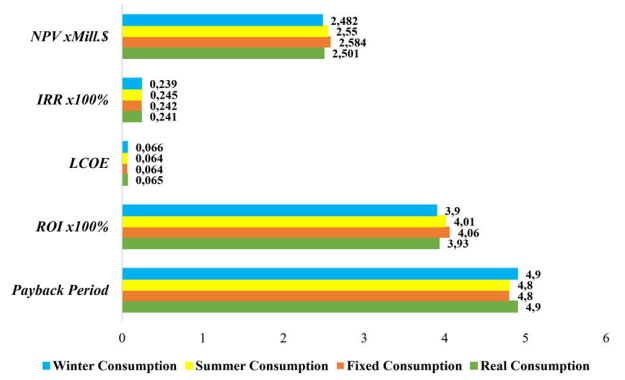


FIGURE 18. Comparison of the economic results according to different consumption scenarios.

scenario. Although the differences are minor, the fixed consumption scenario offers the best return, while the winter consumption scenario yields the lowest return.

F. ANNUAL NET METERING SCENARIO

In this part, the amounts of electricity produced and consumed are net metered annually instead of monthly. Accordingly, financial analysis results have been obtained for both 1 MWp and 600 kWp PV systems, based on the amount of energy that can be sold annually through net metering in the presence of grid sales limitations.

According to the annual net metering, the net present value of the 1 MWp solar PV investment with a cost of 1060000 $ is 2284158 $, the payback period of the plant is 7.8 years, the return on investment is 215.49%, the internal rate of return is 15.4%, and the levelized energy cost is 0.102 $/kWh.

The financial metrics of the 600 kWp solar PV project with a cost of 636000 $ are calculated as a net present value of 2575931 $, a payback period of 4.7 years, a return on investment of 402.02%, an internal rate of return of 24.74% and a levelized energy cost of 0.065 $/kWh.

Figure 19 shows the total energy flows of both the 1 MWp and 600 kWp solar PV systems according to the monthly and annual net metering under the sales restriction.

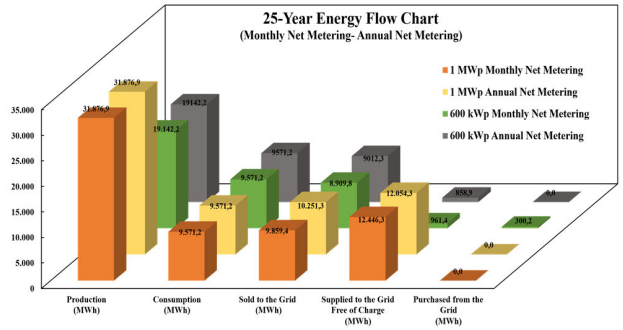


FIGURE 19. Energy flows of the solar PV plants according to the monthly and annual net metering.

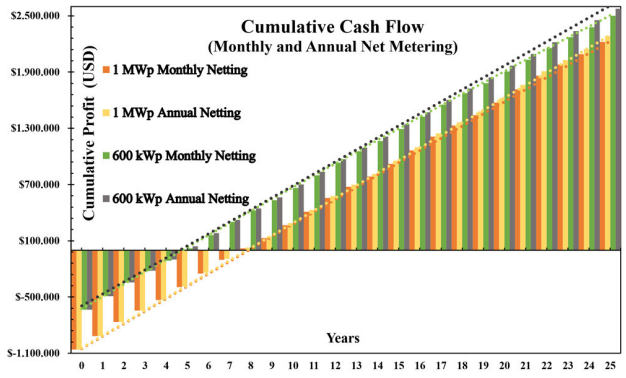


FIGURE 20. Cumulative cash flows of the solar PV plants according to the monthly and annual net metering.

In the annual net metering case, 1 MWp power plant is able to sell 391.9 MWh and 600 kWp power plant is able to sell 102.5 MWh more electricity to the grid compared to the monthly net metering. In addition, the billed consumption of the 600 kWp plant, which is 300.2 MWh in the monthly net metering case, decreased to zero in the annual net metering case despite the restriction.

Figure 20 shows the cumulative cash flows of both solar PV investments based on monthly and annual net metering. Although the difference is small, it is seen that annual net metering is more profitable. Especially for prosumers that do not consume electricity or experience significantly reduced consumption during certain periods of the year due to reasons such as holidays or festivals, it is clear that annual net metering is an advantageous net metering method.

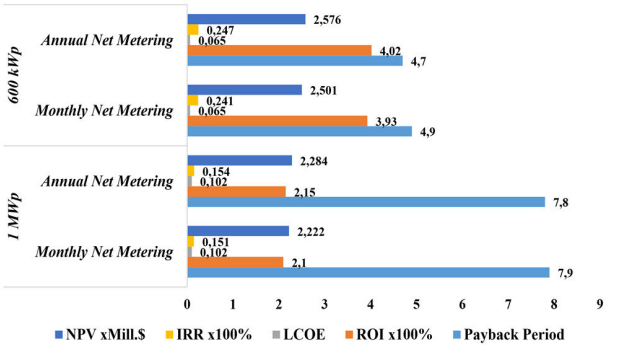


FIGURE 21. Comparison of the economic results according to the monthly and annual net metering.

Figure 21 presents a comparison of the net present value, internal rate of return, levelized cost of energy, return on investment, and payback periods of the 1 MWp and 600 kWp solar PV investments based on their monthly and annual net metering scenarios.

G. COMPLETE GRID SALES CONSTRAINT STATUS

In this scenario with electricity sales to the grid entirely restricted, the financial status of the 1 MWp solar PV investment is analyzed under the assumption that all surplus electricity produced is supplied to the grid free of charge. Over a period of 25 years, the economic analysis results—based solely on invoice savings, without electricity sales revenue—indicate that the net present value of the 1 MWp solar PV, which has an installation cost of 1060000 $, is 500529 $. The investment payback period is 16.7 years, the return on investment is 47.22%, the internal rate of return is 6.3%, and the levelized energy cost is 0.208 $/kWh. These results show that despite the lack of sales to the grid, the net present value of the 1 MWp plant remains positive, as it continues to meet electricity demand. However, at the end of 25 years, it cannot even cover half of the investment cost.

By resizing the PV capacity under complete grid sales constraint conditions, the optimal solar PV plant size is determined to be 300 kWp based on the prosumer's average annual electricity demand of 382.5 MWh. The electricity production data for the 300 kWp power plant, designed using PVsyst, is presented in Table 10 at the end of the first year.

According to the simulation results, a total of 420403 kWh of electricity is generated at the end of the first year of the 300 kWp solar PV plant. Considering an annual aging rate of 0.8%, the average production over 25 years is approximately 382.5 MWh per year. The design of the 300 kWp solar PV incorporates 882 PV modules and 2 string inverters. The installation cost of the project is 318000 $, and the operation and maintenance cost is 3900 $. According to the results of the economic analysis, the net present value of the 300 kWp

TABLE 10. Simulation results of the 300 kWp solar PV plant.

Month	GlobHor (kWh/m²)	DiffHor (kWh/m²)	T_Amb (°C)	GlobInc (kWh/m²)	GlobEff (kWh/m²)	EArray (kWh)	E_Grid (kWh)	PR (ratio)
January	50.6	24.97	6.27	78.8	76.4	21967	21608	0.915
February	59.9	37.88	6.61	77.2	74.7	21485	21146	0.914
March	104.1	61.08	9.14	121.4	117.2	33239	32710	0.899
April	143.8	74.65	12.68	155.0	149.6	41578	41070	0.883
May	194.0	76.56	18.11	193.7	187.1	50572	49674	0.855
June	212.8	83.76	22.87	204.1	197.0	52359	51418	0.840
July	213.9	77.39	26.41	208.8	201.6	52593	51591	0.824
August	183.8	73.89	26.94	195.8	189.2	49413	48480	0.826
September	132.4	57.21	21.83	155.5	150.2	40077	39370	0.844
October	82.8	47.45	17.02	105.9	102.5	28291	27842	0.876
November	50.6	31.02	12.64	71.6	69.3	19534	19233	0.896
December	41.1	27.33	8.38	59.5	57.6	16509	16258	0.912
Year	**1469.9**	**673.18**	**15.77**	**1627.2**	**1572.4**	**427795**	**420403**	**0.862**

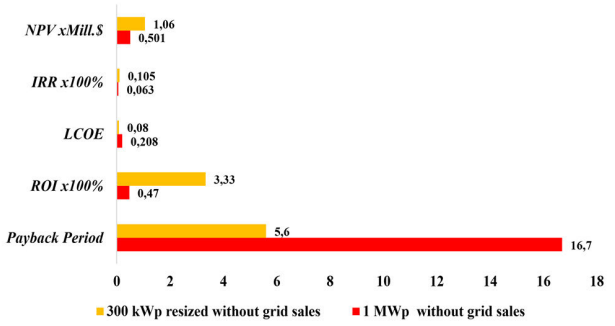


FIGURE 22. Comparison of the economic results under the complete electricity sales restriction scenario.

solar PV investment is 1059774 $ in the absence of grid electricity sales. Additionally, the payback period is 5.6 years, the return on investment is 333.26%, the internal rate of return is 10.5%, and the levelized energy cost is calculated to be 0.080 $/kWh. Figure 22 shows the economic analysis results for 1 MWp and 300 kWp PV systems under conditions where grid electricity sales are completely restricted.

V. CONCLUSION

It is expected that the grid sales restrictions implemented in Türkiye in recent years will affect a large number of PV investments in the country. This study analyses the effect of restricting the excess electricity sold by prosumers to the grid in renewable energy incentive systems on solar PV investments and the effectiveness of optimal capacity sizing through the example of Türkiye.

In order to show the impact of grid sales restrictions on solar PV systems, the study started with 1 MWp solar PV, which is the maximum capacity allowed by the FITs in Türkiye. The numerous 1 MWp solar PV fields located throughout the country were extremely common and profitable investments due to purchase guarantees before the restrictions.

The resizing is carried out for the optimum capacity according to the constraints, and it is determined to be 600 kWp. Accordingly, despite the reduction in energy production of approximately 40% due to the resizing of the solar PV capacity, the electricity sold to the grid decreased by only 9.6% compared to the 1 MWp solar power plant. According to the economic analysis results, the net present value of the 600 kWp solar investment 600 kWp exceeds that of the 1 MWp solar PV under the sales restrictions. As a result of the capacity optimization, the LCOE, return on investment, internal rate of return and payback period are almost the same as the highest yielding maximum capacity without sales restrictions, proving the effectiveness of the sizing.

The rest of the study examines different consumption, net metering and restriction scenarios in more detail. In the fixed consumption scenario, net metering is more profitable than the actual consumption situation. In the seasonal scenarios, the changes in revenue are compared between the cases where the prosumer has high consumption in the summer and high consumption in the winter, and it is found that high consumption in the summer is less costly. As the gap between summer and winter consumption widens, the differences in cash flows are expected to increase. In addition, monthly and annual net metering scenarios are also evaluated in the study and it is determined that the annual net metering system is more advantageous for the prosumers. Moreover, the implementation of annual net metering led to the elimination of the 300.2 MWh electricity bill for the 600 kWp solar PV, which is incurred in subsequent years due to diminished generation resulting from panel degradation.

In conclusion, this study proves that sizing a solar PV investment to meet the prosumer's consumption needs and maximize the electricity it can sell to the grid can significantly reduce the financial disadvantages of grid sales restrictions, and, that the investment is feasible.

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