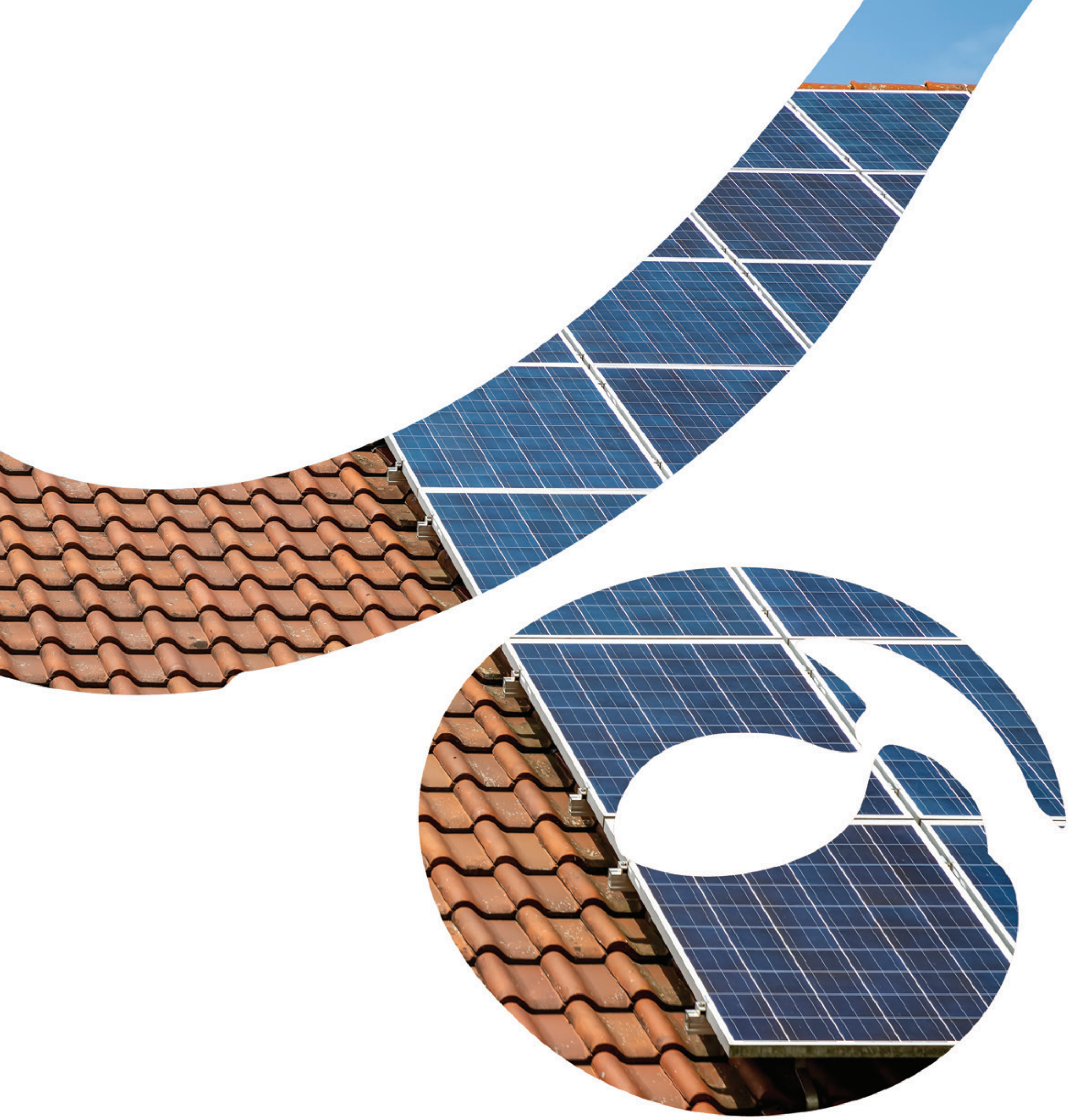

SHURA Energy Transition Center

Rooftop solar energy potential in buildings – financing models and policies for the deployment of rooftop solar energy systems in Turkey

About SHURA Energy Transition Center

SHURA Energy Transition Center, founded by the European Climate Foundation (ECF), Agora Energiewende and Istanbul Policy Center (IPC) at Sabancı University, contributes to decarbonisation of the energy sector via an innovative energy transition platform. It caters to the need for a sustainable and broadly recognized platform for discussions on technological, economic, and policy aspects of Turkey's energy sector. SHURA supports the debate on the transition to a low-carbon energy system through energy efficiency and renewable energy by using fact-based analysis and the best available data. Taking into account all relevant perspectives by a multitude of stakeholders, it contributes to an enhanced understanding of the economic potential, technical feasibility, and the relevant policy tools for this transition.

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Disclaimer

The interpretations and conclusions made in this report belong solely to the authors and do not reflect SHURA's official position.

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Abbreviations

CAPEX	investment cost
CO_2	carbon dioxide
EEG	Renewable Energy Act (Germany)
EİGM	General Directorate of Energy Affairs (Energy İşleri Genel Müdürlüğü)
EPC	engineering procurement construction
EPDK	Republic of Turkey Energy Market Regulatory Authority (Türkiye Cumhuriyeti Enerji Piyasası Düzenleme Kurulu)
ESCO	energy service company
EU	European Union
GDP	gross domestic product
GEPA	solar energy potential atlas (güneş enerjisi potansiyeli atlası)
GÜYAD	Solar Energy Investors Association (Güneş Enerjisi Yatırımcıları Derneği)
GW	gigawatt
IEEFA	Institute for Energy Economics & Financial Analysis
IRENA	International Renewable Energy Agency
IRR	internal rate of return
İZKA	Izmir Development Agency (İzmir Kalkınma Ajansı)
İZODER	Heat Water Sound and Fire Insulation Association (Isı Su Ses ve Yangın Yalıtımcıları Derneği)
kVA	kilovoltampere
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of electricity
LPG	liquified petroleum gas
MJ	megajoule
Mt	million tons
Mtoe	million tons of oil equivalent
MW	megawatt
m^2	square meters
NPV	net present value
OIZ	organized industrial zone
O&M	operations and maintenance

OPEX	operating expense
P2P	peer-to-peer
PV	photovoltaic
SME	small and medium-sized enterprises
SPP	solar power plant
TEDAŞ	Turkish Electricity Distribution Company (Türkiye Elektrik Dağıtım A.Ş.)
TEİAŞ	Turkish Electricity Transmission Company (Türkiye Elektrik İletim A.Ş.)
TMMOB	Union of Chambers of Turkish Engineers and Architects (Türk Mühendis ve Mimar Odaları Birliği)
TRY	Turkish Lira
TSKB	Industrial Development Bank of Turkey (Türkiye Sınai Kalkınma Bankası)
TÜİK	Turkish Statistical Institute (Türkiye İstatistik Kurumu)
TÜREB	Turkish Wind Energy Association (Türkiye Rüzgar Enerjisi Birliği)
TÜROB	Hotel Association of Turkey (Türkiye Otelciler Birliği)
TWh	terawatt-hour
USA	United States of America
US$	United States Dollars

Key findings

Turkey's total final energy consumption reached 109 million tons of oil equivalent (Mtoe) at the end of 2018. Approximately one-third of this amount, about 33 Mtoe, was consumed by buildings (residential, commercial, and public) (EİGM, 2018), which have the highest share in Turkey's final energy consumption, following the industrial sector. The total energy demand of buildings is expected to increase even further due to the rapid speed of urbanization and population growth. In addition to traditional energy generation technologies, renewable energy generation systems—in particular rooftop photovoltaic (PV) systems—have the potential to meet the increasing energy demand of buildings. The production capabilities of rooftop PV systems can reduce the need for electrical grids and improve network efficiency by reducing distribution losses.

The total technical potential of rooftop PV systems that can be installed in buildings in Turkey is estimated as 14.9 gigawatts (GW) based on 2019 data. This potential is nearly three times larger than the currently installed solar energy capacity in Turkey. This potential capacity is expected to produce 22 terawatt-hours (TWh) of electricity per year, which is slightly more than 6% of the current electricity production in Turkey. This potential is almost equal to one-quarter of the theoretical 55 GW potential calculated in case all south-facing roof areas are used. These systems can meet 17% of all electricity demand (cooling, lighting, ventilation, and partial space heating and hot water) of buildings in Turkey. Under the assumption that 100% of electricity is directly consumed (i.e., self-consumption), rooftop PV systems can reduce the primary energy demand of buildings in Turkey by 11% (excluding energy consumed for appliances, office equipment, and cooking).

Although approximately 70% of the total potential capacity of rooftop PV systems is in residential buildings, the levelized cost of electricity (LCOE) of these systems for residential buildings is 30%–50% higher than the grid tariff. Only thirty percent of the total potential capacity of rooftop PV systems in all buildings, however, will reach grid parity (4.5 GW).[1] Reaching grid parity in residential buildings across Turkey necessitates a reduction in the investment costs of low-capacity rooftop PV systems, which range between US $1,500–2,000/kW to the levels of US $1,200/kW and below depending on the building type. Considering operational expenses, if this rate is reduced by 8%, a range of US $600–1,000/kW in commercial buildings and US $700–1,200/kW in other building types is below the current grid tariff.

The return on PV investments in residential buildings will be seen in 14–16 years given current costs, while this period is 4–5 years for commercial investments. Lowering investment costs by 30% would enable investors to see a return in 8–10 years for residential buildings and in three years for commercial buildings.

The deployment of rooftop PV systems with a 4.5 GW capacity in commercial, public, and industrial buildings in Turkey will create excellent business opportunities, provide greater energy security, and help mitigate climate change. Regarding economic potential, the estimated total investment cost for rooftop PV systems is US$6.2 billion. About 1.3 billion m^3 on imported natural gas can be saved in total (i.e., nearly 2.9% of total gas imports in Turkey in 2019, which were 44.5 billion m^3). This volume infers an annual savings of US$300 million on Turkey's gas imports. Assuming all electricity

[1] In this study, grid parity means the level at which the LCOE of rooftop PV systems equals grid tariff.

generation via rooftop PV systems replaces coal-based generation, 5.6 million tons (Mt) of CO_2 emissions (nearly 3.5% of total CO_2 emissions from Turkey's electricity industry) can be reduced annually.

Many financing tools and policy mechanisms have been developed on the global level concerning rooftop PV systems. Concessional loans, grants, risk-sharing mechanisms, consumer loans, and insurance and leasing systems are some of the financial tools currently in place to encourage investors. In terms of policy mechanisms, on the other hand, guaranteed purchase tariffs, premium systems, and net billing methods, in addition to the currently implemented net metering mechanism, are commonly discussed.

In addition to financing tools and policy mechanisms, implementing business models for electricity trade management and small-scale surplus energy sales, as well as favorable regulations, will accelerate the distributed generation capacity across Turkey. In the coming years, decreasing investment costs and interest rates will make rooftop PV systems more economically viable.

1. Introduction

The share of renewable energy in Turkey's total electricity consumption was nearly 44% at the end of 2019 (TEİAŞ, 2020). This value is well over the one-third share observed in previous years. A total of 5.9 GW PV (TEİAŞ, 2019) and approximately 7.6 GW onshore wind energy capacity (TÜREB, 2019) provide approximately 14% of the country's total installed electricity generation capacity. Electricity generation through solar PV systems and onshore wind turbines supplied 10% of Turkey's total electricity demand in 2019 (GÜYAD, 2019a). However, a large share of this production has been at the utility scale, and the share of distributed energy generation remains negligible. Fortunately, in recent years there have been significant developments on the global scale to increase the distribution capabilities of the energy sector (IEA, 2019).

The share of renewable energy in total installed power will increase and energy efficiency will be improved with further rooftop PV integration.

According to the net metering law implemented in May 2019 in Turkey (Official Gazette, 2019), real or legal persons will hereafter be able to produce electricity without obtaining a license or establishing a company and sell their surplus production to the grid. An increase in distributed energy generation can be expected folowing this regulation. Thus, increasing awareness about rooftop PV potential in Turkey has become an important task. Although a number of related studies across Turkey have been published by organizations such as the World Bank (World Bank, 2018), Institute for Energy Economics and Financial Analysis (IEEFA) (IEEFA, 2019), and Internation Solar Energy Society – Turkey Section (GÜNDER, 2019a), no study has been carried out using a bottom-up approach including building data.

In the "Balancing the location of wind and solar PV investments" report published by SHURA Energy Transition Center (SHURA, 2018a), the benefits of allocating a total of 10 GW distributed (rooftop and other systems) solar power capacity to the grid by 2026 are compared with several other scenarios. With rooftop PV deployment, both the share of renewable energy in total installed capacity will increase and energy efficiency will improve through implementing varying flexible methods. Moreover, building integration and power sector integration can be achieved as long as distribution system operators are ready for this transition.

Considering the above-mentioned distributed generation potential, technical knowledge of the deployment of rooftop PV systems should be developed. The World Bank report emphasizes that in order for rooftop PV systems to become widespread in Turkey, sophisticated planning and technical capacity must increase in addition to implementing the necessary regulations (World Bank, 2018). Seeing the need for a study focusing on buildings' total energy demand and the potential capacity of PV systems, as well as aiming to contribute to knowledge of this area, SHURA carried out a bottom-up analysis using buildings' roof areas and energy consumption data.

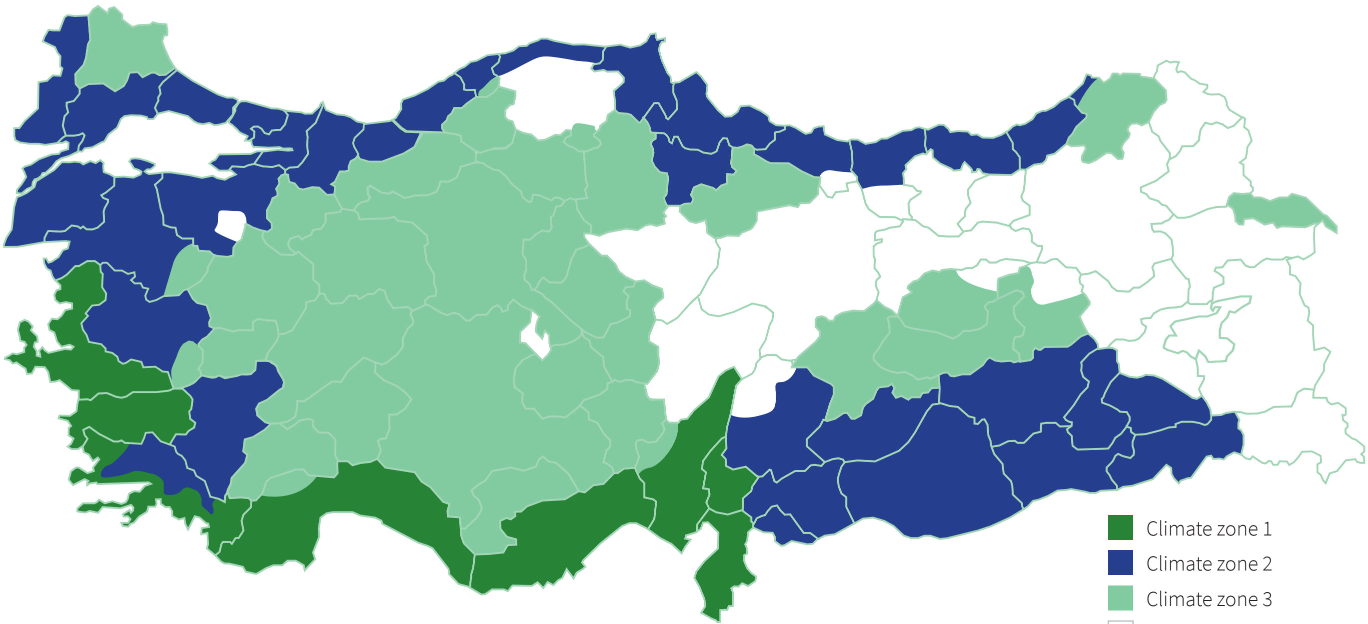
The purpose of this study is to estimate the technical and economic potential of rooftop PV systems to meet the current energy demand of all buildings in Turkey, utilizing outcomes and methodologies from past studies as a starting point. The next section presents a general overview of the energy demand of the building stock in Turkey as well as the methodology used in the study. The following sections introduce the potential capacity of PV systems and cost-benefit analysis. Finally, it will present financial tools, policy mechanisms, and business models to facilitate deployment of PV systems.

2. Building stock data and energy demand of buildings in Turkey

The urban population of Turkey grows nearly 2% per year. This, as well as the short life span of buildings in Turkey, contributes to the rapid growth of Turkey's building stock, in which the number of new buildings increases by 4% each year (Ecofys, İstanbul Aydın Üniversitesi and İZODER, 2018). The construction sector is a driving force in Turkey's economy, having a share of 6% in Turkey's real gross domestic product (GDP) as of the first quarter of 2019 (İNTES, 2019). A comprehensive analysis of the building stock data is an important basis for determining the energy demand of buildings and the potential benefits of rooftop PV systems.

In order to analyse the total final energy consumption of different building types in Turkey, a literature review was conducted revealing the characteristics of the overall building stock, average annual energy consumption per building floor, and a breakdown of total energy consumption by end uses. The data on buildings' energy demand shows us the distribution of building types and climate zones. According to this approach there are four climate zones as defined according to TS 825 - Thermal Insulation Requirements for Buildings Regulation (Official Gazette, 2008) in Turkey that will be examined in this study. The climate zone map is shown in Figure 1.

Figure 1: *Climate zones in Turkey*



Source: (Official Gazette, 2008)

The next two subsections will cover the methodology and assumptions on which this study is based concerning building stock and buildings' energy consumption.

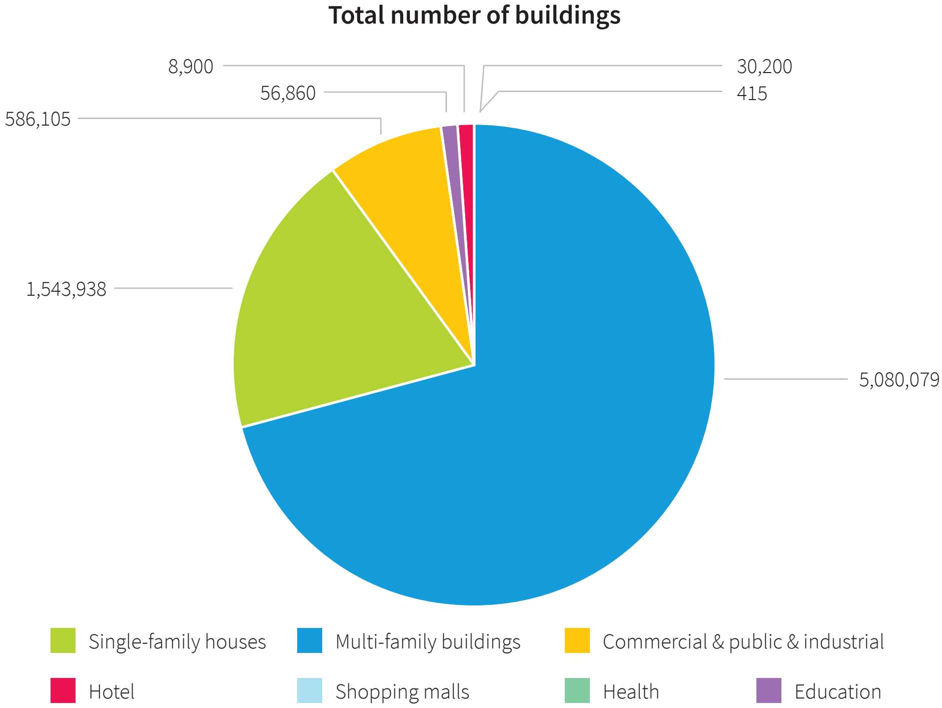
2.1. Building stock data

As of 2018, there was a total of 9.1 million buildings in Turkey (Kabakçı, 2018). Around 7.3 million of these were constructed after 1970 (TÜİK, 2019). Buildings constructed before 1970 were excluded from the analysis assuming that they do not have an appropriate roof structure for rooftop PV systems. There are approximately 1.5 million Single-family houses (detached buildings) and 5 million Multi-family buildings in

Turkey according to data from the Turkish Statistical Institute (TÜİK). The ratio of Single-family houses to Multi-family buildings constructed between 1970 and 2000 is assumed as one to four, based on the overall ratio of residential buildings.

There are around 600,000 commercial, public, and industrial buildings in the building stock in Turkey. Almost 57,000 buildings are used for educational purposes, while there are approximately 9,000 hotel buildings (GM Dergi, 2019 | TÜROB, 2019). There are more than 400 shopping malls and nearly 30,000 healthcare buildings (TÜİK, 2019). Public housing, storage facilities, and farm buildings are not included in the analysis. The total number of each building type is given in Figure 2.

Figure 2: *Distribution of buildings by type*



Source: (TÜİK, 2019)

The total floor area of each building type is given in Table 1. As of 2018, the total floor area of all residential buildings was 2.4 billion square meters (m^2). Approximately 1.9 billion m^2 of this is within Multi-family buildings and 0.5 billion m^2 within Single-family houses (average floor area: 96 m^2). The total floor area of all non-residential buildings is 500 million m^2 (Ecofys, İstanbul Aydın Üniversitesi and İZODER, 2018). According to SHURA's calculations, the total floor area of commercial, public, and industrial buildings is more than 400 million m^2. Educational buildings have an estimated total floor area of 48 million m^2, hotels 8 million m^2, healthcare buildings 25 million m^2, and shopping malls 6 million m^2.

Table 1: *Total floor area of different building types in Turkey*

	Single-family houses	Multi-family buildings	Commercial, public, and industrial	Education	Hotel	Health	Shopping mall
(million m^2)	500	1,900	416	48	8	25	6

Source: (Ecofys, İstanbul Aydın Üniversitesi and İZODER, 2018) and SHURA calculations

According to data obtained from stakeholder interviews, the average roof area that is suitable for installing PV systems for each building type is 150–250 m² for Multi-family buildings, assuming two apartments per floor; 80–120 m² for Single-family houses; 350–650 m² for commercial, public, and industrial buildings; 900–1500 m² for educational buildings; 350–550 m² for hotels; 300–700 m² for healthcare buildings; and 1,100–1,500 m² for shopping malls.

Assuming that the vast majority of residential buildings in Turkey have hipped roofs, it was understood from the interviews with various non-residential building owners and operators that the minimum roof area appropriate for installing rooftop PV systems is one-quarter of the total roof area on south-facing roofs of all building types. Non-residential buildings, however, usually have flat roofs. The remaining areas are typically reserved for other equipment.

Info Box 1: Seferihisar Municipality marketplace – 170 kW

This power plant, which was built on the roof of a marketplace with a TRY 880,000 grant received from the İzmir Development Agency (İZKA) in 2014, generates an average of 310,000 kWh of energy annually, thereby meeting the municipality's heating, cooling, and lighting needs. In addition, 180,000 kg of CO_2 emissions are reduced annually. The system is an example of how clean energy can be used to save money, in this case TRY 125,000 per year.

Source: (Yeşilist, 2019)

2.2. Energy consumption by building type and climate zones

Primary energy consumption per building floor area in Turkey is 100–250 kWh/m² per year for residential buildings (Öz, 2011); 50–300 kWh/m² per year for commercial, public, and industrial buildings; 60–150 kWh/m² per year for educational buildings; 100–350 kWh/m² per year for hotels; 200–600 kWh/m² per year for healthcare buildings; and 150–250 kWh/m² per year for shopping malls (Kabakçı, 2018, and stakeholder interviews). The average of these values was calculated for all buildings in Turkey. The energy consumption of Single-family houses and Multi-family buildings are assumed to be equal.

In Turkey, there are four climate zones as defined in Standards for Thermal Insulation Requirements for Buildings (TS 825) (Resmi Gazete, 2008). According to the Energy Efficiency Technology Atlas report (Ecofys, İstanbul Aydın Üniversitesi and İZODER, 2018), while the need for heating in the fourth climate zone is 2–2.5 times higher than in the first zone, the need for cooling in the first climate zone is 2.5–3 times higher than that of the fourth zone. Climate zone specific values are calculated according to differences and demand relations between the zones, in line with the Energy Efficiency Technology Atlas report (Ecofys, İstanbul Aydın Üniversitesi and İZODER, 2018).

Consumption values reflect Turkey averages. The energy consumption of residences in the fourth zone is twice that of the first zone. Energy consumption between the fourth and the first zone is 2.5 times higher in commercial, public, and industrial buildings; 2 times higher in educational buildings; 1.25 times higher in hotels; 2 times higher in healthcare buildings; and 1.5 times higher in shopping malls. The consumption values in the second and third zones are on average 1.1–1.4 times higher than in the first zone.

Total building area distribution in the first, second, third, and fourth climate zones are recorded as 19%, 42%, 24%, and 15%, respectively, for Single-family houses; 17%, 54%, 23%, and 6% for Multi-family buildings; and 19%, 48%, 27%, and 6% for non-residential buildings (Ecofys, İstanbul Aydın Üniversitesi and İZODER, 2018).

Energy consumption values specific to building types and climate zones are assumed to include heating-cooling, hot water, ventilation, and lighting as defined in Building Energy Performance Regulation (BEP-TR), being expressed as primary energy[2], and excluding devices, office equipment, cooking, and other consumption categories. The data are not based on total floor areas but on conditioned areas. Floor areas indicate regularly occupied spaces, whereas conditioned areas refer to spaces directly or indirectly subject to heating and cooling. Conditioned areas are assumed to be 80%–90% of floor areas in residences, 60%–70% in non-residential, and on average 75% for all buildings in Turkey.

Total energy consumption

Total energy consumption by building type in Turkey is shown in Table 2. TWh/year is calculated by multiplying energy consumption values per area by conditioned areas.

Primary Energy Consumption (TWh/year) = Conditioned Building Area (m^2) x Primary Specific Energy (kWh/m^2year)

Table 2: *Distribution of energy consumption by building type*

Unit	Single-family houses	Multi-family buildings	Commercial, public, and industrial	Education	Hotel	Health	Shopping mall	Total
(TWh/year)	42-106	148-371	13-78	2.4-5.9	0.6-2.0	4.1-12.2	0.6-0.9	211-575
(Mtoe/year)	3.6-9.1	12.7-31.9	1.1-6.7	0.2-0.5	0.1-0.2	0.4-1.1	0.1-0.1	18-50

Source: SHURA calculations

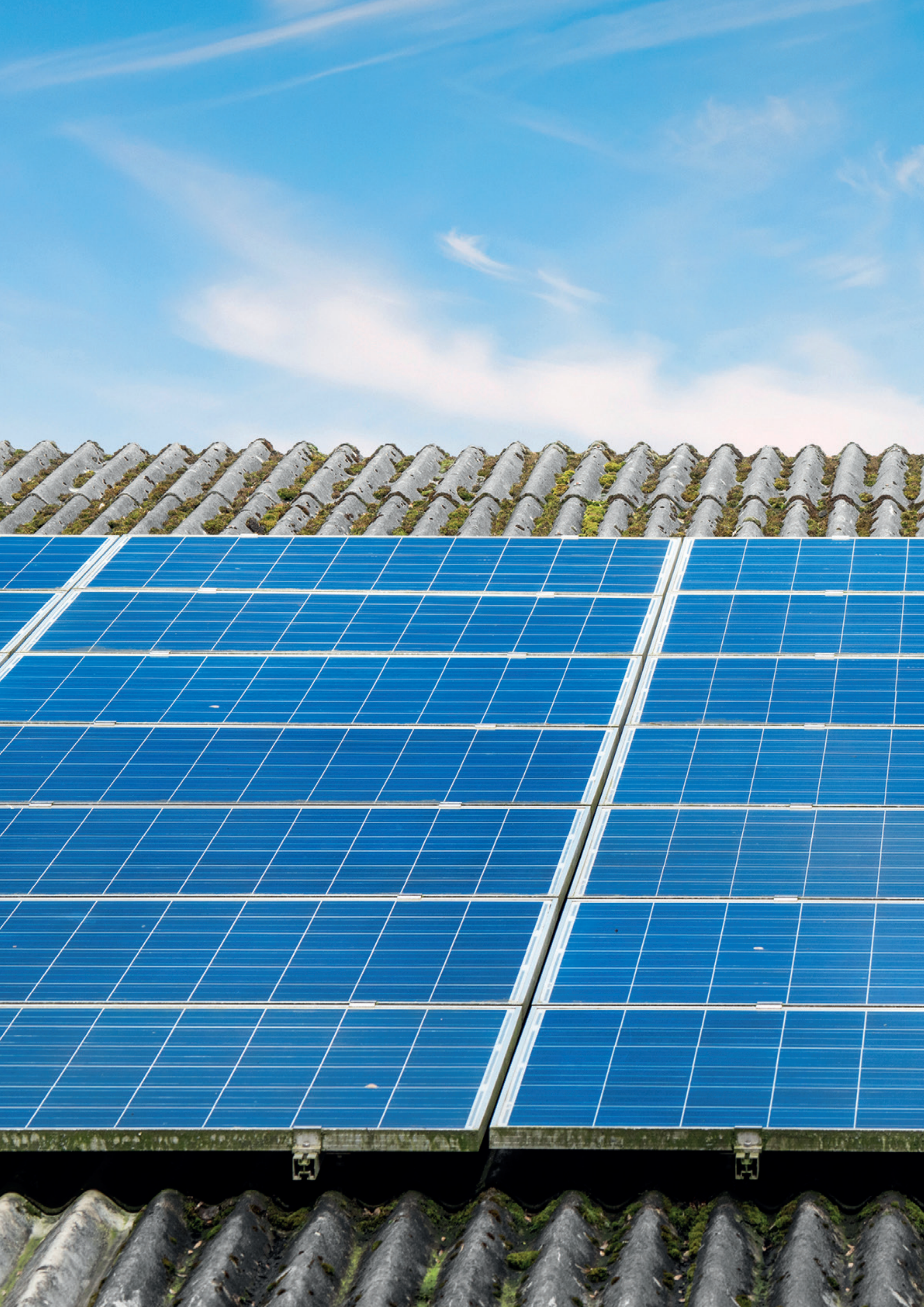
Based on the above bottom-up analysis, the total primary energy consumption of buildings in Turkey is between 18 and 50 Mtoe annually. This study hereafter uses the average of these values (33.82 Mtoe). The total final energy consumption of buildings in Turkey in 2018 was reported as 33.08 Mtoe (EİGM Denge, 2018). This value is divided between demand for electricity (10.96 Mtoe) and non-electricity (22.12 Mtoe). If 2.07 is assumed as the coefficient to convert final energy consumption into primary energy (EİGM Denge, 2018), the total primary energy consumption of buildings in Turkey in 2018 was 44.81 Mtoe. With reference to that, the bottom-up approach represents 75% of the total primary energy consumption of buildings in Turkey. The remaining energy powers appliances, office equipment, cooking, and other categories.

[2] Energy sources utilized without changing essential characteristics are primary energy resources. Coal, nuclear, biomass, hydraulics, wave energy are the energy sources that can be named in this category. Energy sources utilized after their natural qualities are transformed into a different energy source are final energy sources. Electricity, gasoline, diesel oil, secondary coal, coke, LPG energy are the energy sources that can be counted in this category (Enerji Kaynakları, 2018).

Info Box 2: Muğla Metropolitan Municipality Bodrum bus terminal – 630 kW

Six charging stations for electric vehicles were installed in Bodrum Bus Station, a novelty in Turkey. The cost of the 630-kW solar power system on the roof of the Bodrum bus station cost TRY 4 million, which corresponds to nearly US$1,250 per kW.

Source: (Solarist, 2018)



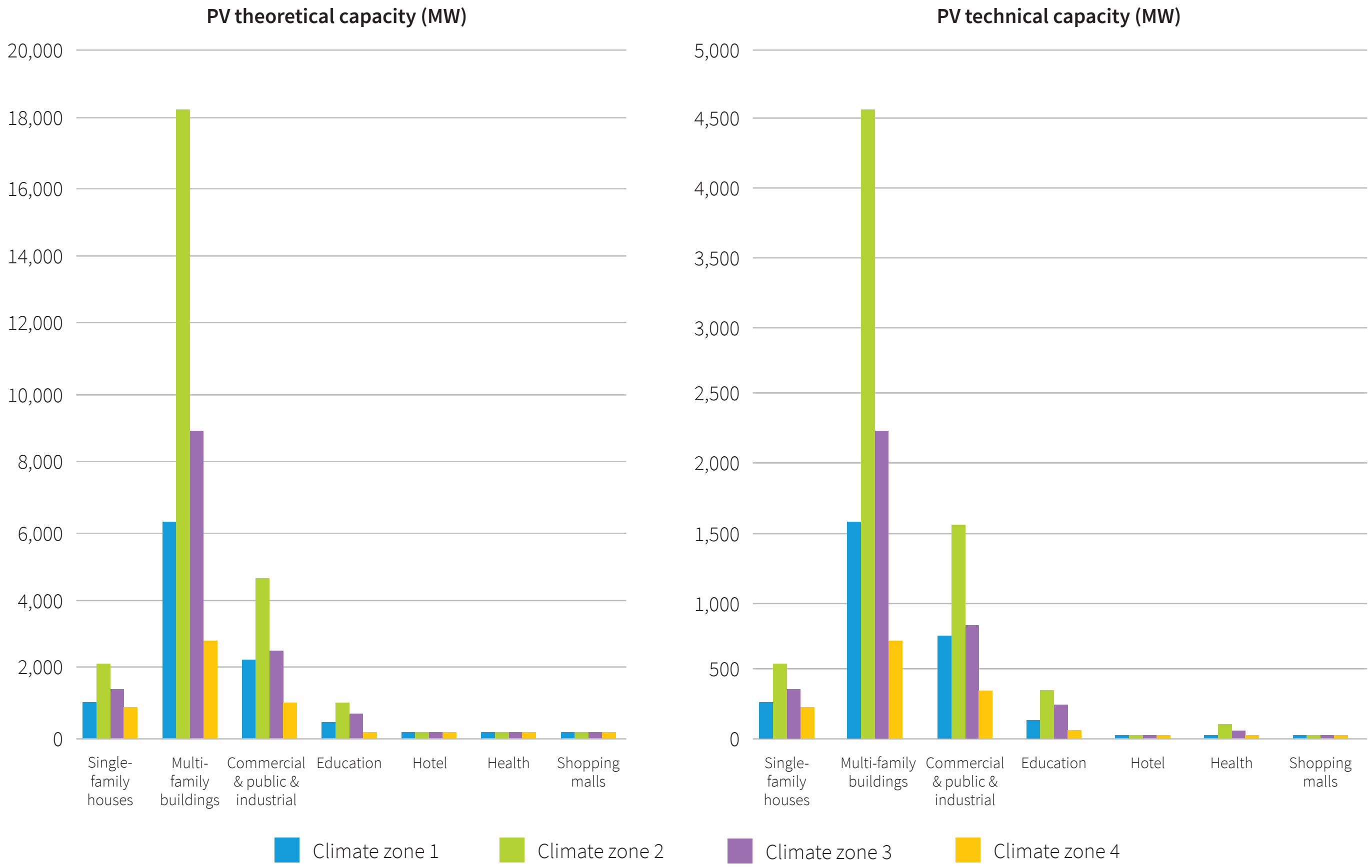
3. Potential of rooftop photovoltaic systems in buildings in Turkey

Every year approximately 100,000 new buildings that are appropriately structured for rooftop PV systems are added to the building stock in Turkey (TÜİK, 2019). An additional 300,000 residential buildings per year are demolished and reconstructed in Turkey, one-third of these being in Istanbul (Kentsel Dönüşüm, 2019). One hundred thousand new buildings built annually means that there have been one million new buildings constructed over the past ten years, which constitutes more than 10% of today's total building stock. Assuming that 15% of the total residential building stock that existed before ten years ago is also compatible with rooftop PV systems, 25% of residential buildings can be used for PV systems. Fifty percent of shopping malls, which are newly built, are also assumed to be available for PV systems. In all other building types, a one-third ratio is assumed on the basis of a mix of new and old buildings. The total area required per kW of rooftop PV systems is estimated as 7 m^2 (EMO, 2019).

There is a 14.9 GW technical potential for rooftop PV systems in Turkey.

In Turkey, the theoretical potential of rooftop PV systems is calculated as 55 GW if all south-facing rooftop areas are used. When calculated in accordance with the appropriate roof area ratios mentioned above, the technical potential is determined as 14.9 GW of rooftop PV capacity. This potential is outstanding compared to the total utility-scale installed PV capacity of around 6 GW in Turkey. At present, about 15% (0.9 GW) of the 6 GW installed capacity is provided via rooftop PV systems, mostly in commercial, public, and industrial buildings (GÜYAD, 2019b). The economic potential of PV systems will be evaluated in the following sections. The distribution of theoretical and technical potential capacities by building type and climate zone is shown in Figure 3. Residential buildings and commercial buildings appear to be far ahead of other building types in terms of potential capacities.

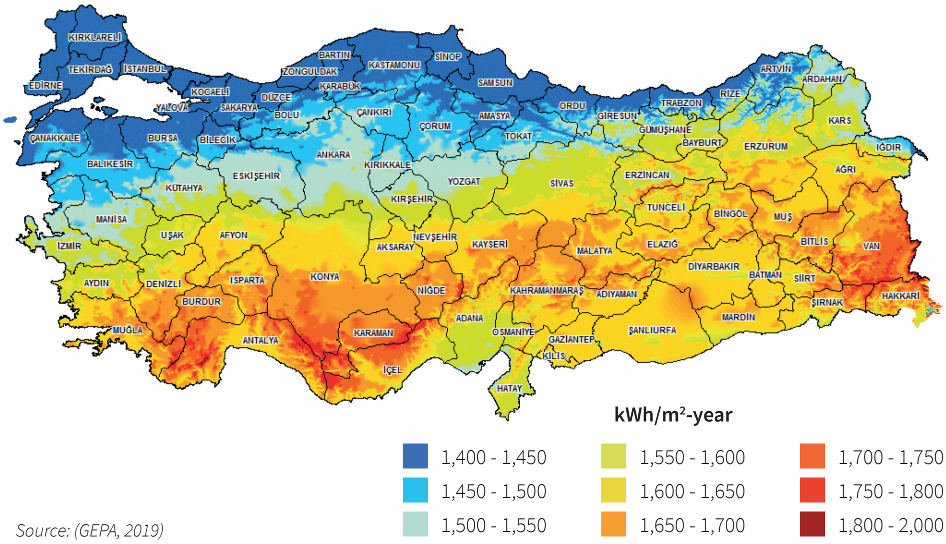
Figure 3: *Theoretical and technical potential capacities of rooftop systems*



Source: SHURA calculations

Capacity factors of PV systems vary by region. On average, capacity factor at utility scale is about 22% in Turkey (SHURA, 2018a). Across Turkey's climate zones, the capacity factor of PV systems is 21.5% in the first and third zones, 20% in the second zone, and 22% in the fourth zone. The solar radiation map is given in Figure 4 (GEPA, 2019). Rooftop PV systems are considered to have 20% lower capacity factors than that of utility-scale systems (Roger Andrews, 2016). These capacity factors are assumed to include shading coefficients.

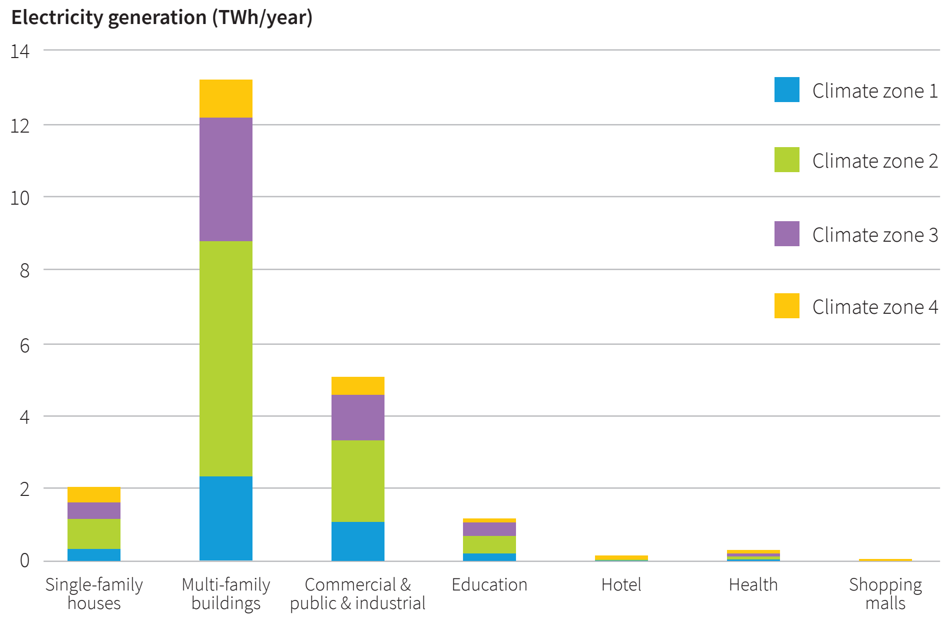
Figure 4: *Solar radiation map*



Source: (GEPA, 2019)

The potential annual electricity generation capacities of rooftop PV systems in different building types per climate zone, calculated by using the above capacity factors, are given in Figure 5. When assessing technical capacities, Multi-family buildings have the greatest potential capacity, with about 13.2 TWh/year. This is followed by a potential capacity of 5.1 TWh/year in commercial, public and industrial buildings. The potential in Single-family houses is 2 TWh/year based on roof areas. Half of the total technical potential is seen in buildings in the second climate zone.

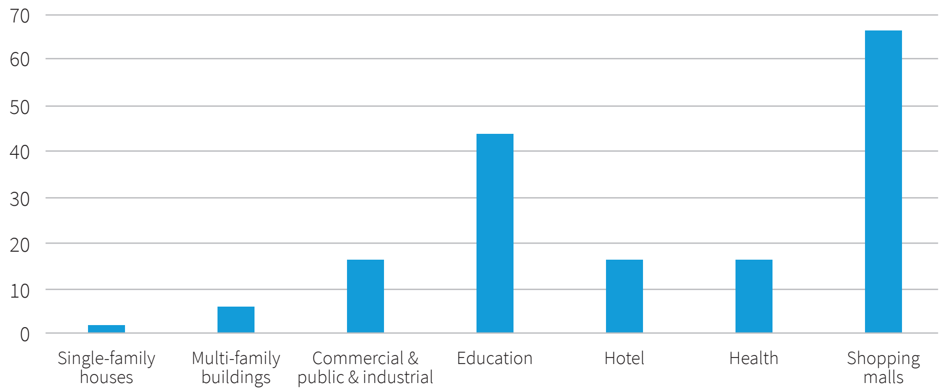
Figure 5: *Annual electricity generation capacities of rooftop systems*



Source: SHURA calculations

Based on technical potentials, assuming 350 W panel capacity, the number of panels required per building type is given in Figure 6. This figure shows that shopping malls and educational buildings can accomodate at least two or three times more panels than other building types as they have larger roof areas, leading to higher capacities.

Figure 6: *Number of panels per building type*



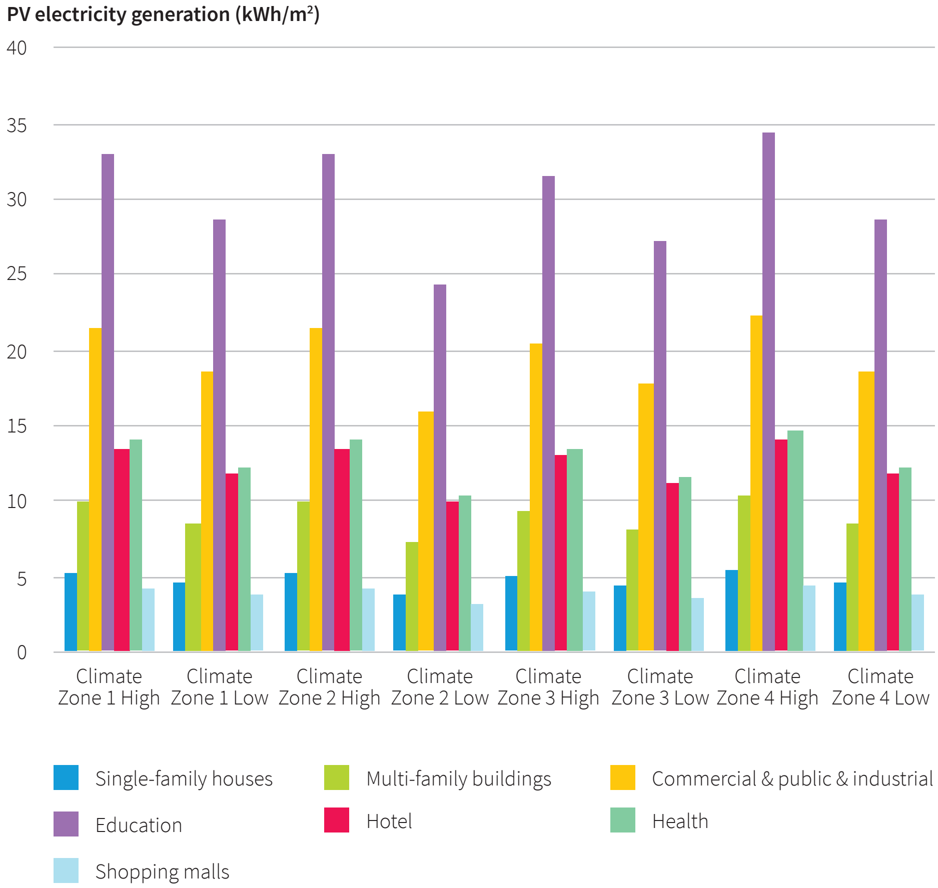
Source: SHURA calculations

Higher values are observed in commercial and educational buildings which have larger roof areas, whereas specific electricity generation in residential buildings appears lower.

Variations in urban density, total roof area, and solar radiation ratios in each climate zone show the need to consider different indicators in determining PV electricity generation potentials. In order to make an accurate comparison between the electricity generation potential and the capacity of PV systems to cover the energy demands of buildings in two cities with similar densities in the same climate zone as well as to see the difference in radiation more clearly, electricity generation potential per building area is included as an indicator in high- and low-resource representative cities. The electricity generation potential of rooftop PV systems per a building's conditioned area for each climate zone is given in Figure 7.

In general, there is an average difference of 12% to 25% between highest and lowest resource values. This fact reveals the potential generation difference that is intrinsic to solar radiation capacity. While educational and commercial buildings, which have a high ratio of roof area to conditioned area, have high values of electricity generation per unit area, residential buildings appear to have lower values due to limited roof areas. Based on our calculations, the fourth zone reflects the highest values, whereas the second zone reflects the lowest.

Figure 7: *Electricity generation potentials per building area and climate zones*



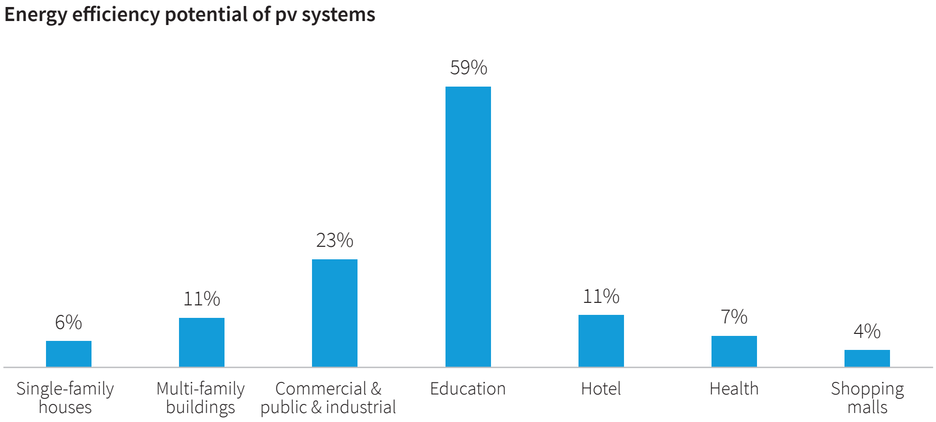
Source: SHURA calculations

Rooftop PV systems have significant energy efficiency potential. In this study, energy efficiency is defined as the reduction in a building's energy consumption via PV systems. Energy efficiency potential is calculated as primary energy multiplying the total PV generation value by the coefficient 2.07 (EİGM Denge, 2018) and proportioning it to the total building energy demand value.

Therefore, the total electricity generated annually by 14.9 GW of PV systems will be 22 TWh. The electricity generation of 22 TWh corresponds to a primary energy amount of 46 TWh. This corresponds to 11% of the total primary energy consumption of buildings in Turkey, calculated through the bottom-up approach. This value also corresponds to 17% of the total electricity demand (128 TWh) of buildings in Turkey (EİGM Denge, 2018). All capacity calculations are made assuming 100% self-consumption.

The energy efficiency value of different building types varies substantially according to the calculations. The largest efficiency potential is in educational buildings with 59%, followed by commercial, public, and industrial buildings with 23%. The potential is 6% in Single-family houses and 11% in Multi-family buildings (Figure 8). The reason for higher potentials in certain building types is larger roof areas as well as lower energy consumption levels compared to other large-roof building types.

Figure 8: *Energy efficiency potential of rooftop systems by building types*



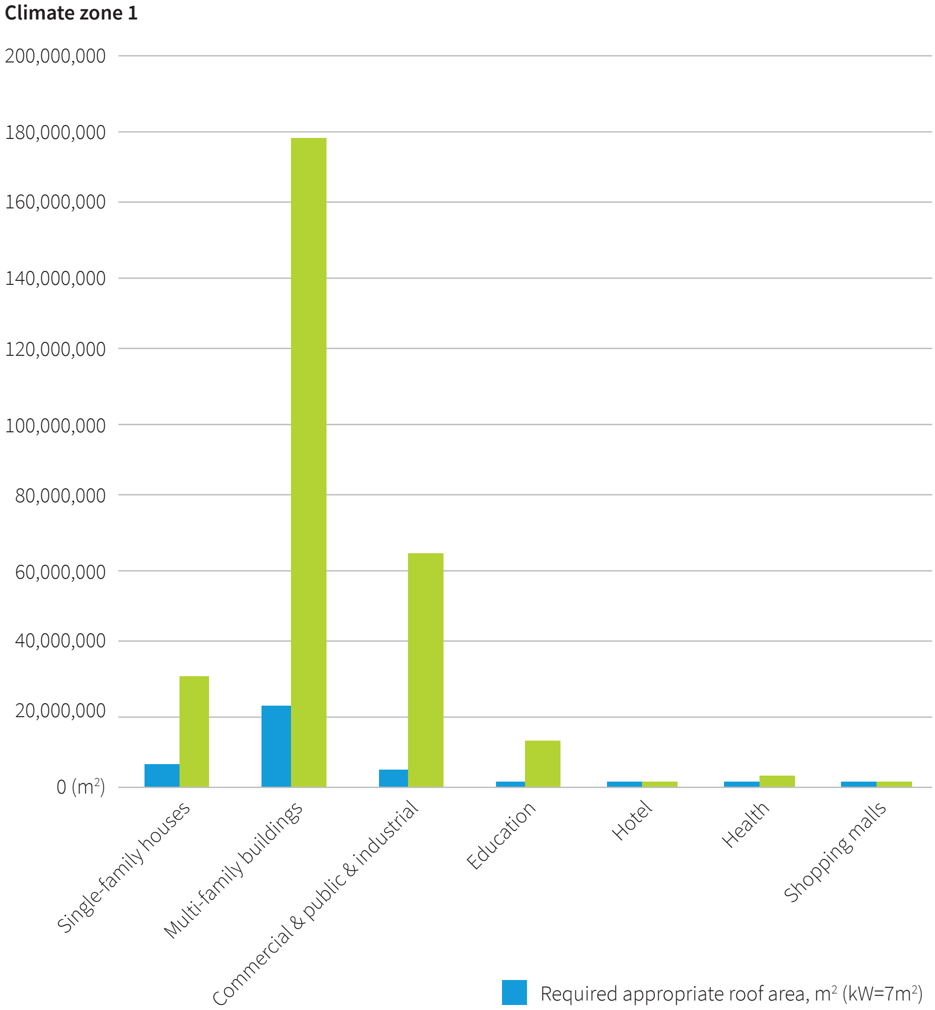
Source: SHURA calculations

Another method has also been applied in order to measure the potential of rooftop PV systems in meeting the energy demand of buildings in Turkey. Based on buildings' energy consumption, the roof area required per building type in order to meet 25% energy efficiency potential was calculated. Roof areas of different building types are assessed in accordance with this calculation. A comparison of the existing and required roof area to achieve 25% energy efficiency potential in the first climate zone is given in Figure 9.

According to the calculations, the required roof areas to meet 25% of the total building energy consumption is nearly 20% of the total roof area of Single-family houses; 12% of Multi-family buildings; 6% of commercial, public, and industrial buildings; 3% of educational buildings; 18% of hotels; 28% of healthcare buildings; and 63% of shopping malls.

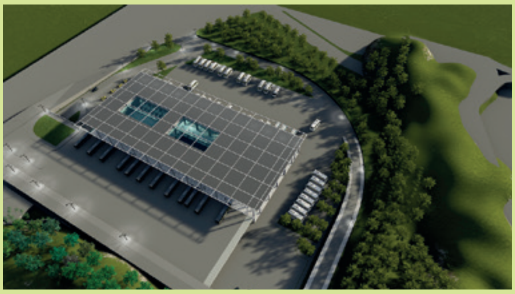
It can be seen that all building types have the required area needed for PV systems to meet 25% of total energy consumption. However, whether or not each building type has an appropriate roof area that would allow for sufficient radiation and PV efficiency in order to achieve this capacity must be reviewed. PV suitability assumptions for building types and south-facing roofs should be evaluated in accordance with the estimated areas, and if necessary, calculations should be reconsidered.

Figure 9: *Required area for rooftop systems to meet 25% of energy consumption*



Source: SHURA calculations

Info Box 3: Muğla Metropolitan Municipality Menteşe bus terminal – 280 kW



The Menteşe Intercity Bus Terminal is the first public building in Turkey with a rooftop PV system. The Muğla Metropolitan Municipality invested TRY 11 million into the construction of this building. It has been a great contribution to the environment and the municipality budget, generating 2.5 times more energy than consumed. According to data from October 2019, Menteşe Intercity Bus Terminal generates a total of 25,636.679 kWh of electricity (a value of TRY 20,000) and uses 9,636 kWh of this amount. Generating 16,000 kWh more electricity than it consumes, the bus terminal saved TRY 12,300 per year by selling this surplus.

Muğla Menteşe Bus Terminal opened in February 2019 as the first solar energy system in Turkey as well as Turkey's largest building fitted with a solar PV system. With an operational area of 4,670 m^2 situated on a 19,550 m^2 site, the bus station has a roof area of 3,840 m^2. At present, 1,760 solar panels exist on the roof.

Source: (Enerji Günlüğü, 2019)

4. Cost-benefit analysis of rooftop photovoltaic systems

A cost range of US$1,500-2,000 per kW is foreseen in residential buildings in Turkey in 2020.

In 2018, the average cost of new utility-scale PV systems in Turkey was US$1,200/kW (IRENA, 2019a). In the second quarter of 2016, residential PV system costs ranged from US$1,800 to US$5,000 per kW in different regions of the world (IRENA, 2017). Investment costs of PV systems decrease by 10% to 15% every year. Referring to interviews with stakeholders, a cost level of around US$1,500–2,000/kW should be expected for residential buildings in Turkey in 2020. For larger capacities in other building types (10 to 1,000 kW), investment costs range from US$600 to US$1,200 per kW.

In order to be able to compare PV systems' viability in different building types, LCOE of PV system investments are calculated. In the LCOE calculations, a discount rate of 8% (which reflects the internal rate of return of energy projects in Turkey), a 20-year lifespan, 2% operating cost, and 0% efficiency loss are assumed (ETIP, 2018).

In the LCOE calculations for each building type, investment costs obtained from stakeholder interviews shown in Table 3 are taken into consideration. Referenced capacities are assumed to range between 1–5 kW in Single-family houses, 1–10 kW in Multi-family buildings, and 10–1,000 kW in other building types.

Table 3: *Photovoltaic investment costs per kW in different building types*

Building Type	Single-family houses	Multi-family buildings	Commercial, public, and industrial	Education	Hotel	Health	Shopping mall
Investment Cost (USD/kW)	1,800	1,600	600-1,000	700-1,200	700-1,200	700-1,200	700-1,200

Source: Stakeholder meetings

Levelized cost of electricity and payback period formulas are given below:

LCOE = ((CAPEX*(8%/(1-(1+8%)^-20))+CAPEX*0,02))/((365*24*Capacity factor/100))*100

Payback Period = CAPEX / (Annual Savings – OPEX)

LCOE: levelized cost of electricity (US$/kWh)

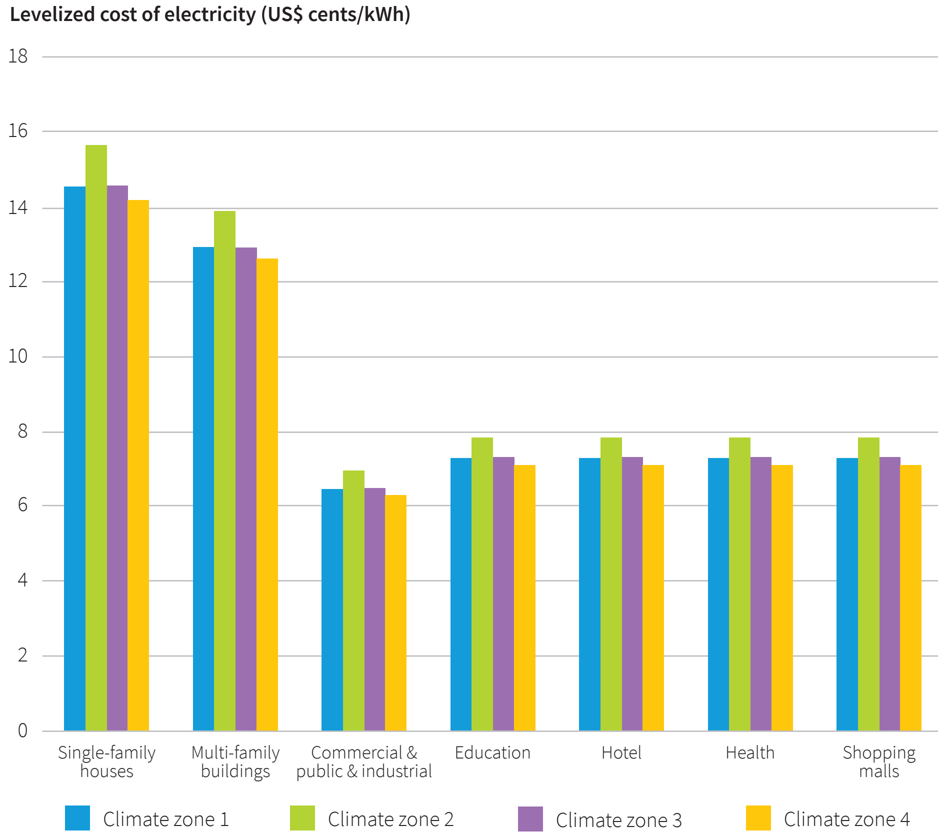
CAPEX: investment cost (US$/kW)

OPEX: operating expenses (US$/kWyear)

Annual savings (US$/year)

According to the calculations, LCOE ranges from US$ cents 6.3 per kWh in systems installed in commercial buildings in the fourth climate zone to US$ cents 15.6 per kWh in Single-family houses in the second climate zone. LCOE in Multi-family buildings is close to Single-family houses. In educational, hotel, healthcare, and shopping mall buildings, LCOE is recorded as US$ cents 7-8/kWh. Lower capacity factors in the second climate zone compared to the other zones led to an increase in unit costs. Levelized costs are shown in Figure 10.

Figure 10: Distribution of LCOE by building types and climate zones



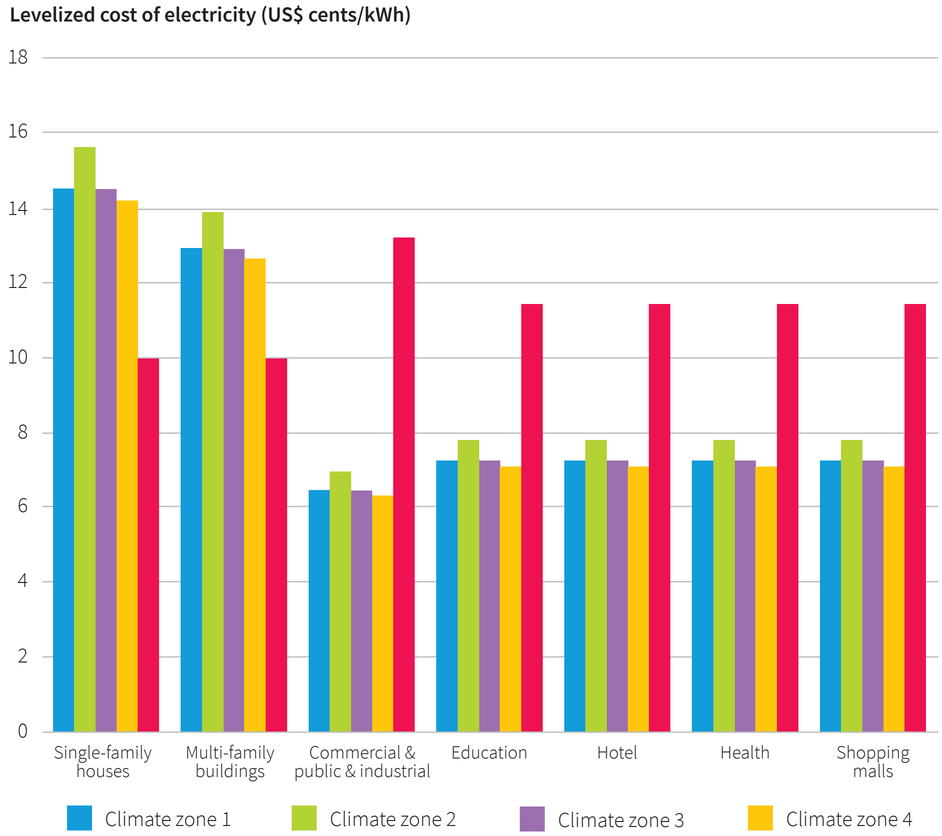
Source: SHURA calculations

As of October 1, 2019 (US$1 = TRY5.73) the grid tariff for households is about US$ cents 10 per kWh (low voltage, single-term tariff, taxes, and funds excluded), while for commercial buildings it is US$ cents 13.21 per kWh and for industrial buildings US$ cents 11.46 per kWh (TEDAŞ, 2019).

LCOE of rooftop PV systems in residential buildings is approximately 30% to 50% higher than the grid tariff, whereas in non-residential buildings this appears much lower.

In Figure 11, LCOE values are compared to grid tariffs on the basis of building type and climate zone. In the comparison, grid tariffs for all non-residential buildings are taken as the average of commercial and industrial buildings' tariff price, which is US$ cents 12.34 (TEDAŞ, 2019). According to this graph, LCOE of rooftop PV systems for residential buildings is approximately 30% to 50% higher than the grid tariff. For non-residential buildings, LCOE is observed as much lower than grid tariffs. LCOE values have reached grid parity for approximately 10% of all buildings (30% of the total technical potential of 14.9 GW). This reveals an economic potential of approximately 6.6 TWh (with 4.5 GW) in total. Grid parity is used as an indicator to evaluate the price competitiveness of rooftop PV systems.

Figure 11: *Comparison of LCOE with grid tariffs in different building types*



Source: SHURA calculations

PV payback periods in residential buildings are around 14-16 years, which seems longer than other building types with 4-6 years.

PV payback periods and other indicators in different building types are shown in Table 4. According to the table, PV payback periods of Single-family houses and Multi-family buildings are approximately 14–16 years, which are substancially long compared to periods of 4–6 years in other building types. The shortest payback period is in commercial, public, and industrial buildings, about 4.5 years. Internal rate of return[3] is highest in commercial, public, and industrial buildings, with a 21.8% return.

[3] Internal rate of return equalizes the net present value of an investment project to zero. In other words, it is the discount rate that equalizes the present value of cash inflows to the present value of cash outflows. The internal rate of return also indicates how much added value the investment will create.

Table 4: *Photovoltaic investment results in Turkey (all climate zones)*

Building Type	Total Investment Cost (US$)	Monthly Savings (US$/month)	Net Present Value (NPV) (US$)	Internal Rate of Return (IRR) (%)	Payback Period (Year)
Single-family houses	2,481,328,929	16,914,511	(854,170,007)	%2.74	16.18
Multi-family buildings	14,514,511,429	110,104,857	(3,778,619,346)	%4.12	14.08
Commercial, Public, and Industrial	2,763,066,429	55,629,147	3,062,734,099	%21.77	4.51
Education	723,746,571	11,230,000	437,738,717	%15.82	6.02
Hotel	42,481,607	657,633	25,526,715	%15.78	6.03
Health	160,167,857	2,480,990	96,409,420	%15.79	6.03
Shopping Mall	8,670,536	134,754	5,267,892	%15.86	6.01

Source: SHURA calculations

At present, assuming that there are no financial supports, the results are as shown in Table 4. Grid parity can be reached by reducing the investment costs of these systems to US$1,200/kW and below for residential buildings. In addition, a discount rate of approximately 5% will enable these systems to be more cost-competitive.

Assuming a decrease of 30% in investment costs in line with new developments in Turkey and the globe and a discount rate of 5%, the results are shown in Table 5 for different climate zones and building types in the fourth climate zone.

According to the table, the payback period is 8–10 years in residential buildings and 3–4 years in other building types. The shortest payback periods are observed in commercial, public, and industrial buildings. The best performance results for all buildings are in the fourth climate zone. The results for other climate zones are given in the Annex. PV investments will become more appealing if investment costs decrease further by 2030. Financial supports such as incentives and tax reductions for residential buildings will also bring the return of PV investments closer to that of other buildings.

Table 5: *Economic results with 30% lower costs and 5% discount rate (fourth climate zone)*

Building Type	Total Investment Cost (US$)	Monthly Savings (US$/month)	Net Present Value (NPV) (US$)	Internal Rate of Return (IRR) (%)	Payback Period (Year)
Single-family houses	292,986,044	2,987,528	76,917,372	% 8.07	9.77
Multi-family buildings	781,139,087	8,960,781	346,876,389	% 10.02	8.50
Commercial, Public, and Industrial	186,111,562	5,640,579	581,933,492	% 34.27	2.91
Education	37,236,763	870,265	79,645,042	% 25.78	3.84
Hotel	2,540,043	59,364	5,432,853	% 25.78	3.84
Health	8,248,716	192,782	17,643,030	% 25.78	3.84
Shopping Mall	601,133	14,049	1,285,753	% 25.78	3.84

Source: SHURA calculations

The LCOE values shown in Table 6 are obtained using October 2019 levels, a 5% discount rate, 20-year lifespan, and 2% operational costs together with a 30% decrease on investment costs. All these values appear below the grid tariff.

Table 6: *LCOE with 30% lowered investment costs*

USD cent/kWh	Single-family houses	Multi-family buildings	Commercial, public, and industrial	Education	Hotel	Health	Shopping mall
Climate Zone 1	8.4	7.5	3.7	4.2	4.2	4.2	4.2
Climate Zone 2	9.0	8.0	4.0	4.5	4.5	4.5	4.5
Climate Zone 3	8.4	7.5	3.7	4.2	4.2	4.2	4.2
Climate Zone 4	8.2	7.3	3.6	4.1	4.1	4.1	4.1

Source: SHURA calculations

In addition to reduced investment costs and discount rates, when operational costs as low as 1% and tariff prices with 20% tax funds are considered, according to SHURA's calculations, payback periods in residential buildings are 6–7 years. In all other building types, these periods decrease to 2–3 years. With prospective systems where surplus production is supported by a variety of policies, these periods will have the potential to decrease even further.

Payback periods fall to 6-7 years in residential buildings with reduced investment costs and discount rates, and to 2-3 years in other building types.

Installing a rooftop PV system with a potential of 14.9 GW requires an investment volume of approximately US$20.7 billion in total. When the environmental impacts of switching to rooftop PV systems in order to meet the energy demand of buildings are considered, striking results are observed. Rooftop PV systems that generate 6.6 TWh electricity per year based on their economic potential will reduce CO2 emissions. If the same amount of electricity is generated with rooftop PV systems instead of coal, with 855 grams of CO2/kWh emission density, 5.6 million tons (Mt) CO2 emissions can be reduced every year. This value corresponds to 3.5% of the total CO2 emissions of the electricity sector in Turkey.

The use of PV systems will also reduce the cost of fossil fuels imported for electricity generation. Replacing PV systems with natural gas in order to generate 6.6 TWh of electricity annually, savings of US$300 million can be achieved in fuel imports (40% power plant efficiency, 36.6 MJ/m3 gas heating value, and US$250/1,000m3 gas import cost, all based on lower heating value) (SHURA, 2019). This value corresponds to approximately 0.8% of Turkey's total energy import expenditures (Enerji İthalatı, 2019).

Info Box 4: Muğla Metropolitan Municipality Konacık service building – 52.4 kW

Muğla Metropolitan Municipality facilities will soon have a total of 1,067 kWh installed capacity, including Menteşe Terminal, which is the first PV integrated structure in Turkey with 280 kWh capacity; Menteşe abattoir facility PV with 105.4 kWh capacity; Konacık administrative building roof PV with 52.4 kWh capacity; and Bodrum Terminal roof, which will have a capacity of 630 kWh once installed. Muğla Metropolitan Municipality will meet the energy demand of approximately 1,000 households per year through its solar power plants. The facilities will generate 1,400 MWh energy annually, as well as providing 30 tons of paper recycling and prevent 840 tons of CO_2 from being released into the atmosphere.

Source: (Enerji Günlüğü, 2019)

5. Financing models for photovoltaic systems

In October 2019, SHURA published the report Financing Energy Transition in Turkey, which assesses renewable energy, energy efficiency, and distributed energy generation, emphasizing rooftop PV systems. Taking into consideration sectoral opinions, expectations, forecasts, and suggestions on how to solve this matter, the deployment of and reliability on distributed energy generation is extremely critical (SHURA, 2019).

Distributed system means electricity generation for on-site consumption using renewable energy sources.

Distributed generation entails production from renewable energy resources for on-site and self-consumption and implies that households are positioned as “prosumers” along with industrial and commercial legal entities. Developments in variable renewable energy technologies, particularly in obtaining resources and market efficiency by improved demand response models, point to more beneficial uses of digitalization, particularly smart grids.

Local banks and leasing companies have been developing products to finance self-consumption investments of industrial and commercial entities. Financing in TRY for up to ten years can be provided for rooftop systems or utility-scale solar power plants connected to the same transformer (SHURA, 2019). While it is known that corporately and financially well-structured institutions will be prioritized, secure loans are also provided based on savings from electricity expenses and, if any, electricity sales income. However, the existence of technical barriers for self-consumption investments to become widespread and the need for additional regulations and development of insurance products are obvious. It is also known that investments made in foreign currency disable the expansion of local currency-based financing.

Public buildings, local government buildings, and public areas such as parking lots and market places have high potential for distributed system investments. Although there are pilot studies on residential rooftop systems, the technology needs to be further improved, investment costs should decrease, and panels should be smaller particularly for rooftop systems in Multi-family buildings. In line with the assessment that payback periods are short for systems in Single-family houses or at the utility scale where high radiation is available, efforts to develop financial products are currently in place. For rooftop systems installed for self-consumption, the dominant view is that the priority for users is industrial and commercial buildings and that further time is needed for viability in residential buildings.

Financing models based on long-term loans provided by the Turkish banking system will remain important. However, alternative financing tools should be developed in addition to the current models. Growing investment levels and changing business models in the renewable energy sector necessitate new tools. Consumer financing institutions’ efforts to finance rooftop systems for the residential segment indicate that the importance of retail solutions may also rise on the agenda.

In renewable energy and energy efficiency financing, leasing companies may be included in the financing system as alternatives to banks. Partially enabling customers to overcome collateralization problems, leasing companies foster the widespread use of leasing models in self-consumption and rooftop systems financing.

Local administrations and municipal networks are noteworthy for their distributed generation projects. Instead of using centralized municipal funds, funders working directly through municipalities may enable the development of new financing models for local governments. Municipal projects, even on a small scale, seem to be suitable for the conversion of funds into bonds by financial institutions; there are many examples of best practices around the world.

In distributed system financing, in addition to corporate and commercial loans, there are several areas within individual loan-based models that have yet to be developed. Reduced risk consumer loans will attract further attention from banks (SHURA, 2019).

Info Box 5: Examples of rooftop systems besides local governments

Year	Project	Location	Power
2014	Has Çelik Solar Plant	Kayseri	4.43 MW
2017	Tiryaki Agro Mersin Tarsus OIZ SPP	Mersin	4.00 MW
2017	Mimar Sinan OIZ SPP	Kayseri	3.92 MW
	Güven Tekstil SPP	Kahramanmaraş	2.00 MW
2016	Irmak Oto SPP	İzmir	2.00 MW
2015	Arena (Stadyum) SPP	Antalya	1.24 MW
2016	EMTA Kablo SPP	Osmaniye	1.17 MW
2015	Saray Tarım Hayvancılık SPP	Kayseri	1.15 MW
2017	Özdörtler Gıda SPP	Kayseri	1.12 MW
2015	Germencik Tavuk Çiftliği SPP	Aydın	1 MW
2014	Beşler Tekstil SPP	Kayseri	1 MW
2015	Dimer Mermer SPP	Diyarbakır	1 MW
2019	PMS Aluminium Bursa SPP	Bursa	900 kW
2017	Nalpaş Gıda SPP	Kayseri	770 kW
2017	Erciyes Çay SPP	Kayseri	758 kW

Source: (Türkiye Güneş Enerjisi Potansiyeli Haritası, 2019)

Requirements and suggestions for development of financing models
Reducing investment scales in distributed system financing offers opportunities for developing new types of financing tools. While narrowing investment scales creates uncertainties in resource-investment match, it is important to develop models and tools that provide financing from climate finance sources for SMEs or individual segments in order to ensure this coupling. When developing products for individuals, low-risk loans should be considered.

Within the scope of distributed generation, several policy recommendations should be put forward: development of effective public policies for distributed systems, resource allocation and development of appropriate financing models for retail products, development of insurance in order to reduce risks through high coverage and integrated financing packages, use of distributed system investment benefits reducing transmission loss as incentives for a certain period of time.

Enhancing public policy mechanisms for the distributed system
In order to enable the use of climate finance resources for distributed systems funding, more direct public policy initiatives and legal requirements should be implemented.

In addition to resource allocation by international financial institutions that will be expanded through local banks specific to the distributed system, local banks should also develop financing models and tools to match projects with these sources. In accordance with this, local banks need capacity improvements at the regional and local levels. Energy companies can contribute to the development of new business models, supporting the development of distributed system capacity as investors or energy service managers. At the same time, the potential to consolidate combined distributed system investments is an opportunity to attract international corporate investors.

Providing sources for financing distributed system investments, measuring the investment portfolio
Novel policy mechanisms should also be implemented in order to develop the distributed system approach. The continuation of regulations distinguishing profit-based investments and distributed systems are recommended while developing financing models and tools. International financial institutions need to increase resources for financing distributed system investments, and local financial institutions need to develop their retail products with a reasonable cost and maturity term structure. Mobilization of funds such as crowdfunding, grants, etc., for energy cooperatives and local governments is also important.

Developing risk-reducing products for rooftop systems, activating more inclusive insurance products and integrating financing packages and funding
Building insurance policies for rooftop systems, especially for small-scale investments such as residential investments, is vital in order to minimize technology risks. This will reduce negative consequences such as the use of inappropriate technology and application errors as well as provide examples of best practices. Including insurance policies along with financing packages will also help the development of advanced financial solutions. Local financial institutions should steer these initiatives.

Reducing transmission losses as a benefit of distributed systems
Investments in distributed systems will reduce the need to connect to the grid and help reduce transmission losses. The profit should be used as a support fund for energy transition in general and for distributed system investments in particular.

The financial support mechanisms that can be applied for rooftop PV systems are explained below.

5.1. Concessional loans

Concessional loans provided by development finance institutions will be an important tool for financing rooftop PV systems.

Concessional loans provided by development finance institutions will be an important tool for financing rooftop PV systems. Concessional loans will be particularly useful in the initial phase, where investment feasibility and recognition are relatively low. The fact that these loans include favorable interest rates and maturities that shorten investment payback periods and include technical support for partner organizations, users, and professionals will also be effective in the deployment of rooftop systems. The World Bank is currently preparing a special loan package for rooftop systems in Turkey.

It is anticipated that concessional loans will be provided for rooftop systems through three channels.

5.1.1. Partner financial institutions
Loans provided by development finance institutions can be extended to companies that invest in rooftop systems in Turkey through development banks, commercial banks, and leasing organizations. This channel has been frequently used for loans provided by development finance institutions for investments in Turkey. In this respect, it is considered as one of the most advantageous methods in terms of both using current connections and accessing local banks' present customer portfolios. On the other hand, some alternative channels have been proposed due to the possibility that this channel may face some restrictions in accessing residential buildings, small businesses, and individual consumers.

5.1.2. Aggregators/technology providers/EPC/ESCO companies
In prosumer financing, loans are foreseen to be used through aggregators. Aggregators will negotiate technical support and installation for a large number of consumers. It is expected that aggregators will finance the prospective prosumers of rooftop PV systems through models similar to equipment sales or to sell energy through models such as "savings sharing". Within the scope of this model, it is envisaged that loans provided by development finance institutions will be used by aggregators under specific conditions, and aggregators will conduct contracting/consulting for prosumers under suitable financial conditions.

5.1.3. Direct loans to producers
It is also possible for concessional loans to be extended directly by producers via development finance institutions. However, it is assumed that this channel is used less often because of the small and fragmented scales of such loans. In this context, it seems possible to finance loans for larger industrial organizations and energy cooperatives.

5.2. Grants and technical assistance

Grants and technical assistance will play a significant role in the deployment of rooftop PV systems. Grants and technical assistance provided by international and public organizations, especially for low efficiency applications on residential buildings may be supportive. Loan packages provided by development finance institutions may also include a certain number of grants and technical assistance. Technical assistance includes training of qualified staff for assembling PV systems and addressing financial, legal, and technical issues related to rooftop applications.

5.3. Risk-sharing mechanisms

5.3.1. Loan guarantees

Creating mechanisms similar to loan guarantee funds will facilitate loans from financial institutions and increase the extent of investments in rooftop systems.

5.3.2. Other mechanisms

In this context, insurance products that guarantee income and technical performance of equipment will be effective in the proliferation of investments.

5.4. Commercial loans

5.4.1. Consumer/Prosumer loans

With an increase in electricity prices and the expansion of rooftop systems over time, commercial and individual loans for rooftop systems are expected to increase in addition to concessional loans. In this context, the development of loan products with adjusted installments around electricity bill levels and flexible collateralization methods will increase the prevalence of investments.

5.4.2 Leasing

Similar to commercial loans, leasing products, which can be repaid in the long-term through installments close to electricity bill levels and flexible collateralization methods, will also be beneficial in supporting investments.

5.5. Other mechanisms

5.5.1. Crowdfunding

Crowdfunding, which is not yet implemented in Turkey, is expected to develop with the participation of international funds, once the relevant legislation is in place. It is estimated that energy cooperatives and similar structures can benefit from crowdfunding with the integration of international funds. With the crowdfunding method, the creation of alternative financial sources from the domestic market may be on the agenda in the medium to long term.

5.5.2. Equity financing

The development of venture capital, risk capital, and similar equity financing methods is expected in the medium to long term, especially consolidated financing. In this context, the mobilization of international funds will be important.

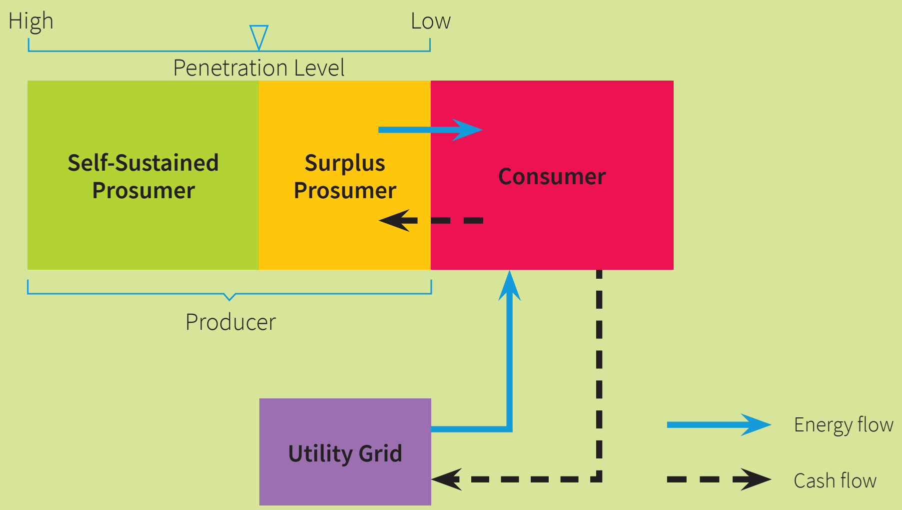
Info Box 6: Distributed generation strengthens prosumer

End users are now the main actors in supply security, the provision of economic access, and sustainability goals in energy transition. The prominent reasons for not having reached the desired levels of end use efficiency can be summarized as follows:

- Uncertainties of the energy market,
- Behaviours of end users,
- Failure to monitor energy consumption instantly and transparently.

Efficiency is a research subject itself, and it is necessary to address each of these reasons separately in order to make progress. On the other hand, a promising fact is that the energy transition embodies methods, tools, and a mindset that will directly contribute to end-use efficiency, transparency, and traceability and that will follow innovation and digitalization processes, support the steps to be taken toward efficiency, in addition to the strength and predictability of markets. In this way, we can predict that consumer behaviours will not remain stagnate but will evolve in a positive manner. These steps will be beneficial to the private sector in core business areas, as well. Considering the fact that almost all of the systems that produce goods or services are dependent on energy, monitoring the energy efficiency of the equipment will also shed light on the overall production efficiency and help prepare the necessary data infrastructure for operational optimization. Thus, private sector enterprises will not only use energy efficiently but will also be able to identify operational departments that they need to improve (SHURA, 2018b).

As distributed energy generation becomes more widespread around the world, new opportunities and mechanisms for prosumers have begun to develop. Prosumers generating electricity with rooftop PV systems will now be able to create new revenue paths by selling surplus electricity to neighbours. To the extent that this system is established, the socio-economic benefits will increase rapidly, and many individuals will participate in production, which will help reduce energy poverty. Continuous access to energy will be possible, and producers will be able to increase income and to consume electricity more efficiently. Mechanisms developing around the world support prosumer-consumer relationships as shown in the example below.



Novel peer-to-peer (P2P) energy trading

Source: (Kuruseelan, S. ve Vaithilingam, C., 2019)

5.6. Current support and insurance mechanisms in Turkey

5.6.1 Consumer loan - Example

Energy companies' contributions to this loan type are determined as a percentage of rooftop PV systems. In other words, energy companies initially support customer investment and hence lower the amount of interest to be paid. After project delivery, energy companies receive payments from the bank, and the customer repays the loan in installments to the bank. In this way, the customer pays for the installed system directly to the bank with the support of the energy company, similar to paying electricity bills. This loan has no interest for up to eight months. Table 7 shows a sample repayment scheme for a TRY 100,000 loan. Interest rates are updated monthly.

Table 7: *Example loan repayment table*

Loan: 100.000,00

	FOR CONSUMER		
Maturity	**Interest rate**	**Installment (TL)**	**Total (TL)**
3	0.00%	33,333.33	100,000.00
4	0.00%	25,000.00	100,000.00
5	0.00%	20,000.00	100,000.00
6	0.00%	16,666.67	100,000.00
7	0.00%	14,258.71	100,000.00
8	0.00%	12,500.00	100,000.00
9	0.09%	11,168.82	100,519.4
10	0.21%	10,139.82	101,393.7
11	0.31%	9,297.53	102,272.8
12	0.40%	8,596.40	103,156.7
13	0.48%	8,003.51	104,045.6
14	0.54%	7,495.66	104,939.3
15	0.60%	7,055.86	105,837.9
16	0.65%	6,671.34	106,741.4
17	0.69%	6,332.34	107,649.8
18	0.73%	6,031.28	108,563.0
19	0.77%	5,762.17	109,481.2
20	0.80%	5,520.21	110,404.2
21	0.83%	4,921.86	111,332.2
22	0.86%	5,102.95	112,265.0
23	0.88%	4,921.86	113,202.7
24	0.91%	4,756.05	114,145.3
25	0.96%	4,603.71	115,092.7
26	0.95%	4,463.27	116,045.0
27	0.96%	4,333.41	117,002.2
28	0.98%	4,312.01	117,964.2
29	1.00%	4,101.07	118,931.0
30	1.01%	3,996.76	119,902.7
31	1.02%	3,899.33	120,879.3
32	1.04%	3,808.14	121,860.6
33	1.05%	3,722.63	122,846.8
34	1.06%	3,642.29	123,837.7
35	1.07%	3,566.67	124,833.5
36	1.08%	3,495.39	125,834.1

Source: CW Enerji

For residences and small businesses, personal information requested from legal entities or individual customers is entered into the bank's system. More information on the loan is sent to the customer if their credit score is sufficient. The customer's loan is approved within 30 days of signing the agreement.

5.6.2 Concessional loan – Example 1

The bank offers financing support through credits under the appropriate conditions for self-consumption of electricity generated with rooftop PV investments.

Investors can take out the loan in TRY, US$, or Euro with maturity periods of up to ten years without principal reimbursement for a maximum of one year, and they can repay loans flexibly or with equal monthly installments similar to paying bills.

Businesses can invest in savings and obtain competitive advantages by loan savings that are mostly provided to industrial and commercial buildings.

5.6.3 Concessional loan – Example 2

One example of such a financing program is a loan package of approximately €500 million provided by international banks to SMEs through participating banks in order to finance eligible energy efficiency and small-scale renewable energy investments. The program, which has been running since 2010, includes participating local banks. Within the scope of this program, investors whose projects are at a certain energy efficiency level can receive up to €5 million. Customers should be financially eligible to apply for loans, meet the criteria of participating banks, and undergo the loan approval processes. As of the end of 2015, approximately 152 MW of PV system financing was provided to various unlicensed projects under this program (GÜNDER, 2019b).

The new regulation for unlicensed distributed generation offers opportunities, such as monthly net metering mechanisms, to those who want to produce electricity. The following persons can apply for this financing model:

- Industrial and commercial enterprises planning to invest in rooftop PV systems, companies with less than 250 full-time employees and whose turnover does not exceed €50 million, and companies with total annual balance sheets that do not exceed €43 million;
- Municipalities and other public institutions that want to invest in rooftop PV systems;
- Large-scale businesses applying with energy performance contracts.

Financing program consultants ensure that projects are properly implemented (Enerji Panorama, 2019).

5.6.4 Concessional loan – Example 3

Local banks offer support for unlicensed generation projects and facility installations below 1 MW, as well as major energy producers. This loan offers non-recourse loan possibilities for up to two years. The loaning conditions are as follows:

- Natural or legal persons who have at least one grid subscription and want to produce unlicensed electricity (1 MW and below) through solar PV systems are eligible to apply.
- To be able to use the loans, a connection agreement must be signed with a distribution system operator.
- A two-year non-recourse plan should be offered.

- Repayment plans may be tailored to suit cash flows of SMEs and individuals with fixed incomes.
- Loans can be in TRY or in US$.
- If annual consumption is below 1 MWh, surplus production can be sold to the state through a legal arrangement, and support for loan payments can be obtained. According to the law, a ten-year purchase warranty is valid.

5.6.5 Concessional loan – Example 4

Local banks sign a new loan agreement with another international bank procuring “sustainable energy and infrastructure loans” worth US$200 million.

This loan is provided according to the Ministry of Treasury and Finance reimbursement guarantee and used in financing renewable energy, energy efficiency, transportation, energy transmission, waste-water management, and telecommunications investments across Turkey.

Sixty-eight percent of the local bank’s loan portfolio consists of sustainability-based investments. Two hundred and forty-five renewable energy and 78 energy efficiency projects have been financed so far with medium- and long-term funds since 2002.

The loan from the international bank, which was established in 2016 with the aim of supporting sustainable infrastructure projects in Asia and provides direct financing to investments in member countries accordingly, is a novelty in the global context (TSKB, 2019).

5.6.6 Concessional loan – Example 5

A loan agreement of €45 million has been signed between two banks in Germany and the Turkish Ministry of Treasury and Finance.

According to the statement made by the bank, financial resources are provided across a 40-year term for PV investments in Turkey.

Investors can benefit from these loans provided that they develop solar energy projects that comply with Turkey’s environmental legislation requirements, have no adverse effect on biodiversity, and contribute to the socio-economic well-being of the population (Yeşil Ekonomi, 2019).

5.6.7 Energy fund – Example

The World Bank approved a fund of US$200 million for the “Energy Efficiency in Public Buildings in Turkey” project on November 5, 2019. An international bank provides US$150 million of this funding, and the Clean Energy Fund provides US$50 million.

The goal of the project, which will be carried out under the financial guarantee of the Ministry of Treasury and Finance and in cooperation with the Ministry of Environment and Urbanization and the Ministry of Energy and Natural Resources, is to create a transition plan in order to reduce energy use in public buildings and develop appropriate sustainable financing and institutional mechanisms to support the national program.

Within the scope of the five-year project, conducting energy audits in public buildings (schools, hospitals, administrative buildings, university campuses, etc.) in Turkey, issuing energy labelling documents, determining energy saving levels, and reporting investment costs are planned together with mechanical and electrical refurbishment projects in appropriate public buildings.

The project aims to achieve energy efficiency in public buildings so as to prove energy costs reduction and savings, provide social and economic benefits at the national level, and raise awareness on energy efficiency in public buildings (Yeşil Ekonomi, 2019).

5.6.8 Leasing – Example 1

A collaboration protocol covering rooftop PV system projects has been signed between the leasing bank and Solarçatı. According to the statement made by the company, within the framework of the protocol, consultancy and installation services are administered by Solarçatı, and the leasing bank is a solution partner.

With the latest regulation amendments in the solar energy sector, operators can acquire a rooftop PV system by paying leasing installments for the first five years (Enerji Panorama, 2019).

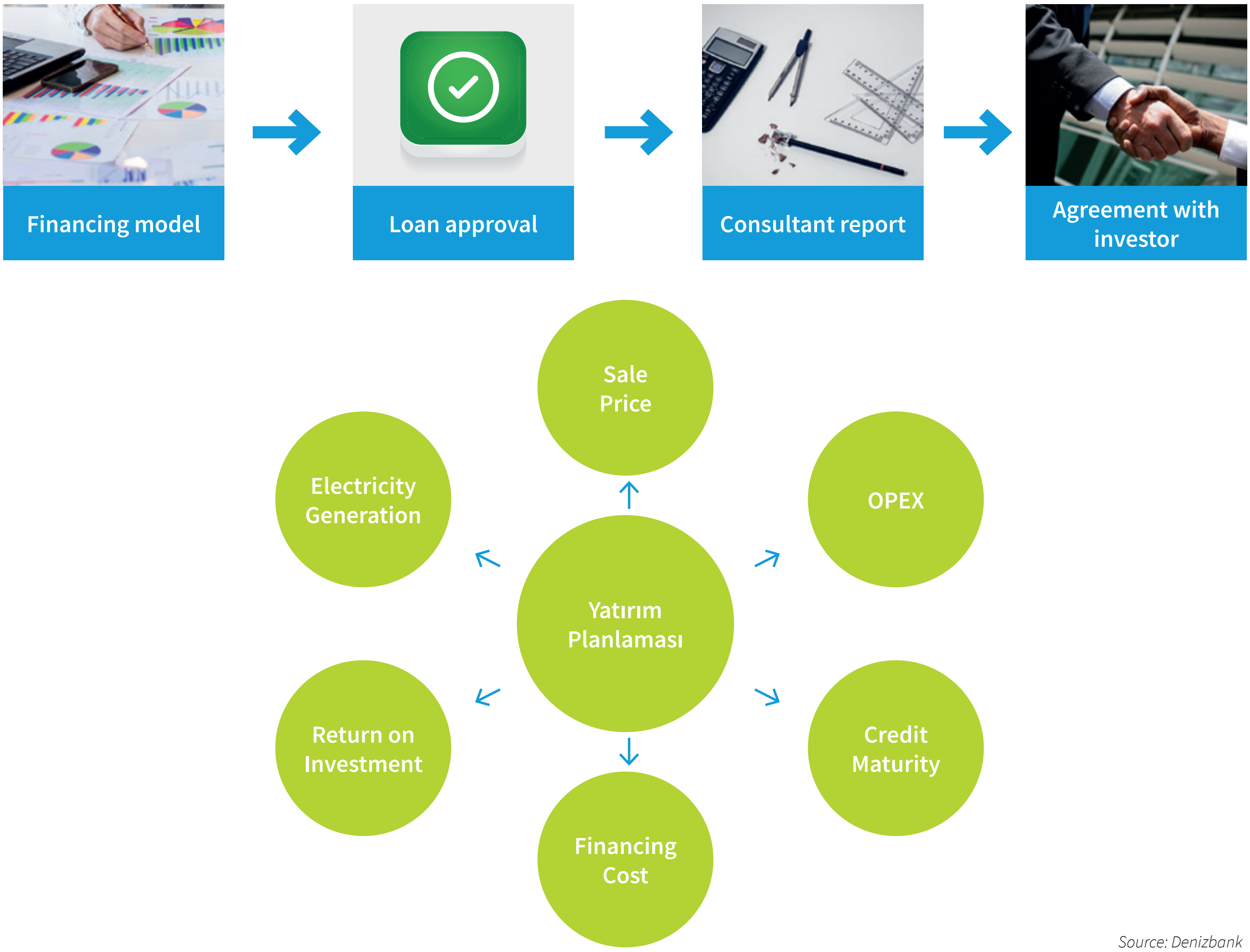
5.6.9 Leasing – Example 2

Since the relevant legislative changes were made in 2013, financing for licensed and unlicensed utility-scale PV systems at 150 MW levels has been provided by Finansal Kiralama A.Ş., a subsidiary of the bank financial services group.

In this respect, Finansal Kiralama A.Ş. is one of the first institutions to offer both the first financing model extended to renewable energy investors and US$-based maturities for up to 120 months for sustainable financing.

Financial modelling/investment planning is carried out as shown in the diagram in Figure 12.

Figure 12: *Investment planning*



Source: Denizbank

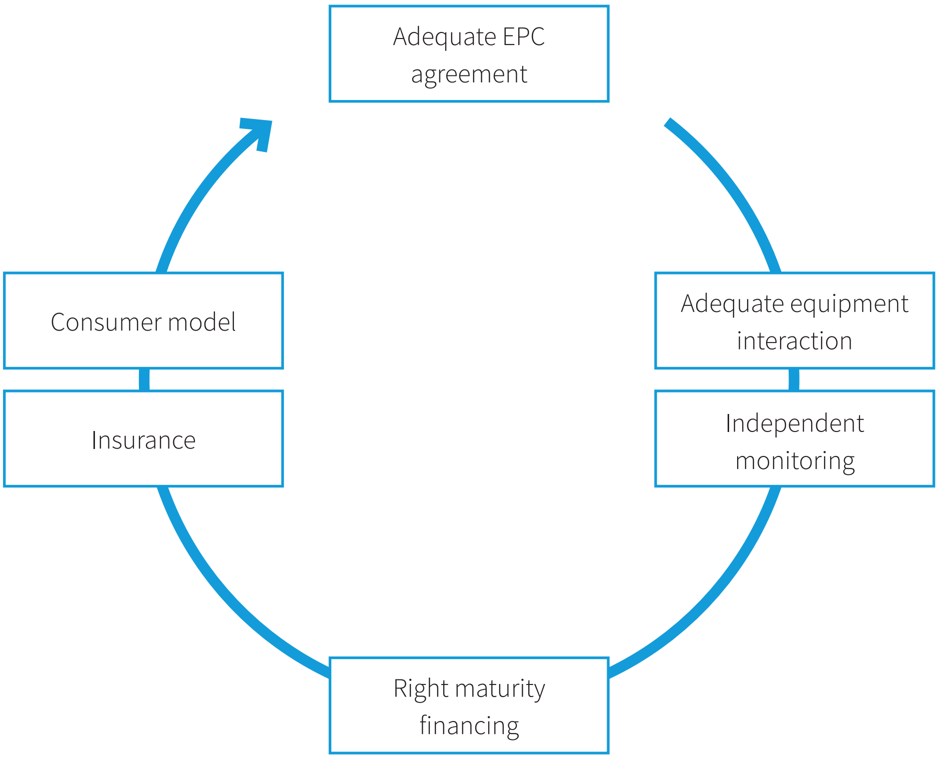
For projects analyzed through equipment and technical consultancy reports, a feasible investment period is planned in which cash generated during the project creates income for investors as well as project OPEX items.

The cash flow cycle can be revised, or investors can be redirected when necessary, based on the data retrieved from projects dispersed in different regions, directions, and locations in Turkey and occasionally based on meteorological forecasts and warnings.

The bank whose main operation and focus area is financing renewable energy investments, has developed operations in the last three years within the framework of the newest net-metering legislation dated 05/12/2019 (GÜNDER, 2019a). They were presented to investors for a rooftop PV system at 50 MW with a self-consumption cash flow model, for which financing preparations were completed.

In financing PV projects for self-consumption, operations continue in line with the model in Figure 13, with low-cost resource use and a low utilization rate.

Figure 13: *Resource utilization model*



Source: Denizbank

5.6.10 Insurance - Example

In addition to the guarantees provided for PV systems, insurance companies provide guarantees for system components such as devices and hardware in case of system damages due to force majeure as well as loss of profit and loss of performance guarantees.

Loss of Profit: Following incurred damages (fire, storm, voltage fluctuation, machine breaks, etc.), the insurance company compensates for the decrease in energy generation due to the deterioration of devices.

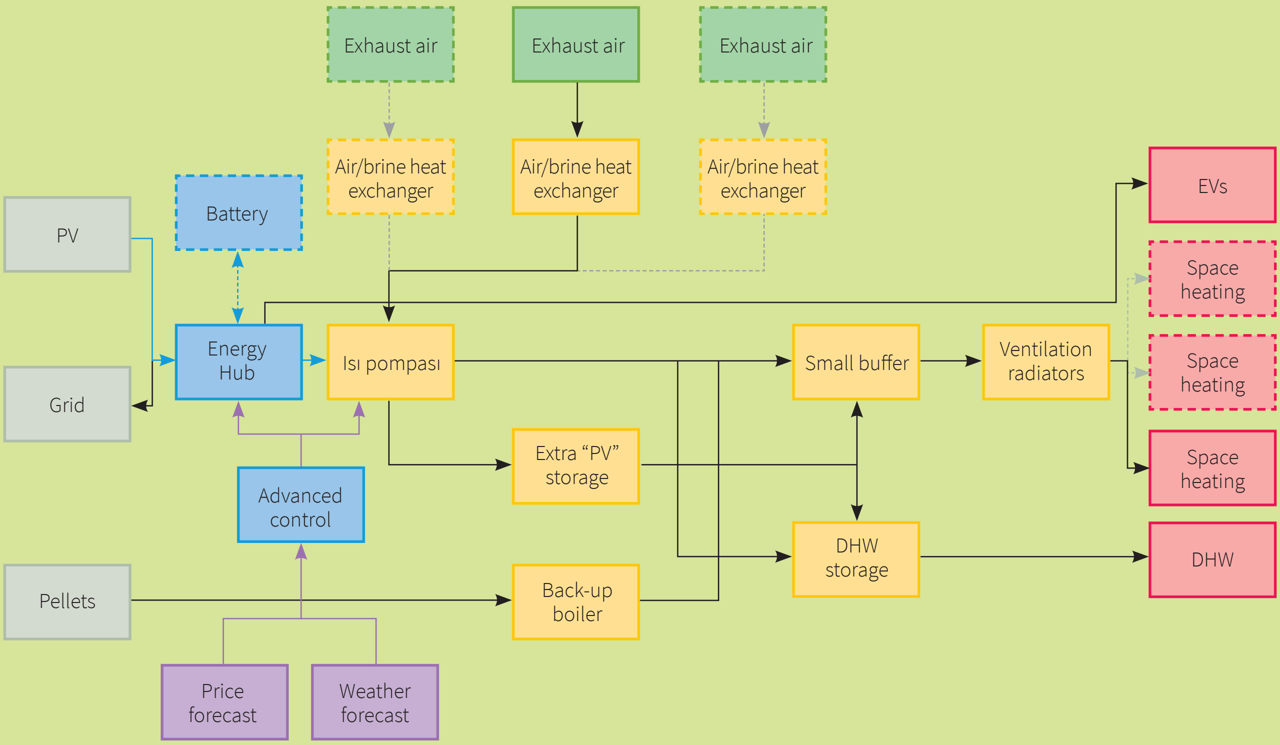
Performance Loss: The insurance company compensates for reductions in energy generation due to low radiation.

Guarantees work in the following way: When calculating compensation, 90% of the estimated annual energy produced based on the energy generation report is compared to the actual annual energy production measured at the output meter of the insured PV unit. Meter readings are recorded at the beginning and at the end of the relevant insurance year. If the actual annual energy generation is found to be lower, a production deficiency arises, and this amount is multiplied by tariff guarantees paid by the related energy supplier.

Performance and loss of profit guarantees in particular help investors achieve financial stability and make clearer investment decisions.

Info Box 7: Rooftop photovoltaic systems with flexibility methods

In the transition phase to distributed energy generation across the world, flexible options that increase renewable energy generation in buildings in an efficient manner have become more widespread. These flexible options include charging electric vehicles, demand response, and electrification methods for heating and cooling using heat pumps. These integrated structures in buildings can charge items such as electric vehicles, for example, in spots where time-varying electricity amounts produced from rooftop PV systems are higher than consumption. The extra energy is stored in batteries and used when production is less than consumption, therby reducing consumption through implementing variable time of use with smart energy management. As heat pumps replace natural gas-based heating as a method that increases electricity demand but reduces carbon, electric vehicles can also provide some support for decarbonization in transportation. Research on integrated systems with maximum efficiency and benefits are currently being carried out. An example of such a system is pictured in the diagram below.



Kaynak: (Huang vd, 2019)

6. Policy mechanisms regulating distributed generation

The share of distributed generation is rapidly growing worldwide. Approximately 40% of the total installed solar power capacity in the world is from distributed systems, and the majority of these utilize rooftop PV systems. This study examines the technical potential of producing 14.9 GW of distributed energy and the economic potential of producing 4.5 GW based on the capacity of building rooftops in Turkey and energy demand values. On top of this, there is a potential of producing 10 GW according to transmission grid modeling results revealed in SHURA's studies published in May and October 2018 (SHURA, 2018a) (SHURA, 2018c). All these potentials remain within the range of 4–47 GW from the World Bank study (World Bank, 2018) published in February 2018 as well as the bespoke 10–30 GW range in Turkey (Enerji Panorama, 2019).

A well-designed electricity pricing system is required for the successful deployment of distributed generation.

A well-designed electricity pricing system is required for the successful deployment of distributed generation. Demand levels may sometimes be lower than expected or a certain amount of generated electricity may need to be sold to the grid in order for an investment to be feasible. In this context, many policy alternatives are available. Some country examples are given in the Additional Information box. It is important to understand the policy mechanisms in place for electricity demand structure, retail electricity tariffs, technical complications, operating and maintenance costs as well as tax liabilities and grid tariffs (SHURA, 2020). The following sections examine several policy mechanisms that are commonly applied around the globe.

6.1. Feed-in tariffs

Within the scope of guaranteed purchase tariff mechanisms, distributed energy producers are usually paid a fixed tariff (e.g., 100% of their production) for gross production of a renewable energy system. This is the case in Germany's guaranteed purchase tariff mechanism. This mechanism allows individuals and businesses to finance solar energy systems without any self-consumption. In recent years, as guaranteed purchase tariff levels have decreased, a growing number of users have begun to consume the electricity they produce. As grid electricity prices have risen, the tendency to reduce grid electricity consumption has increased.

Country example: A feed-in tariff is applied to distributed generation in Germany. The German example underlines the critical role governments play in establishing a safe and long-term policy framework, which is necessary for the private sector and civil society to continue to make investments in distributed generation. Since the 1990s, the deployment of renewable energy in Germany has been supported by various regulatory instruments, particularly the Renewable Energy Act (*Erneuerbare Energien Gesetz, EEG*), which came into force in 2000. EEG provides reliable investment conditions for renewable energy producers. Since then, a national consensus has been reached on energy efficiency and renewable energy, and both SMEs and citizens support the energy transition. Feed-in tariffs for large- and small-scale renewable energy production have encouraged investors, stimulating more than 1.65 million solar power systems and 30,000 wind turbines countrywide. Many of these rooftop PV systems are situated on residential buildings and wind turbines developed and purchased by local cooperatives.

6.2. Net feed-in tariffs

For net feed-in tariffs, a fixed purchase tariff is available only for the user's production surplus (the remaining amount of produced electricity after consumption by the system user).

Country example: In the Australian case, surplus production is sold within the net feed-in tariff system. In this system, solar energy producers are paid only for surplus electricity. For instance, electricity that is not consumed during daytime can be sold to the grid.

The net feed-in tariffs used in Australia focus on providing support for distributed solar energy generation, especially at the residential scale. The upper limits of each project have been determined according to installed capacity (e.g., 10 kW). This tariff system does not support projects such as solar thermal projects or large wind capacity installations but only PV systems.

6.3. Premium systems

Some countries use a fixed or floating premium system above wholesale market price instead of the fixed feed-in tariff mechanism. Market-based support programs such as premium tariffs are well-suited for renewable energy technologies where production can be adjusted based on demand (for instance, biomass and geothermal technologies). Renewable energy technologies with variable production such as wind and solar, however, have limited possibilities to adjust the supply amount and adapt to market price signals. For these technologies, premium tariffs may incur additional costs.

Country example - I: One of Denmark's most important incentives to leverage renewable energy technologies is grid sale premiums. Denmark promotes renewable electricity generation through a premium tariff. Facility operators receive a variable premium above market price. The total of the premium and market price should not exceed a legal maximum value, which is determined according to the commissioning date of the facility and the energy resources used. In some cases, facility operators are provided a premium that is guaranteed at market price. Maximum support levels are not legally defined in such cases.

Country example - II: The market premium system implemented in 2014 with the EEG reform in Germany has become the model program for supporting electricity production from renewable energy sources. This system is only valid for projects of a certain size. The premium is calculated as the difference of the fixed purchase price level and the market value of electricity sold monthly. The facility operator has to sell produced electricity directly to the grid. A third party can be integrated through a power purchase agreement, or it can be sold on the spot market. In accordance with the change made in the EEG in 2017, premium levels for most technologies are determined via auctions.

6.4. Net metering

Unlike feed-in tariffs, net feed-in tariffs and premium systems, net metering policy mechanisms do not incur direct sales of electricity. On-site electricity generation system users connect to the distribution grid and receive premiums for their production surplus. Net metering generally applies to systems with a certain capacity upper limit, and billing periods may vary from hours to months. It is recommended that net metering models are devised based on the specific needs of the country/region/area of use and regularly updated.

Based on the net metering regulation in Turkey, grid-fed electricity and consumed grid electricity are subject to monthly production offsetting.

In Turkey, net metering policy began with the Unlicensed Electricity Generation in Electricity Market Directive in May 2019. According to the regulation, only rooftop and façade PV systems can generate electricity, and surplus production of PV systems up to 10 kW in residences and 5 MW in commercial and public buildings are supported for sales to the grid. Based on the regulation, grid-fed electricity and consumed grid electricity are subject to monthly production offsetting (GÜNDER, 2019a).

Net metering is widely implemented in many countries around the world, including EU member states, the USA,[4] and Malaysia. A net metering model in Massachusetts, USA, is implemented on a monthly basis. At the end of each month, the electricity amount consumed from self-production and the grid is compared. In case the user has a production surplus at the end of the month, this surplus is reflected on next month's utility bills as a loan. In December 2015, the Nevada Public Services Commission identified a decrease in the net metering rate paid to rooftop PV users in the south of Nevada. The commission took action, and the government equalized the rate paid in the net metering mechanism with the rate paid to other power sources. The commission also determined a low-energy cost for rooftop PV system users and created a separate customer class.

An example of an hourly net metering model is applied in Denmark. The regulation "Net-Metering for Producers of Electricity for Own Needs" exempts electricity producers from paying various taxes for the amount of electricity sold to the grid. All producers generating electricity from renewable energy technologies (except 6 KvA geothermal energy) can benefit from this exemption. All installed capacity must be integrated into the grid, installed in locations where electricity is consumed, and belong to users. Surplus electricity is loaned through feed-in tariffs.

An annual net metering model is applied in the Netherlands. Solar energy systems within certain power limitations and whose users are designated as "small users" (capacity of less than 3 x 80 A system owners) are subject to annual net metering regulation. All electricity that is not consumed is fed into the grid and accredited for future consumption. A loan mechanism based on a predetermined price level (US$ cents 5 per kWh) is applied to the surplus production.

[3] Net metering policy is adopted in 44 states of the USA.

6.5. Net billing

According to this mechanism, surplus electricity production is sold to the grid at a different rate than retail tariff price. Some countries, such as Italy, have switched from "net metering" to "net billing" in recent years.

Country example: Italy sets different prices called "scambio sul posto", for the electricity consumed and produced through the net billing system. This system also provides financial compensation through offering additional features (such as guaranteed export price). It allows prosumers to balance the electricity generated and used in a given moment and the electricity supplied/used to/from the grid. The power system is used as a tool for virtual storage of surplus electricity. Scambio sul posto can also be applied in combination with other tools, such as tax deductions.

Additional Information: Time-of-use pricing

The time-of-use pricing system used for prosumers on a real-time basis is an important facilitator supporting distributed energy use. This system demands that producers sell surplus electricity to spot markets or set a different market price according to time of use. This price structure sends price signals to users through informing them of the system's status and provides two main benefits for prosumers: First, the prosumer will be able to receive more payments for surplus production fed to the grid during peak hours. Second, prosumers can avoid high tariff prices through self-consumption during peak hours. Different pricing systems can be applied for larger-scale solar energy systems owned by commercial customers. Aggregators can also help a large number of prosumers by providing a package of services and delivering considerable system benefits in cases where small amounts of production surplus require high-cost measurement infrastructures. Increased demand response, reduced peak load, and reduced investment requirements are some examples of these benefits. Using digital technologies for automation and dynamic pricing connecting wholesale and retail markets will facilitate the implementation of these methods.

There are a number of time-of-use pricing models:

Real-time electricity pricing (Dynamic pricing) - In real-time electricity pricing, electricity rates change frequently throughout the day. Prices change at very short intervals (e.g., every one hour), and the consumer receives a different price signal for each interval. This signal reflects electricity generation costs within the relevant interval. This pricing model is often used for major commercial customers as they are able to respond to high price volatility. For instance, they can use technologies that shut down machines whenever prices rise above a certain limit.

Example: Major commercial customers in New York are subject to real-time (hourly) electricity pricing. In Illinois, two organizations (Commonwealth Edison and Ameren) have started implementing a real-time electricity pricing model for residential users. This type of pricing requires the use of smart meters that provide detailed daily use data and allow service providers to measure and record energy use during each hourly interval.

Time-of-use pricing (Static pricing) - Time-of-use pricing, which is the most widely used pricing model, divides the day into two or three large intervals and sets a different electricity price for each interval. Prices can be determined as non-peak prices (usually from midnight to early morning), semi-peak prices (daytime and evening) and peak prices (peak hours of electricity - usually afternoon/evening). These daily rates remain constant for one season and can be updated in the following seasons. This simple pricing method encourages consumers to reduce electricity use during peak times. However, it does not encourage reducing electricity use in peak periods, such as during heatwaves. Many distribution companies in the USA offer electricity users voluntary time-of-use pricing; however, this pricing system is not widely used.

Variable peak-load pricing - This pricing system is a mixture of static and dynamic pricing methods. Variable pricing periods are predefined in this model. Actual prices for peak-load periods vary according to market conditions.

Critical peak-load pricing - Users in this pricing system receive a signal (such as an e-mail, text message, or phone call) stating that the electricity price will significantly increase the following day or hours. Customers can avoid paying high rates by reducing electricity use and/or self-consuming during high demand periods and/or earning income by selling electricity to the grid. Critical peak-load pricing has been implemented by various states and organizations through pilot programs across the USA (for instance, in Oklahoma).

Critical peak-load discount - Similar to critical peak-load pricing, in this model, distribution companies pay electricity users for every kWh of electricity that is saved from average consumption during critical peak times. The critical peak-load discount model is offered to all users in Washington, DC and Baltimore, according to the relevant policy implementations.

Source: (IRENA, 2019b)

Info Box 8: Environmental performance of Istanbul district municipalities

Yeşil Gelecek Derneği (Green Future Organization) conducted research to examine the current status and approach of district municipalities in Istanbul in addressing environmental issues. In this context, several analyses were made under the following sections: Climate Crisis, Biodiversity, Waste, Air, Water, Transportation, Land Use, Energy, Environmental Management, and Noise-Image-Electromagnetism-Light. The overall score of municipalities and their scores under each section were determined, and Green Municipal Scorecards were created in line with this scoring system. The scores were awarded with regard to the assessment of municipalities' 2015–2019 strategic plans, performance and activity reports for the years 2016–2019, and their official websites. Reviewing the documents of 37 district municipalities, 'yes' was entered for those who answered "yes" in the indicator set and '0' for those who gave "no" answer. Analyses were made in line with 249 indicators.

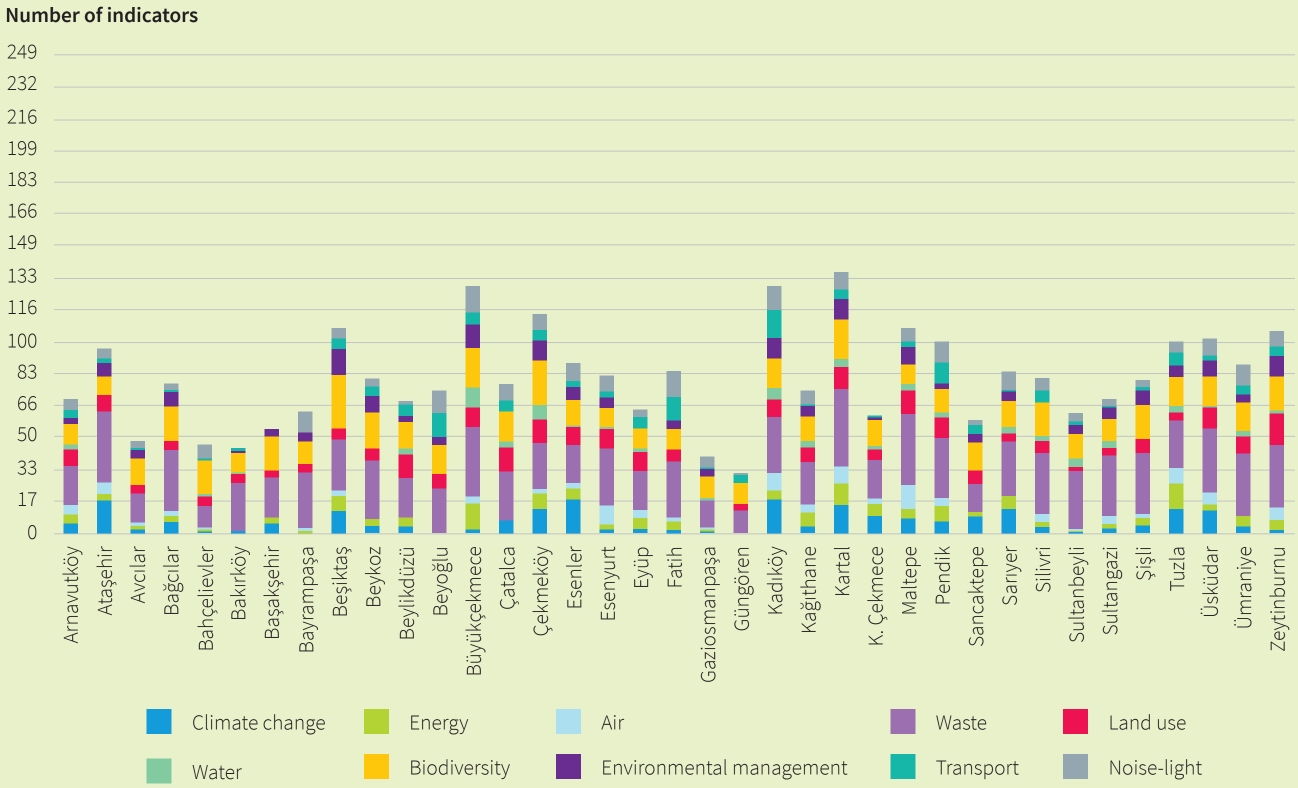
The indicators related to Renewable Energy and Energy Efficiency are given below:

Is there an in-house energy unit at the municipality? / Are there clean renewable energy plants? / Are the quantity and quality of clean renewable energy plants shared with the public? / Is there any study on electricity savings? / Is the public informed about the work on energy savings through the website and local sources? / Does the municipality support clean renewable energy generation? / Has it announced that it supports renewable energy generation? / Is there in-house education on internal clean renewable energy? / Does the municipality share the quality and content of in-house renewable energy education with the public?

Is there an in-house education on energy efficiency at the institution? / Is the quality and content of in-house renewable energy education shared with the public? / Is thermal insulation used in municipal buildings? / Is the quantity and quality of thermal insulation used in municipal buildings shared with the public? / Does the municipality carry out public activities to support energy efficiency within the boundaries of the district? / Are these public activities supporting energy efficiency promoted within the boundaries of the district? / Are there any energy savings studies for city lighting? / Are energy savings studies for city lighting publicized?

According to the results of this research, the performance of the municipalities in each title is depicted in the below graph.

Number of applications



Source: (Yeşil Gelecek Derneği, 2019)

Info Box 9: Cezeri green school building – Ankara

The Cezeri Green Technology Technical and Industrial Vocational High School Campus, designed with the goal of using an integrated design approach within the scope of the Increasing Energy Efficiency in Buildings Project, was built as a model to display how energy consumption and related greenhouse gas emissions can be reduced effectively in public buildings in Turkey. This design was led by Ekodenge and carried out with contributions from German architectural firm Willen Associates, British sustainability engineering firm Atelier Ten, and other teams and valuable experts under this international consortium.

A design was prepared in which social, environmental, and economic sustainability criteria were evaluated, and solutions were offered for all aspects. During the design phase, all studies focused on achieving the highest level of building performance, user comfort, and health. Building information and energy modeling studies were carried out in order to analyse technical features and parameters concerning energy efficiency. Design decisions were made in light of this analysis, such as building orientation, climate data, building fabric, heating, cooling, air conditioning, thermal comfort, renewable energy systems, and lighting. Cost and life cycle impact analyses were also carried out. Implementation projects and environmentally friendly design specifications were created following the improvements made, and the architectural product was also contextualized as an educational tool on sustainability.

In order to achieve energy and material efficiency, architectural and passive design principles, such as solar orientation, were evaluated. By designing a high performance building envelope, heat losses were minimized through woodworking features and details. Landscape design was considered as an important component of the building and was designed to support energy efficiency. The latest technologies such as solar energy, renewable energy systems, and heat recovery air conditioning units were included in the design. Moreover, the building's operations are managed through an automated system that will ensure all integrated systems work appropriately.

Source: (Arkiv, 2017)

7. Conclusion

This study has evaluated the technical and economic potential of rooftop PV systems to meet the energy demand of buildings in Turkey with the assumption of 100% self-consumption. PV systems, which can meet, on average, 17% of buildings' total electricity demand with the exception of appliances and cooking, can supply 11% of all primary energy needs of buildings in Turkey. With a theoretical potential of 55 GW, a technical potential of 14.9 GW can generate 22 TWh of electricity annually. The economic potential of this scenario is 4.5 GW, which is within grid parity. The investment cost of deploying rooftop PV systems in residential buildings is below US$1,200/kW.

Unless otherwise stated in the economic assessment, costs and other indicators are calculated assuming no financial support. Commercial, public, and industrial buildings in the fourth climate zone display the highest economic performance. Financial support packages for residential buildings would need to be implemented in order to obtain similar benefits in other building types. Following the cost-benefit analysis, this study details the relevant policy mechanisms and possible financing tools for increasing distributed energy as well as some current examples of rooftop PV systems in Turkey. While this study examines alternative mechanisms to net metering such as feed-in tariffs, premium systems, and net billing, a cost-benefit analysis of these mechanisms is needed in order to assess their benefits. Apart from this, there are several financing tools such as loans, grants, and insurance policies that can support the deployment of rooftop PV systems.

The aim of this study is to assess the potential of rooftop PV systems rather than present a roadmap to their future distribution. This study is expected to foster additional in-depth analyses for policies and practices to be implemented in order to develop distributed energy systems, as well as projections and planning for the years 2023 and 2030.

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ANNEX – Economic indicators with 30% lower investment cost assumption in climate zones

First climate zone

Building Type	Total Investment Cost (US$)	Monthly Savings (US$/month)	NPV (US$)	IRR (%)	Payback Period (Year)
Single-family houses	328,533,702	3,273,864	75,405,923	7.70%	10.04
Multi-family buildings	1,775,513,353	19,904,773	722,514,125	9.63%	8.73
Commercial, Public, and Industrial	418,118,686	12,384,135	1,266,354,269	33.44%	2.98
Education	93,735,492	2,140,915	193,397,987	25.12%	3.94
Hotel	5,808,962	132,676	11,985,231	25.12%	3.94
Health	19,164,884	437,725	39,541,586	25.12%	3.94
Shopping Mall	1,345,005	30,720	2,775,056	25.12%	3.94

Second climate zone

Building Type	Total Investment Cost (US$)	Monthly Savings (US$/month)	NPV (US$)	IRR (%)	Payback Period (Year)
Single-family houses	664,571,478	6,160,472	86,728,688	6.57%	10.96
Multi-family buildings	5,115,978,388	53,352,346	1,511,953,848	8.43%	9.51
Commercial, Public, and Industrial	864,279,820	23,812,885	2,363,273,859	30.92%	3.22
Education	226,559,700	4,813,595	416,026,712	23.13%	4.26
Hotel	14,377,979	305,481	26,401,973	23.13%	4.26
Health	52,809,362	1,122,013	96,972,698	23.13%	4.26
Shopping Mall	2,629,251	55,862	4,828,037	23.13%	4.26

Third climate zone

Building Type	Total Investment Cost (US$)	Monthly Savings (US$/month)	NPV (US$)	IRR (%)	Payback Period (Year)
Single-family houses	450,839,026	4,492,647	103,477,765	7.70%	10.04
Multi-family buildings	2,487,527,171	27,886,956	1,012,255,704	9.63%	8.73
Commercial, Public, and Industrial	465,636,433	13,791,549	1,410,271,065	33.44%	2.98
Education	149,090,646	3,405,225	307,608,464	25.12%	3.94
Hotel	7,010,141	160,111	14,463,541	25.12%	3.94
Health	31,894,538	728,470	65,805,804	25.12%	3.94
Shopping Mall	1,493,986	34,123	3,082,438	25.12%	3.94

Notes

About Istanbul Policy Center at the Sabancı University

Istanbul Policy Center (IPC) is a global policy research institution that specializes in key social and political issues ranging from democratization to climate change, transatlantic relations to conflict resolution and mediation. IPC organizes and conducts its research under three main clusters: The Istanbul Policy Center–Sabancı University–Stiftung Mercator Initiative, Democratization and Institutional Reform, and Conflict Resolution and Mediation. Since 2001, IPC has provided decision makers, opinion leaders, and other major stakeholders with objective analyses and innovative policy recommendations.

About European Climate Foundation

The European Climate Foundation (ECF) was established as a major philanthropic initiative to help Europe foster the development of a low-carbon society and play an even stronger international leadership role to mitigate climate change. The ECF seeks to address the "how" of the low-carbon transition in a non-ideological manner. In collaboration with its partners, the ECF contributes to the debate by highlighting key path dependencies and the implications of different options in this transition.

About Agora Energiewende

Agora Energiewende develops evidence-based and politically viable strategies for ensuring the success of the clean energy transition in Germany, Europe and the rest of the world. As a think tank and policy laboratory, Agora aims to share knowledge with stakeholders in the worlds of politics, business and academia while enabling a productive exchange of ideas. As a non-profit foundation primarily financed through philanthropic donations, Agora is not beholden to narrow corporate or political interests, but rather to its commitment to confronting climate change.

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