KADIR HAS UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF ENGINEERING AND NATURAL SCIENCES

A ROAD MAP TO INCREASE SOLAR ENERGY PROSUMERS IN TURKEY

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MASTER’S DEGREE THESIS

ISTANBUL, FEBRUARY, 2021

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Director of the School of Graduate Studies

APPROVAL DATE: …./…./…….

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AI	Artificial Intelligence
BNEF	Bloomberg New Energy Finance
BP	British Petroleum
CO^2	Carbon Dioxide
DS	Demand Response
DSOs	Distribution System Operators
EMRA	Energy Market Regulatory Authority
EÜAŞ	Electricity Generation Company
EXIST	Energy Market Operation Corporation
FiT	Feed-in Tariff
FS-UNEP	Frankfurt School – United Nation Environment Program
GHG	Greenhouse-Gas
GUNDER	International Solar Energy Society – Turkey Section’s
GW	Gigawatt
IEA	International Energy Agency
IoT	Internet of Things
KWh	Kilowatt Hour
LNG	Liquefied Natural Ga
MENR	The Turkish Ministry of Energy and Natural Resources
MTOE	Million Tons of Oil Equivalent
MW	Megawatt
MWh	Megawatt Hour
P2P	Peer to Peer
PV	Photovoltaic
R&D	Research and Development
TEAŞ	Turkey Electricity Generation and Transmission Corporation
TEDAŞ	Turkish Electricity Distribution Corporation
TEİAŞ	Turkish Electricity Transmission Corporation

TEK	Turkey Electricity Authority
TETAŞ	Turkish Electricity Trade and Contracting Corporation
TWh	Terawatt Hour
VC/PE	Venture Capital and Private Equity
YEKA	Renewable Energy Resource Areas
YEKDEM	Renewable Energy Resources Support Mechanism
YETA	Renewable Energy Tariff

A ROAD MAP TO INCREASE SOLAR ENERGY PROSUMERS IN TURKEY

ABSTRACT

Climate change is forcing countries to transition from fossil fuels to renewable resources. Solar energy comes to the forefront among renewable sources with its modular structure and low installation costs. In solar energy systems, there is a trend towards self-consumption in many countries. One these countries is Turkey. With the Unlicensed Electricity Generation Regulation in the Electricity Market issued in May 2019, solar energy investments were directed to self-consumption. This change has formed an important basis for the development of the prosumer concept in solar energy investments. Prosumers not only produce the energy they consume but also take an active role in the energy market. Therefore, the development of the prosumer concept is one of the most important steps in the energy transition. However, solar energy prosumer is underdeveloped in Turkey. In the current studies, formulating a roadmap to increase solar energy prosumer in Turkey has been targeted. For this purpose, first of all, case studies in other countries were examined by the literature review. The mieterstrommodell (tenant electricity model) in Germany and a peer-to-peer (P2P) energy trading application implemented by Power Ledger in Australia were selected as the case studies. The applicability of these models in the current situation in Turkey was discussed. As a result, in case tenant electricity model and P2P energy trade implementations are realized, it is claimed that solar energy prosumers are expected to increase in Turkey.

Keywords: Solar Energy, Photovoltaic, Prosumer, Electricity Market, Tenant Electricity Model, Peer-to-Peer Energy Trade.

TÜRKİYE'DE GÜNEŞ ENERJİSİ TÜRETİCİLERİNİ ARTIRMAK İÇİN YOL HARİTASI

ÖZET

İklim değişikliği, ülkeleri fosil yakıtlardan yenilenebilir kaynaklara geçişe zorlamaktadır. Yenilenebilir kaynaklar arasında modüler yapısı ve düşük kurulum maliyetleri ile güneş enerjisi öne çıkmaktadır. Güneş enerjisi sitemlerinde, birçok ülkede öz tüketime doğru bir eğilim vardır. Bu ülkelerden biri de Türkiye'dir. 2019 yılının mayıs ayında çıkan Elektrik Piyasasında Lisanssız Elektrik Üretim Yönetmeliği ile güneş enerjisi yatırımları öz tüketime yönlendirilmiştir. Bu değişiklik, güneş enerjisi yatırımlarında türetici konseptinin gelişmesi için önemli bir temel oluşturmuştur. Türeticiler hem tükettikleri enerjiyi üreten hem de enerji pazarında aktif rol alan oyunculardır. Dolayısı ile, türetici konseptinin gelişmesi, enerji dönüşümü sürecindeki en önemli adımlardan birini oluşturmaktadır. Ancak güneş enerjisi türeticileri Türkiye'de yeterince gelişmemiştir. Bu tezde de Türkiye'de güneş enerjisi türeticilerinin gelişmesi için yol haritası oluşturulması hedeflenmiştir. Bu amaçla, öncelikle diğer ülkelerdeki örnek uygulamalar literatür taraması ile incelenmiştir. Almanya'daki mieterstrommodell (kiracı elektrik modeli) ve Avustralya'daki Power Ledger şirketi tarafından hayata geçirilen eşler arası (P2P) enerji ticareti uygulaması örnek vaka olarak seçilmiştir. Bu modellerin Türkiye'deki mevcut durumda uygulanabilirliği tartışılmıştır. Sonuç olarak, kiracı elektrik modeli ve P2P enerji ticareti uygulamalarının gerçekleştirilmesi halinde güneş enerjisi türeticilerinin Türkiye'de artacağı öngörülmektedir.

Anahtar Sözcükler: Güneş enerjisi, fotovoltaik, türetici, elektrik piyasası, kiracı elektrik modeli, eşler arası enerji ticareti.

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To My Dearest Family...

1. INTRODUCTION

Energy is one of the basic needs of human life and throughout human history various types of energy sources have been used. Humanity started to use energy with renewable sources. Until the 17th century, the usage of human and animal muscles, dung, windmills, waterwheels and woods was widespread. However, with the invention of steam engines in the 18th century and later internal combustion engines in the 19th century, fossil fuels reached the most widespread use (Smil, 2019). First, wood is replaced by coal and then coal is replaced by oil and natural gas. When the factors such as local resource scarcity, convenience, pollution, technical innovation, cost, energy quality, storage, and other factors come into play, it is natural to shift between energy sources to better options (Solomon and Krishna, 2011). This change in the structure of primary energy supply and demand is defined as 'energy transition' (e.g., Leach, 1992; Podobnik, 2006, Kern and Smith, 2008, Fouquet, 2010, Smil, 2010).

According to BP's (2020) data, fossil fuels still have the biggest share in global energy consumption with a share of 84.32%. In 2019, oil was the dominant energy source with a share of 33.1%, and it is followed by coal (27.0%), natural gas (24,2%), hydroelectricity (6.4%), renewables (5.0%), and nuclear (4.3%). However, CO_2 emission from the combustion of fossil fuels and biomass accounts for more than 70% share in the world, causing global climate change (OECD, 2020). In addition, fossil fuels also have resource scarcity problem. They have limited reserves and with the increasing need for energy day by day, these resources are decreasing. Because of these problems it is expected that fossil fuels will be replaced by renewable energy sources in the foreseeable future (e.g., Lazarus et. al., 1993; Boyle, 1994; Bradshaw, 2013).

Statistical Review of World Energy Report of BP (2020) indicates that the renewable energy grew by 13.7% in 2019 and the total renewable power generation reached 2.805,5 TWh. 51% of this was obtained from wind, 26% from solar, and 23% from other renewable sources. While the growth of wind energy was 12.6% compared to 2018, solar energy doubled with a growth of 24.3% (BP, 2020).

In 2020, the energy sector is affected by Covid-19 like other sectors. During the COVID-19 pandemic, the consumption of electricity in residential buildings is increased due to curfews and restrictions. As a result, it is seen that electricity demand fell much less compared to the demand for other types of energy (Robinson and Keay, 2020). According to IEA forecast, renewable electricity generation will grow by about 5%, despite the delay of supply chain and construction caused by the Covid-19 crisis. Although this growth is smaller compared to predictions, renewable energy sources are less affected by the crisis than the other sources. This is because, renewable energy sources are generally more resilient to lower electricity demand than other electricity sources, due to their low operating costs and government subsidies that prioritize purchasing in the market (IEA, 2020a).

Solar energy, which is the conversion of sunlight into usable energy forms such as heat and electricity, has a very important place among the renewable sources. It is one of the cleanest and most abundant local renewable energy sources (Singh, 2013). The solar PV became the world's fastest-growing energy technology between 2009 and 2019 (REN21, 2020). While the total installed capacity of solar PV in the world was less than 23 GW only a decade earlier, it reached 627 GW in 2019. One of the most important reason of that is the reduction of cost and the cost of the PV module has dropped to approximately 80% since 2010 (BNEF, 2018a). These reasons make solar energy a competitive option for electricity generation in the future (Phillips, 2019).

Solar PV power installations, which mostly continue with private company investments, have boomed after 2000. It started to receive government subsidies in many countries, not only because it is an alternative domestic resource for the energy-import dependent countries, but also because a cleaner option for the mitigation of climate change. Solar energy companies started to sell electricity at a special tariff price by making an agreement with the state (Jones and Loubna, 2012). However, at present unlicensed solar PV installations became popular among prosumers.

The term “prosumer”, which is derived from the words of “producer” and “consumer”, was first coined in 1980 by futurist Alvin Toffler. In his book, *The Third Wave,* he argued that the consumer society, the phenomenon of the Industrial Age, will decrease in number as it moves towards the Post-Industrial Age. The old type of consumers will be replaced by prosumers who produce most of their own goods and services. It is defined as “people who produce some of the goods and services entering their own consumption” (Kotler 1986, p. 51). This term was later used in energy sector for people and institutions that produce the energy they consume (Verschae et. al., 2016).

The applications of prosumers in energy market have many advantages. It promotes price competitiveness of distributed power, solves the problem of system stability degradation, and supports energy democracy and sustainability (e.g., Hwang et. al., 2017; Espe et. al., 2018). The modular structure of solar PV allows prosumers to set it up according to their needs. It became very attractive for prosumer with its economic advantages. In addition to the gradual decrease in investment costs in solar energy, feed-in tariffs and government subsidies also reduce the payback time of investments for prosumers. It does not require any extra cost and maintenance to operate. Another advantage is technical possibilities. Solar PV installation is very simple and easy to integrate into systems; if it is desired to store, monitor, measure and trade. All these make solar energy more preferable for prosumers (PVP4GRID, 2018).

Turkey is one of the fastest growing country on energy demand in the world. The energy consumption of Turkey increased 51% in the last 10-year period between 2009 and 2019 (BP, 2020). Turkey’s primary energy consumption is 6.49 Exajoules (155 mtoe), which is consisted of oil (32.3%), coal (27%), natural gas (24.8), hydroelectricity (8.6 %), and renewables (5.4%) in 2019 (BP, 2020). The total installed power capacity of Turkey is 91.267 MW in 2019. This capacity consists of 31.2% hydraulic, 28.4% natural gas, 22.2% coal, 8.3% wind, 6.6% solar, 1.7% geothermal, and 1.6% other resources (TEİAŞ, 2020). As can be seen, fossil fuels have an important place in Turkey's electricity generation with the share of %58,9. With these values, Turkey ranks 4th in primary energy consumption and 3rd in electricity generation in Europe.

As it is indicated by Ediger and Kentel (1999), due to Turkey's geographical characteristics, renewable resources abundant in Turkey, on the other hand, fossil fuels are limited. Therefore, the transition to renewable energy is the only option for Turkey. Almost 75% of the fossil fuels were met by import (Paksoy, 2018). The energy imports cause a high amount of foreign trade deficit (KPMG, 2019). In 2019, the value of imported energy reached US $ 41.731 billion, which corresponds to 20% of total imports (T.C Ticaret Bakanlığı, n.d.). This situation is also seen as a problem in the eyes of the public. According to the survey on Turkish public preferences for energy, import dependence and higher energy prices, energy was seen as Turkey's most important energy problems (Ediger et al., 2018)

Turkey promotes solar PV installations since the geographical features of Turkey favor solar PV installations. Considering the annual sunshine duration and the total radiation intensity, Turkey is the 2nd best country in Europe after Spain (Cetinkaya, 2013). The National Energy and Mines Policy, which ensures Turkey's energy security and reduce high energy-import dependency, was developed by the Ministry of Energy and Natural Resources (MENR) in 2017 (Karagöl et al., 2017). This policy targeted to increase solar PV installed capacity to 5 GW by 2023. However, Turkey reached this target 2018, 5 years before the targeted year (REN21, 2019). In the 2019-2023 Strategic Plan published in 2020, the solar PV target was revised as 10 GW by 2023. The plan also aims at increasing the ratio of the installed capacity based on domestic and renewable energy resources to the total installed capacity from 59% to 65% by 2023 (MENR, 2020).

In May 2019, significant changes occurred in the solar energy in Turkey. The Unlicensed Electricity Generation Regulation in the Electricity Market was published by the Energy Market Regulatory Authority (EMRA). Through this law, an environment was created which supports the prosumer concept, together with three important changes in the law. The first change is that the 13.3-cent feed-in tariff (FiT) for solar PV installations removed from the regulation. The second, the ten-year purchase guarantee is just valid for self-consumption facilities, not for utility-scale. The final change is that; regulation of monthly net-metering system is entered into force. Accordingly, surplus of the solar PV production will be purchased by the government according to active energy price during ten years (EMRA, 2019). These improvements have made roof-top solar PV investments more advantageous. Therefore, this provides opportunities for the development of prosumer systems in Turkey. However, there are still some deficiencies in physical infrastructure, financial support mechanisms, implementation of correct regulations, and integration of new management technologies. It is very important to eliminate these shortcomings and to fasten the development of solar prosumers.

Many studies have been carried out on the subject in the world. The academic studies on the developments in the prosumer concept on a global scale increased significantly in the last 10 years, such as European Commission (2015), PVPS (2016), PVP4Grid (2018), Solar Power Europe (2018), and Inderberg et al. (2018). The solar PV prosumer applications in different countries, including incentives and regulations, were discussed in these studies. The subjects as integration of solar PV prosumers, including technologies such as smart grid, demand response, blockchain, and storage were analyzed in detail in Rathana et al. (2014), Pillai et al. (2014), Velik and Nicolay (2016), Razzaq et al. (2016), Quoilin et al. (2016), Sommerfeldt and Madani (2017), Plaza et al. (2018), Schopfer et al. (2018), Keiner et al. (2019).

In Turkey, Başoğlu et al. (2015), Kilickaplan et al. (2017), Usta et al. (2017), Akpolat et al. (2019), Duman and Güler (2020) provided important information about the potential and efficiency of solar PV. In the studies carried out by Taşçıkaraoğlu et al. (2014), Çolak et al. (2014), Uğurlu and Muratoğlu (2019), Erol et al. (2020), Çolak and Kaya (2020), new technologies which can be integrated into solar energy systems in Turkey, and also subjects such as demand response, smart grid, blockchain, and storage have been handled in terms of monitoring and management systems are discussed. Financial models, economic feasibility and capacity-building program of solar energy installation in Turkey have been discussed in Çetinkaya (2015) and World Bank (2020). Mutlu and Türkeri (2011), Güneş and Güneş (2014), Gözen (2015), and Köksal and Ardıyok (2018) examined the issue of regulations and legal framework in their studies. In

PVP4GRID (2018), Özesmi (2019), Mert et al. (2020), and SHURA (2020), solar energy potential to be used by prosumers in Turkey was examined. On the other hand, PVP4GRID (2018) dealt with legislation and regulations of solar PV prosumer applications, Özesmi (2019) examined the prosumer economy, Mert et al. (2020) studied how to enhance prosumer market in Turkey through P2P trading and finally SHURA (2020) made a detailed study on rooftop solar energy potential in buildings financing models, and self-consumption potential.

All of these studies made important contributions to the literature on solar PV prosumer applications. This thesis will provide further explanation through three ways. Firstly, there are few studies in Turkey which examine technical and legal implementation on solar PV self-consumption concept separately; however, there is need for more comprehensive explanation to be able to provide holistic view. In that regard, examining PV self-consumption in terms of prosumer will eliminated these limitations. Therefore, the main purpose of this thesis is to provide a framework through government regulations which include technical and legal perspectives. Furthermore, this study will be the first thesis examine prosumer concept especially in terms of solar PV in Turkey. Secondly, most of the previous studies in Turkey is published before ‘The Unlicensed Electricity Generation Regulation in the Electricity Market’ in May 2019, thus, this creates disadvantageous in examining the current condition. Thirdly, by examining the best practices as case studies, this study will provide comparative investigations to able to applied model implementation in Turkey conditions. The thesis will compare Turkey with Germany and Australia in terms of legal and physical infrastructure, examine advantage and disadvantage of prosumer implementation and seek the way of implementation for Turkey. Overall, this thesis aims to investigate on a roadmap and make policy recommendations for a successful application of solar PV prosumer in Turkey. The primary research question of this thesis is “How to increase the number of prosumers in solar energy sector in Turkey?” Auxiliary research questions are “Which countries can be taken as a best practice?”; “How did they adopt the prosumer concept in their energy sector” and “What should Turkey do to be able to adapt the best practices in its energy system?”

The relevant data which is handled in the current study gathered from British Petroleum (BP), European Commission (EC), International Energy Agency (IEA), International Renewable Energy Agency (IRENA), Renewable Energy Policy Network for 21st century (REN21), SHURA Energy Transition Center, Solar Power Europe and other international organizations. The local data about Turkey used in the thesis is collected from Energy Market Regulatory Authority (EMRA), Ministry of Energy and Natural Resources (MENR), Ministry of Trade, Turkish Electricity Transmission Corporation (TEIAS) and other related local organizations. Additionally, two cases which are Germany and Australia are used for comparison. The data about the cases was obtained from regional research institution, academic journals, newspapers and websites. The data used will be explained and interpreted in the context of government regulations and in the light of this information; predictions will be applied in the Turkey conditions.

In the literature review, initially, previous studies about solar energy are handled and current data is collected. However, solar energy technologies, investments and regulations have experienced significant changes in the last decade (FS-UNEP, 2020), thus, in the current study, the most up-to-date publications are selected from the relevant reports. According to this change, it has been seen that solar PV systems is the most ideal source for energy prosumers.

In that regard, the term of prosumers is conceptualized in line with its origin, historical process and role in the energy sector. Afterwards, the suitability of legal and physical infrastructures for solar energy prosumer are examined in light of the information obtained from state institutions such as TEİAŞ, EMRA and MENR. Respectively, investment forecasts and infrastructures are compared. Following this information, country overview in the reports of the IEA Photovoltaic Power Systems (IEA- PVPS), IEA Renewable Energy Technology Deployment (IEA–RETD), PV-Prosumers4Grid (PVP4Grid), Solar Power Europe and relevant institutions are studied to be able to determine the case studies. Therefore, Germany and Australia are chosen as best practices in terms of cases. Overall, global improvement of solar energy, current situation of Turkey and best practices are examined and, in the thesis, attempt to increase solar energy prosumers in Turkey.

The structure of the remaining thesis is as follow. In the second chapter, the increasing importance of solar energy in the energy sector will be examined. In the third chapter, energy prosumer concept is discussed in detail. The following chapter the best practices in different countries will be examined. The fifth chapter will examine the Turkish case; in this chapter, the development of Turkish energy market, legislative background, renewable energy policies, government strategies, energy outlook, and national targets will be investigated. The sixth chapter will be devoted to answer the question of what can be done to increase solar energy prosumers in Turkey in terms of three aspects which are financial, technical and bureaucratic. Finally, in conclusion, the major outputs of the thesis together with conclusions will be given.

2. RISE OF SOLAR PV IN THE ENERGY MARKET

Energy consumers are looking for reliable, affordable, and environmentally friendly energy sources. In this sense, renewable energy is the best option to meet this demand. Renewable energy sources have started to be accepted as mainstream energy sources and are increasingly preferred. Solar power, moreover, ranks first among these sources (Motyka et al., 2018). By the end of 2019, total installed solar PV capacity increased by 23% and reached 633.7 gigawatts (GW) from 516.8 GW in 2018 (Solar Power Europe, 2020).

Investments in new technologies are growing daily, which reduce costs for renewable energy installations and facilitate the integration of renewable energy systems into our lives. As a result, the energy transition is accelerating (Motyka et al., 2018). According to the Frankfurt School report (FS-UNEP, 2020), 118 GW of solar energy capacity was added in 2019, and solar energy has become the most installed power generating technology worldwide, as seen Figure 2.1. Also, solar energy ranks first with $1.369 trillion when compared to capacity investments of other resources between 2010 and 2019, as indicated in Figure 2.2 (FS-UNEP, 2020).

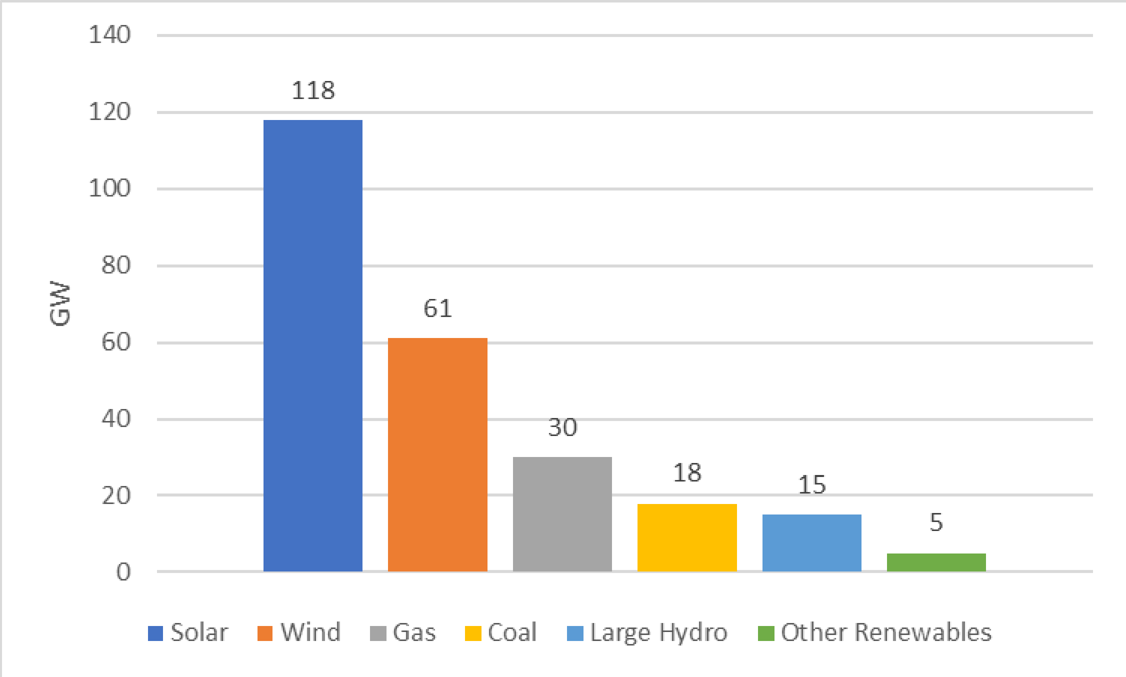

Figure 2.1: Net Power Generating Capacity Added in 2019 by Main Technology

Source: FS-UNEP, 2020

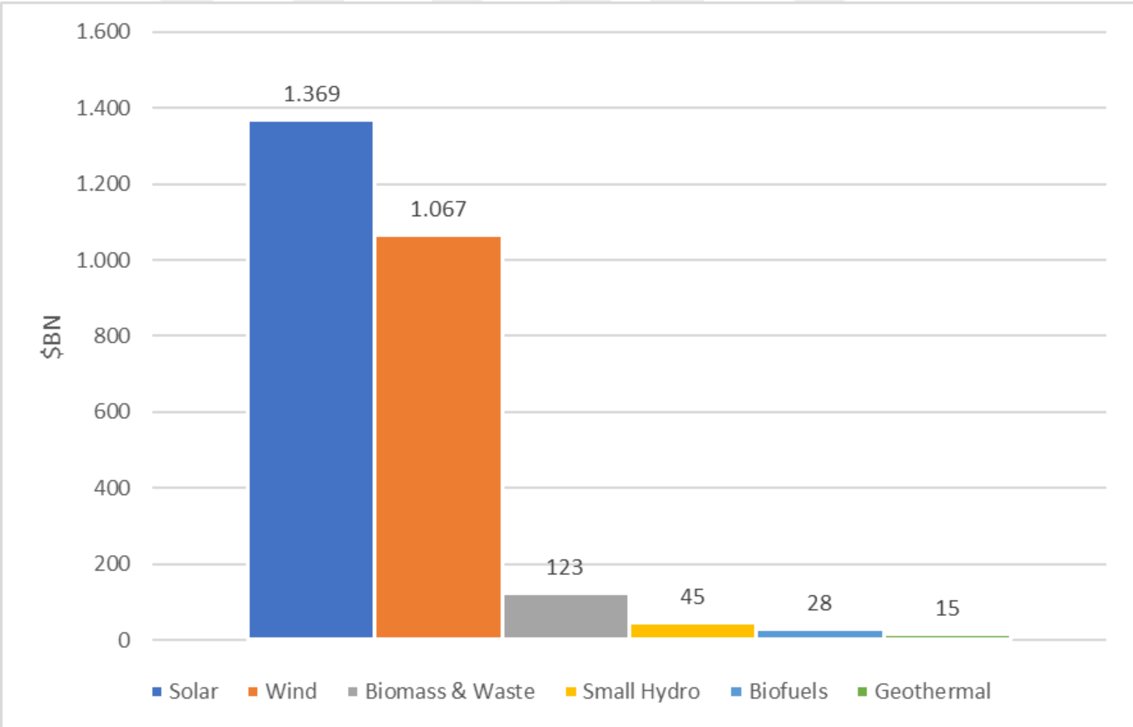

Figure 2.2: Renewable Energy Capacity Investment Over the Decade, 2010-2019.

Source: FS-UNEP, 2020

2.1 COST AND INVESTMENT TRENDS IN SOLAR POWER

According to International Solar Energy Society – Turkey Section's (GÜNDER) report, more than half of electrical energy will be obtained from renewable energy sources by 2050 in the world (Günder, 2018). At present, solar energy is the leading renewable energy source when considering the growth in installed capacity for power generation (IEA, 2020). The primary reason for this growth is the dramatic decrease in the levelized costs of energy (LCOE). Figure 2.3 shows that the LCOE of solar energy decreased by 90% between 2009 and 2020. In 2009, the cost dropped from $359 per megawatt hour (MWh) to $37 per MWh in 2020 (Lazard, 2020). In forecasts made for 2050, it is predicted that this cost will experience an additional decrease of 71% (BNEF, 2018). Solar energy has become most competitive source with conventional electrical energy sources such as natural gas, coal, and nuclear energy.

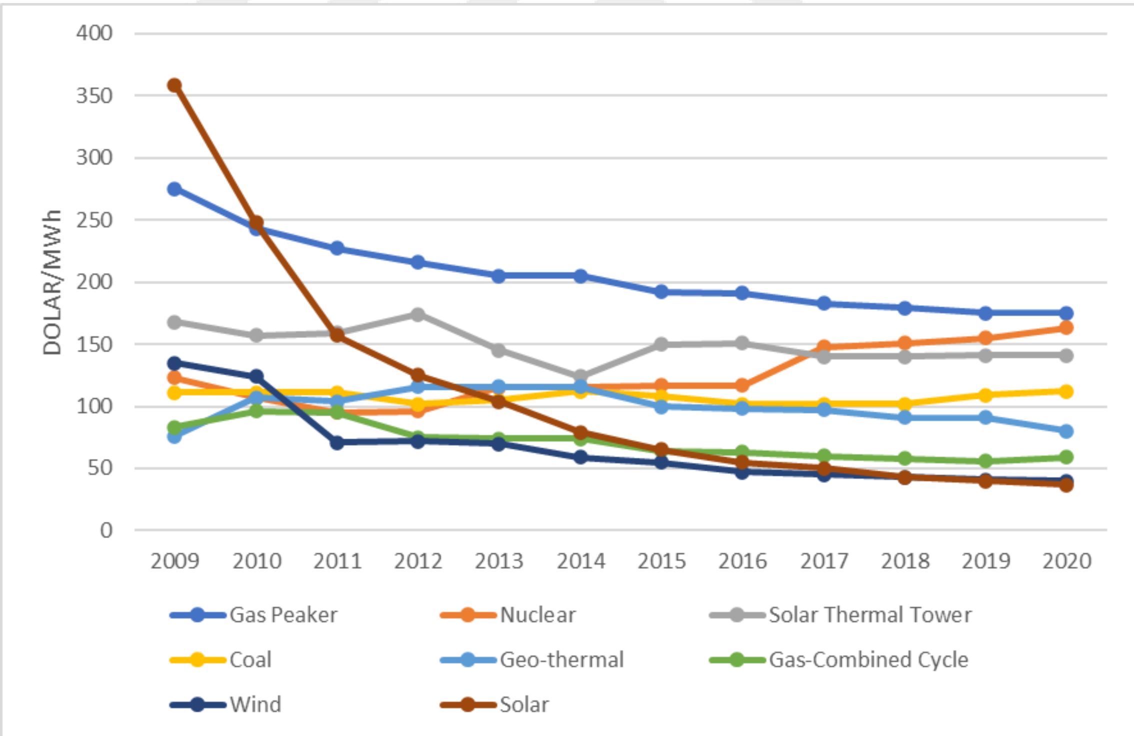

Figure 2.3: Levelized Cost of Energy Comparison Graph

Source: Lazard, 2020

On the other hand, electricity demand is expected to increase by 62% by 2050. As a result, the global production capacity is predicted to nearly triple, which will require $13.3 trillion in new investment, of which $5.3 trillion will be made in wind energy and $4.2 trillion in solar energy. In addition, $840 billion will be spent on batteries, and $11.4 trillion on grid expansion (BloombergNEF, 2019).

2.2 MAJOR IMPROVEMENTS IN SOLAR PV TECHNOLOGIES

Research and development (R&D) expenditures by companies and governments play an important role in the advancement of renewable technologies. According to (FS-UNEP, 2020), R&D spending in renewable energy increased 1% to $13.4 billion in 2019. As seen in Figure 2.4, the largest R&D investment was realized in solar with $6.7 billion. The same report also shows that both companies and countries are making significant investments to develop solar energy technologies, with budgetary allocations for these investments increasing steadily. On the other hand, that the venture capital and private equity (VC/PE) investments in renewable energy have grown 22% to $3 billion, the highest level since 2015. Of this investment, solar rose 29% to $1.8 billion, tripling investment in wind, which reached $529 million but biofuels fell by just over a third to $396 million.

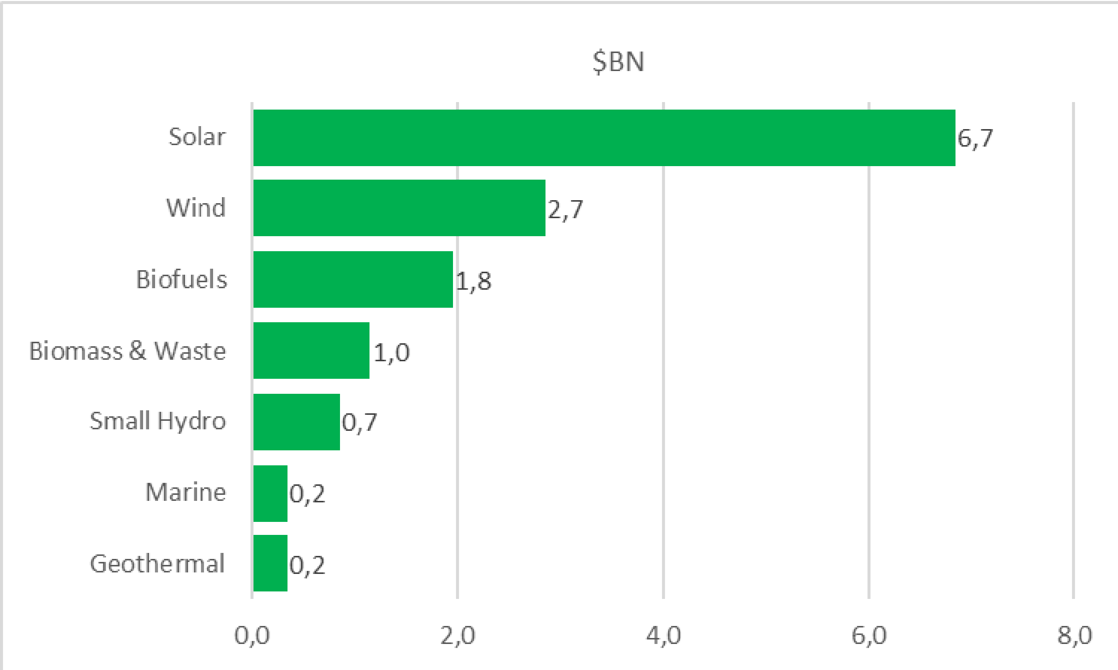

Figure 2.4: R&D investment in renewable energy by sector in 2019.

Source: FS-UNEP, 2020

2.2.1 Efficiency and Digitalization

Solar panel efficiencies are increasing annually thanks to developing technology. Between 2010 and 2019, the efficiency of PV monocrystalline modules increased from 17.5% to 21.1% (FS-UNEP, 2020). Furthermore, new developments in panel efficiency are continuing. The bifacial solar cell is one such development that collects sunlight on both the top and reflects light underneath. On sandy landscapes, it can increase efficiency by 9% and is thus forecast to increase its market share by 15%-21% in a next few year. The efficiency of the installed solar system does not depend solely on the efficiency of the panel or module, but also relates to the output of the facility.

Digitalization has a vital role in establishing and managing flexible and efficient energy systems. 'Digital technologies' include concepts such as big data analytics, artificial intelligence (AI), the Internet of Things (IoT), blockchain, mobility, connectivity and cloud computing. The ‘digitalization of solar’ can be described as the application of these technologies to solar energy to generate new sources of value, to create new business models, and to integrate solar PV into the grid more seamlessly. For a successful energy transition, the digitalization of the electricity system is a cornerstone. To reach this achievement, zero marginal cost renewables such as solar PV play a significant role (Solar Power Europe, 2018).

Digitalization of solar energy comes with many benefits. It provides real-time data analysis, proactive decision-making, detailed monitoring, and productivity maximization. The outcomes of digitalization have directly improved the efficiency and cost effectiveness of electricity systems (Taşaltın, 2019). According to the IEA (2017a), digitization in the energy sector creates an opportunity to save $80 billion, which will naturally lower electricity bills first and foremost, but will also make electricity grids more efficient. The report also draws attention to forecasts that estimate an investment savings of $270 billion in energy infrastructure until 2040. Digitalization can double low-voltage capacity with solar energy and digital grid supporting storage without any additional investment.. Modeling by the European Commission has even shown that increased digitization will generate 3.772 million Euros of additional profit per year by reducing the need for backup capacity (EC, 2015).

2.2.2 Microgrid systems

Microgrids are defined as independent networks that operate below 10 MW and distribute electricity to a limited number of customers, who can work both independently and together with the main electricity grid (REN21, 2019). Microgrid systems are seen as the most appropriate solution for both infrastructure cost and system efficiency for regions without access to the main grid (IEA, 2017b). Microgrids are also more resilient systems in handling production constraints or extreme climate conditions (REN21, 2019).

With solar PV prices falling, microgrid systems have become more prominent and preferable for industrial and rural areas. When they are installed with solar energy, they permit produced energy to be consumed more efficiently within a single region. In addition, when companies are negatively affected by market conditions, network problems, and the provision of quality electricity, they can choose to have their own safe and low-cost power source and have thus embraced the combination of solar and microgrid systems (Solar Power Europe, 2019).

On a macro scale, microgrids are capable of leapfrogging traditional electricity grids and securing power supply globally. There are approximately 1 billion people in the world who do not have access to energy. Solar PV can play an important role in meeting this electricity need from clean energy sources, and is considered the most feasible way with the regional facilities. From this point of view, together with solar PV, microgrid systems have a market share of $64 billion until 2030, even on a household scale only. Microgrid systems enter the market at a competitive price, and the private sector possess potential in this regard because it can enable microgrid systems to spread widely. Accordingly, retail sales and distribution methods of energy can be reconstructed thanks to microgrid systems, and a more optimized system can be established (Willuhn, 2018).

2.2.3 Decentralization

Decentralization is defined as power generation in areas where customers are not connected to a central power grid. Decentralized systems have started to appear in many industrialized countries (Karger and Hennings, 2009). Decentralized energy systems try to bring power closer to end users, who are scattered in different regions, and offer an opportunity for a newly designed system that reduces transmission and distribution inefficiencies and economic and environmental costs (ESCAP, 2012). Decentralized grids also play a significant role in the transition from fossil fuels to renewable resources. In the central grid system, power is generated by conventional energy sources, which are installed on large scales. Decentralized systems, on the other hand, can provide power to a region where consumption is available, with resources such as biogas, wind, and solar, according to the geographical conditions of the region (Altmann et al, 2010).

Economic and technical advantages support the expansion of decentralized energy systems. They facilitate multi-player, local energy systems, are easily managed, and lower investment costs. Even though they are heavily used with renewable resources, they can also work in a hybrid system with conventional resources. In this process, decentralized grids integrate all the innovations of the digital age and increase productivity (Kumar, 2018). Decentralization relies on energy storage, distributed generation, and demand response (ESCAP, 2012). Solar PV fits with decentralization. With the fall in prices for solar energy, the rooftop installations, in turn, have enabled the transition of electricity consumption from a central grid system to a decentralized system at the level of the end-user more effectively (PVPS, 2018).

2.2.4 Blockchain

Bitcoin was first introduced in an article entitled "Bitcoin: Peer-to-Peer Electronic Cash System", which was written yb the crypto currency's founder Nakamoto Sang in 2008. Blockchain deploys decentralized database technologies via Bitcoin payment systems. That is why blockchain systems can be coupled with the concepts of decentralization, transparency, data security, and system autonomy. The purpose of applying blockchain technology in the energy industry is to provide a completely decentralized energy system that can be transmitted and commercialized directly between the producer and the consumer. Blockchain technology helps strengthen the market power and autonomy, in other words, of producers but particularly consumers (Pan et. al, 2018).

As mentioned previously, microgrid and decentralized systems provide benefits for both producers and consumers. In addition to production and consumption activity, transactions need to be managed independently. All these activities must be interconnected and reliable, transparent, and convincing in terms of data security. In this context, when a central institution is established as a traditional solution, all transactions will be managed through it. Doubt grows, however, about whether the central institution can be effectively controlled or can manage these processes successfully. Blockchain technologies thus present a challenge to centralized institutions because they can create decentralized energy-trading platforms based on consensus mechanisms. All participants are, after all, allowed to query transaction data in the blockchain, which guarantees the security of the platform. In addition, encryption algorithms and distributive data storage further protect system data (Wu and Tran, 2018). Through real-time and transparent data management, end-user and small-scale producers thus become direct players in the energy market (Pop et. al, 2018).

2.2.5 Storage

Energy-storage systems vary considerably, including mechanical, electrical, chemical, electro-chemical, and thermal storage. These systems play an important role in ensuring the system integration of renewable energy. Different energy-storage technologies can operate at various stages of the network from production to end-use and contribute to broader electrical stability. Considering the prevalence of use, thermal storage, compressed air, hydrogen, pumped hydroelectric storage, flywheels and batteries are seen as the leading energy-storage technologies (UCSUSA, 2015). Storage technologies allow the use of renewable energy sources efficiently, even if they have fluctuating and intermittent production characteristics. Although storage is not compulsory for renewable systems, it increases system flexibility and enables systems to overcome energy constraints (McPherson and Tahseen, 2018).

According to the data published by BNEF (2018b), the global energy-storage market will grow by 942 GW between 2018 and 2040 and reach an investment of $620 billion. The same report forecasts a further 52% reduction in the cost of storage technologies between 2018 and 2030, following the earlier sharp drops in cost. With these price decreases, millions of storage systems are expected in the business, industrial, and residential sectors, which will lead to increased demand for electricity grids and further reduce electricity costs. This will, moreover, increase power quality and reliability, facilitate balancing, allow the creation of commercial benefits through electricity trade, meet variable supply and demand levels, and enable the use of the network more efficiently (BNEF, 2018b). Therefore, it is anticipated that a customer-oriented system design will be created in the future and participation in the day-ahead market will grow (REN21, 2019).

Solar energy naturally has intermittent and fluctuating production characteristics. In order to increase the utilization rate, it needs complementary technologies, namely storage systems. The latest trends show that the most used energy-storage technology along with solar energy is lithium-ion batteries (BNEF, 2018b). The use of batteries at the network scale plays an important role in helping to balance flows, by providing auxiliary network services such as backup power (Fu et al, 2018). New digital technologies such as big data analytics, IoT, artificial intelligence, robotics, and blockchain are also the basis of “smart” consumers as a result of their integration with storage technologies. With these consumers, the energy transition can accelerate. On the solar side, storage can unleash a huge potential to run solar systems through a grid and in a consumer-friendly way (Solar Power Europe, 2019).

3. CONCEPT OF THE PROSUMERS

3.1 DEFINITION

Alvin Toffler coined the word ‘prosumer’ in his book *The Third Wave*, in which he argued that the structure of society had changed in the post-Industrial Age (Toffler, 1980). In this perspective, people would no longer simply be consumers; they would instead become ‘prosumers’, who produce most of their own goods and services. The name is derived from the combination of the words 'producer' and 'consumer'. Based on this, it is defined as “people who produce some of the goods and services entering their own consumption” (Kotler 1986, p. 51). In the light of this definition, Ritzer et al. (2012) argued that, in fact, looking at the historical process, human beings have always been productive. Since hunter-gatherer societies, all those who engaged in agriculture and livestock can also be define as prosumers. Even factory workers, who produce the product they consume, can be included in this class. Therefore, Ritzer et al. (2012) indicated that the strict separation of the concepts of producer and consumer was a historical anomaly.

The term prosumer was later used in the energy sector for people and institutions, which produce the energy that they consume (Verschae et. al., 2016). Also, they are able to sell the surplus electricity production back to the distributor or can make peer to peer (P2P) energy trade through new technologies like blockchain. Prosumers provide flexibility to energy systems and are active players in the energy market (Lavrijssen, 2017). Prosumers are frequently associated with solar PV and smart grid technologies for generating electricity, trading, storing, and using integrated energy-management systems. As discussed in the previous chapter, solar PV has a modular structure and technicality that makes it easy to install. It thus gives people a great opportunity to generate their own electricity (Lavrijssen and Parra, 2017).

3.2 IMPORTANCE

To support renewable energy sources and facilitate the localization of energy consumption, the surplus electricity can be sold to the grid with a legal regulation called a feed-in tariff (FiT) mechanism. However, the FiT is generally designed as lower than the purchasing price of end users. In this way, it provides a basic motivation for consumers to share their surplus production with each other instead of returning it to the grid (Zhou et al., 2017). While crafting energy policies, economic production was the top priority of energy policies. In addition to economic concerns, energy security and the environment have also become important criteria for all countries. (Oliver and Sovacool, 2017). The current, dominant structures in the power-generation sector support a system in which large volumes of production are generated in remote locations based on conventional sources. In addition, a “top-down” supply chain has been established, and actors have been assigned to roles and responsibilities in this framework. Therefore, in the current system, users are seen as passive agents instead of active players who want to act as prosumers (Lavrijssen, 2017). The tendency towards liberalization in the energy market started to shift the traditional mentality to a more vertically structured supply chain. Therefore, the domination of companies that control the whole supply chain has started to break, and the legal framework has started to extend progressively to new players in market activities (Arretsen and Künneke, 1996).

Overall, prosumers decrease energy inefficiencies and create a new type of market participation. This will expand the range of market possibilities in the energy sector and ensure the efficient use of decentralized renewable energy resources. Also, prosumers increase the integration of renewable sources into the energy system, which will play an important role in mitigating climate change and providing energy security (Diestelmeier, 2019).

3.4 ROLE OF PROSUMERS IN THE SOLAR ENERGY MARKET

It has been observed that many countries have taken progressive steps towards self-consumption. The current trend has allowed countries to utilize the over-production of solar PV electricity with FiT, net-metering, or net-billing systems. Solar PV is very important in maximizing self-consumption, not only in terms of economy, but also in terms of ensuring optimum integration into the electrical system. Moreover, it supports the use of complementary technologies such as storage, which help to increase the share of solar PV in the self-consumption (PVP4GRID, 2018).

According to the global data of IEA (2019), the distributed solar PV market has exceeded 36 GW installed capacity. As new business models emerge in this field, the U.S. and European markets are increasingly turning to prosumer systems with PV installations. The 37% of the PV installations realized in 2018, were made to meet the local consumption of buildings. Thanks to the decrease in the cost of solar PV, the electricity produced by prosumers started to compete with the retail electricity supplied from the grid (PVPS, 2019).

Prosumers also play an important role in controlling energy demand in the solar PV market, which is more prominent with rooftop applications in individual and small-scale installations. Since the ability to control consumption and production must be bidirectional, power consumption and production at both endpoints can be coordinated by prosumers, making consumption, production and capacity more controllable in the energy market. Thus, while developing energy management from the perspective of the demand side, a decentralized management can also be developed, resulting in a more efficient energy system (Verschae et al. 2016). Additionally, if the correct policy framework is applied to harness prosumers for the development of solar PV, they can provide the necessary flexibility to operate solar energy systems in a network, making the market more consumer friendly (Solar Power Europe, 2019).

4. CASE STUDIES OF PROSUMER IN SOLAR ENERGY

4.1. CASE STUDY 1: ENERGIEWENDE IN GERMANY AND MIETERSTROMMODELL

Germany has been one of the leading countries in the fight to reverse climate change. It was seen as a successful model in the ongoing energy transition process. As early as 2000, it enacted a renewable energy resources law, introducing an expensive FiT to support renewable energy investments. Thanks to these regulations, Germany increased its wind and solar PV capacities from 6.2 GW to 83.3 GW between 2000 and 2015 (Pflugmann et al., 2019).

According to BP (2020), Germany’s energy mix consists of 36% oil, 24% natural gas, 18% coal, 5% nuclear, 1% hydro, and 16% renewable sources. When we compare 2018 and 2019, primary energy consumption decreased 2.2% in 2019. However, in the 10-year period, consumption remained almost the same. In terms of electricity generation, the shares of primary sources are 37% renewable resources, 28% coal, 15% natural gas, 12% nuclear, 3% hydroelectric, 1% oil and 4% other sources. In terms of renewable resources, the proportion of wind energy in general electricity production is 21%, solar power is 8%, and other sources is 8% (BP, 2020).

Germany's energy transition, called *Energiewende*, has been an important step towards increasing the share of renewable energy sources in consumption and making Germany’s energy system more efficient. With the "Energy Concept Document" accepted in 2010, Germany formulated its energy policy up to 2050. This document, which included important decisions on renewable energy and efficiency, aimed to achieve a low-carbon and nuclear-free energy system. In this way, *Energiewende* aimed for renewable energy sources to constitute 35% of gross electricity consumption by 2020. However, it surpassed this target with 38% in 2018. By the first half of 2019, the

RES share reached 44%. At present, according to the new plan approved by the climate cabinet, Germany aims to reach 65% by 2030 (IEA, 2020b).

Compared to other European countries, Germany is the country that has made the most effort to use solar PV in buildings. In 2017, it developed a new model called "*Mieterstrommodell*" that aimed that multi-apartment buildings would be able to use shared PV systems (Fina et al., 2018). *Mieterstrommodell*, which is also called “tenant electricity model,” is described as selling rooftop solar PV power for self-consumption to any consumer in close proximity, so long as the public grid is not used. Thanks to the model, property owners and tenants can benefit from solar PV support programs in ways that were not possible before (Brinker, 2019). On the other hand, other consumers in the building may choose to participate in the program or not. Thus, a building may have participating and non-participating tenants (Solar Power Europe, 2018).

Of German households, 53% live in multi-apartment buildings. To encourage this potential, Germany amended the *Mieterstromgesetz* (Tenant Electricity Law), which is regulated in the Renewable Energy Act (EEG). This legal framework sought to increase local production and consume electricity from renewable energy sources. Doing so, the law fosters consumers to invest in solar PV on rooftop in their buildings (Braeuer, 2019). According Zimmermann and Madlener’s (2018) study, which modeled the potential of *mieterstrommodell* for transforming consumers into prosumer, there are about 3.8 million suitable apartments in 370,000 multi-tenant buildings. The maximum potential of this model could reach approximately 3-4 terawatt-hours (TWh) of direct solar PV electricity use (Zuber, 2017).

Different players in the market can be the part of this model. Public utilities, energy supply companies, green electricity providers, energy and housing cooperatives, homeowners’ associations, and building management companies can all be plant operators (Zuber, 2017). The consumer can have a single supply contract with the facility operator or have two contracts, one with the operator and another with a company that meets the extra electricity demand (PVP4GRID, 2018).

In addition, an incentive mechanism was developed called *Mieterstrompremium* to support these prosumers. *Mieterstrompremium* is calculated as the difference between the reference value (when the installation is activated) and the deduction value (8.5 cents/kWh). Excess electricity fed into the grid can be sold with normal feed-in tariff (PVP4GRID, 2018).

There are certain conditions required to receive government incentives. Primary housing in the building must constitute at least 40% of the total share of apartments. It allows PV installations up to 100 kW, and up to 500 MW of such installations can be subsidized each year. The third-party plant operator must sell the electricity either to owners of residential apartments or tenants within the residential building. The solar-PV electricity that is supplied within this model must always be 90% or less of the basic tariff of the basic electricity providers (Solar Power Europe, 2018).

The *mieterstrommodell* encourages consumers to invest in rooftop solar-PV, but there are some obstacles to implementing and developing the model. First, the model can be implemented in a wider range, but it is limited to individual buildings. Commercial or industrial buildings are not directly included. Also, the program is only intended for solar PV producers with an installed power capacity of not more than 100 kW, and annual add-on is limited to 500 MW. These cause restrictions for potential investors. Thus, the range of the program must be extended (PVP4GRID, 2018). Secondly, there are unclear legal definitions in the regulations regarding *Mieterstrommodell*. This reduces planning reliability and prevents innovative supply solutions. For example, ‘close proximity’ terms, which allow the sale of electricity to nearby customers is not clearly defined. A legal amendment must be made to clarify these kinds of concepts (Solar Power Europe, 2018). Thirdly, in order to make the model more efficient, e-mobility and intelligent network operations investments are made which increase project costs. However, there is no government incentives. Also, the Germany’s renewable energy surcharge (EEG surcharge) still must be paid by the *mieterstrommodell* user, and the state should also provide support in these areas (GSA, 2019). Fourth, the supplied solar electricity should always be 10% cheaper than the basic provider's base tariff. In Germany, local grid tariffs differ by region, therefore this requirement may be difficult to meet in terms of increasing the users of *mieterstrommodell*.

Thus, a more flexible pricing system should be determined (PVP4GRID, 2018). The digitized measurement system is complex in its current legislative form. The commonly used "*Summenzählermodell*" does not accurately represent the physical distribution of tenant supply in a building (Schneidewindt, 2017). Smart-metering models and blockchain systems can be used to visualize buildings' energy flows and savings, thereby increasing tenant involvement. The German Act on Digitalization of the Energy Transition requires the gradual expansion of smart meters, but still needs to be improved (Solar Energy Europe, 2018). Although legal and financial regulations are more related to the power of the state, the digitalization process requires more detailed study and adaptation, as it is the most important factor in the development of the prosumer system. Therefore, this process, which Germany has not completed, will be examined in detail in the next case, the example of Australia.

4.2. CASE STUDY 2: DIGITALIZATION IN AUSTRALIA AND P2P ENERGY TRADE

Australia is one of the most important countries in the global energy market. It is a leading exporter of coal, uranium and liquefied natural gas (LNG). Asian countries, especially India and China, have increased their energy imports from Australia every year. However, Australia is undergoing a significant transformation in its electricity markets. The share of solar and wind energy in the sector is increasing (PWC, 2019). Just five years ago, fossil fuels accounted for 85% of Australia's electricity generation, which was the highest among the IEA member states. For this reason, the energy sector was responsible for 50% of carbon emissions in Australia (IEA, 2019). Moreover, wholesale and retail electricity prices have also increased in recent years due to lack of competition and increasing domestic gas prices, transmission, and distribution costs. Residential electricity prices have more than doubled since 2004. As a result, consumers have turned to alternative solutions, notably solar PV (IEA, 2019).

When the current situation is examined, it is important to note that primary energy consumption of Australia has increased 17% in last ten years. In 2019, it increased 6.9% and reached 6.41 exajoules or 153 Mtoe. Australian energy consumption consists of 33% oil, 30% natural gas, 28% coal, 2% hydroelectric, 7% renewable sources. Renewable energy power generation increased 27.3% and reached 41.1 TWh in 2019. Renewable energy generation grew sixfold compared to a decade ago. Share of renewable energy consist of 47% wind, 44% solar, and 9% other renewable sources. Among these energy sources, solar energy is the source with the highest growth rate (46.2%) compared a decade before (BP, 2020).

An important step has been taken for the digitalization of solar PV implementation and the creation a new economic model in Australia. Power Ledger, an Australia-based startup, used blockchain to build a P2P online electricity-trading system for excess solar PV electricity. In the first half of 2017, Power Ledger initiated an official trading system that included 80 homes. It was the world’s first P2P electricity-trading system. Through this system, residents sold excess electricity directly to other users for prices higher than what they sold to the electricity companies. In this system, blockchain technology determines the consumers and producers of energy when it was generated, then completes transactions via a series of protocols. Consequently, consumers experienced lower electricity costs and producers received higher benefits (Wang and Su, 2020). Moreover, in the trial, this system was tested on solar energy. Furthermore, in blockchain-based energy trading, consumers can choose not only the suppliers but also the type of energy supplied, which means that consumers can choose clean energy among the available resources (Wang et al., 2019).

On the other hand, using blockchain provides transparency and traceability in energy trade and creates a smart and energy-efficient platform in electricity generation and distribution via smart grid and smart power generation (Perra et al., 2020). The blockchain system developed by Power Ledger enables interoperability between the pricing mechanisms and the electrical units (kWh) (Kim et al., 2018). PV prosumers are usually paid 7c/kWh for returning surplus power to the main grid. However, it charges consumers 25c/kWh. Power Ledger’s P2P project agreed to pricing of 20c/kWh for power purchased via the platform. Prosumers get 75% of the electricity charges, and the utility company gets 25%. According to future expectations, blockchain platform developers or operators will get smaller cuts (Andoni et al., 2019).

Similar to most countries, Australia receives electricity via long distance transmission and distribution lines. However, in recent years, the number of distributed power generators and storage systems like rooftop solar PV and battery systems have increased. This system integration has been an important step to enhance the adoption of microgrid systems. Microgrids are an independent network operating below 10 MW that distribute electricity to a limited number of customers. They can work not only independently but also integrated with the main grid. Microgrids are more resilient under production constraints, volatile market conditions, and extreme climatic conditions (REN21, 2019). They also have an important place in the energy transition and can work more efficiently in operational conditions with blockchain. Thus, distributed renewable energy sources can be increased in Australia's energy market because energy transactions and financial payment processes are more reliable via blockchain (Yahaya et al., 2020).

In that regard, the implementation of preprogramed "smart contracts" provides the revenue of surplus electricity immediately to energy producers unlike the current system, which causes delays in payments. Smart contracts perform the role of a virtual aggregator, and transactions are stored as byte codes in the blockchain and executed by stored transactions. Smart contracts reflect the match-up and results when a block is added. Afterwards, the contract can be executed if the conditions of the transaction are met (e.g., Kim et al., 2018; Leeuwen et al., 2020). In the next stage, it is planned to implement demand response (DS) systems into the grid (ARENA, 2017). DS is expected to facilitate the transfer of energy from low-demand users to high-demand consumers when it is needed, increasing flexibility and balance as a consequence (Ali et al. 2020).

Even though there are considerable advantages in P2P energy trading, there are also some obstacles. From the technical side, large-scale implementation has not occurred yet, which is why the developer and operator of this system, like Power Ledger, may face great technical challenges (Wang and Su, 2020). On the other hand, in implementation larger systems, regulations have not been written yet, so they will also be faced with regulatory barriers. Market solutions are, in other words, still immature (Micropowergrids, 2020). Overall, The Australian P2P energy trading case conducted by Power Ledger was the first to be taken as an example, and the information from it is quite helpful for developing countries like Turkey that might develop their own P2P energy-trading platforms.

5. THE CASE OF TURKEY IN SOLAR PV PROSUMERS

Turkey’s growing economy and increasing population rates in urban areas make electricity markets strategically important. Turkey is Europe's fifth largest market in terms of electricity consumption (The Investment Office of the Presidency of the Republic of Turkey, 2019). Considering the growth rate in consumption, it is predicted that Turkey will enter the top four in the near future (TÜSİAD, 2018).

The growth in the electricity market has produced structural changes over the past two decades. The first reform, the 2001 ‘Electricity Market Law’, launched Turkey's electricity market-liberalization process (Resmi Gazete, 2001). The legislation changed the energy market in every aspect and created a more competitive, environmentally friendly, and more consumer-oriented vision for the country. During this process, an independent energy regulatory body was constituted: The Energy Market Regulatory Authority (EMRA). In addition, many steps were taken to bolster the market, such as licensing players, determining the tariffs, organizing the operations of options, and initiating privatizations. These show that the liberalization process was progressing step-by-step (SHURA, 2018).

Through the private investors entering the market in the liberalization process between 2003 and 2018, $95 billion was invested, including $67 billion in electricity generation and $28 billion in electricity distribution (TÜSİAD, 2018). Among these, the increase rate of solar energy investments has attracted great attention in the last five years. According to the report published by the Presidency of the Load Dispatch Office in the Turkish Electricity Transmission Corporation (TEİAŞ) (2020), Turkey recorded 91.3 GW of installed capacity at the end of 2019, of which solar accounted for 6.0 GW of 6.5%.

When Turkey's solar energy potential is taken into account, there is still a lot of progress that needs to be made. At this point, a feasible roadmap for Turkey must examine the development of electricity market, the legal and physical infrastructure, and the current situation of solar PV prosumers.

5.1 DEVELOPMENT OF ELECTRICITY MARKETS AND HISTORY OF SOLAR ENERGY IN TURKEY

With the establishment of the Ministry of Energy and Natural Resources in 1963, efforts to improve power plants gained momentum. Due to factors such as industrial growth, rising electricity generation, and rising public demand, it became necessary to institutionalize the electricity sector. In order for the state to coordinate activities in the energy sector, Turkey Electricity Authority (TEK) was established in 1970 (Küfeoğlu et al, 2019). Thus, all components of the electricity—generation, transmission and distribution—were coordinated under the same roof. However, in 1993, TEK was divided into two institutions in order to liberalize the market. One of them is Turkey Electricity Generation and Transmission Corporation (TEAŞ), which is responsible for generation and transmission, and the other is Turkish Electricity Distribution Corporation (TEDAŞ), which is responsible for distribution. These two institutions continued to operate as state companies. In 2001, with the Electricity Market Law, TEAŞ was further divided again into three legal entities, which are Electricity Generation Company (EÜAŞ) was responsible for generation, TEİAŞ responsible for transmission, and the Turkish Electricity Trade and Contracting Corporation (TETAŞ) responsible for wholesale markets (Taşdöven et al, 2012). In 2001, EMRA was also established to operate production, transmission, distribution, wholesale, retail, import and export for all players in Turkey. EMRA is authorized as a public institution with regulatory and licensing authority (Küfeoğlu et al, 2019).

In 2013, TEDAŞ transferred the operations of 21 distribution regions to private sector companies for the following 30 years. However, the facilities remained under the ownership of TEDAŞ. On the other hand, TEDAŞ has worked with distribution companies and, at the same time, controls the 21 distribution companies that are responsible for the distribution of electricity in their respective regions (TEDAŞ, 2019). In 2015, the Energy Market Operation Corporation (EXIST) was introduced as an energy exchange market. Operating under the market operation license, EXIST has undertaken the planning, installation, development and management processes in the energy market (Küfeoğlu et al, 2019). Its main tasks are: operating the day-ahead and intraday markets, regulating financial transactions in the market, providing support to balance market efficiency, and organizing new potential energy markets (Yılmaz, 2019). The liberalization process has continued to take important steps thanks to EXIST. Two years after its establishment, in 2017, the private sector reached three quarters of total electricity generation capacity. Despite all these liberalization steps, it still cannot be said, however, that market prices are determined solely according to market dynamics. For Turkey, energy is also a part of its national security. Therefore, it has created direct and indirect programs to support power plants that can contribute to energy security such as renewable energy (SHURA, 2018).

Studies on solar energy in Turkey began 50 years ago. In the early 1960s, solar energy in Turkey began to be discussed as an alternative energy source. Following the technological developments in the world, universities, government agencies and industry in Turkey began to show interest and work on solar energy in the 1970s. The first passive solar system was implemented in the buildings of the Middle East Technical University in 1975. In the years that followed 1975, solar energy systems grew to be widely used for water heating mostly (Hepbaşlı and Özgener, 2004).

However, solar PV has grown dramatically in the last five years. Turkey's first PV Power Plant License Auction applications were received in June 2013, but evaluations were not completed until 2015. 43 projects won the tender. Although two years have passed, two licensed projects, with a total power of approximately 13 MW, have been put into operation and it continued. In addition, PV installations gained momentum with the creation of the Renewable Energy Resource Areas (YEKA) tenders. In 2017, With the YEKA-1, the tender for the capacity of 1,000 MW was completed. Special areas reserved only for solar energy, also called "Energy Specialized Industrial Zones," were created. With the incentives given in the field of energy, it was aimed that not only to generate electricity with solar PV, but also to create a value chain (TÜBA, 2018). Solar energy's uptake in the last five years is owed to falling prices, new regulations, and government support. Figure 5.1 shows the increase of solar energy since 2010. At the end of 2019, solar energy reached an installed power capacity of the 5,995 MW (IRENA, 2020) of which 5,825 MW (97%) comes from unlicensed electricity generation facilities (EPDK, 2020a).

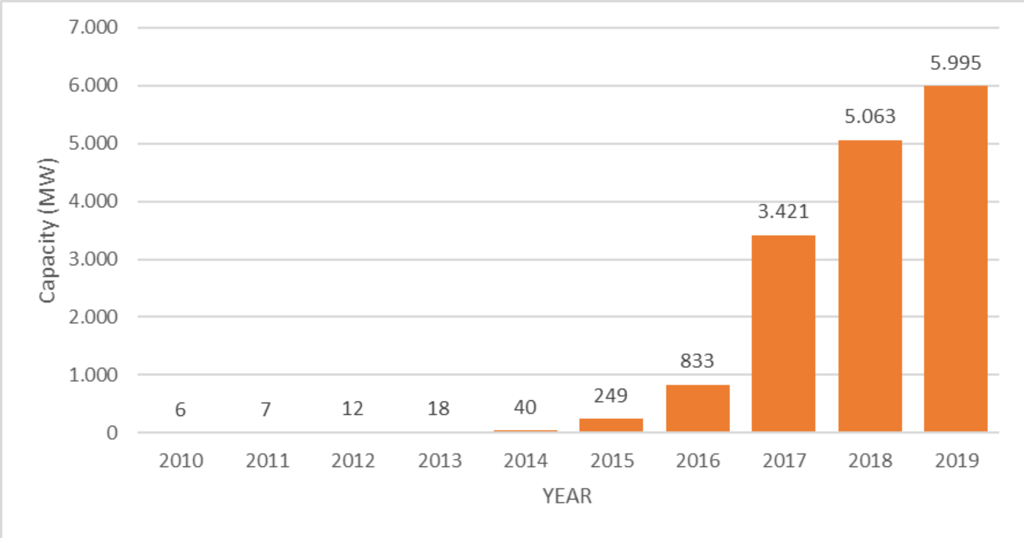

Figure 5.1: 2010-2019 Installed Solar PV Capacity in Turkey

Source: IRENA, 2020

5.2 LEGAL AND PHYSICAL INFRASTRUCTURE OF SOLAR ENERGY

On 10 May 2005, Turkey passed its first legislation to encourage the use of RES-E, Law 5346 on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy. This legislation implemented various incentives and financial-support instruments for producing renewable energy resources and increasing the share of these resources in the country's energy consumption (Ulusoy and Daştan, 2018).

The purpose of the law, according to its language, was: "spreading the use of renewable energy resources for electrical energy production, bringing these resources to the economy in a reliable, economic and quality manner, increasing resource diversity, reducing GHG emissions, recycling waste, providing environmental protection, and developing the manufacturing sector achieve these goals" (Resmi Gazete, 2005, p. 1). With Article 6/A (Annex: 29/12 / 2010-6094 / 4 art.) added to the law in 2010, a decision was made to support the prosumer system: "Real and legal persons generating electrical energy from renewable energy sources within the scope of this article; if they give electrical energy, having produced more than their needs, to the distribution system, they can benefit from prices in Schedule I for ten years. In this context, the relevant distribution company holding a retail license must purchase the electricity supplied to the distribution system. The electricity purchased by the relevant companies in accordance with this article is deemed to have been produced and given to the system by the said distribution companies within the scope of the Renewable Energy Resources Support Mechanism (YEKDEM)" (Resmi Gazete, 2010 p. 1). In 2021, For licensed solar power plants, the price of YEKDEM to be applied between 01.07.2021 and 31.12.2025 was determined as 32 kr / kWh. (Resmi Gazete, 2021). In addition, prosumers received additional incentives if mechanical or electro-mechanical parts used in production facilities, that started operations before 31 December 2015, are produced domestically. With these incentives, domestic production and R&D support were provided. So, in addition to the solar energy price (13.3 cents) indicated in Table 1, the prices in table 2 were added. Also, for prosumers who wanted to meet their own consumption, a support mechanism up to 1000kW was created, along with the opportunity to benefit from incentives and discounts (Resmi Gazete, 2005).

Type of Production Facility Based on Renewable Energy Source	Prices to be applied (US Dollar cent / kWh)
a. Hydroelectric production facility	7.3
b. Wind power-based production facility	7.3
c. Geothermal energy-based production facility	10.5
d. Biomass-based production facility (including landfill gas)	13.3
e. Solar energy-based production facility	13.3
(Annex to Law No. 6094 dated December 29, 2010)	

Table 5.1: Prices to be Applied to Production Facilities Based on Renewable Energy Sources

Source: Resmi Gazete, 2005

Type of Plant	Manufacturing Made in the Country	Additional Local Content Incentive (US Dollar Cent/kWh)
C- Photovoltaic Solar Power Generation Facility	1- PV panel integration and production of solar structural mechanics	0.8
	2- PV modules	1.3
	3- Cells composing the PV module	3.5
	4- Inverter	0.6
	5- Equipment focusing the sunlight on PV module	0.5
D- Concentrated Solar Power (CSP) Generation Facility	1- Radiation collection tube	2.4
	2- Reflective surface panel	0.6
	3- Solar tracking system	0.6
	4- Mechanical equipment for thermal energy storage system	1.3
	5- Mechanical equipment of steam generation system that accumulates sunlight on the tower	2.4
	6- Stirling engine	1.3
	7- Panel integration and structural mechanics of solar panel	0.6
TABLE II - (Annex to Law No. 6094 dated December 29, 2010)		

Table 5.2: Additional Local Content Incentive applied Production Facility Based on Renewable Energy Source

Source: Resmi Gazete, 2005

On 10 May 2019, the ‘Decision Regarding the Price and Time Requirements to be Applied “For Plants Operating Generating Based on Renewable Energy Resources and the Addition of Domestic Contribution” was amended and the upper limit of installed power in unlicensed generation facilities was increased from 1 MW to 5 MW. With this legal arrangement, the production limit was raised for large facilities that wanted to meet their consumption.

With the Unlicensed Electricity Generation Regulation in the Electricity Market, it was determined that solar energy-based generation facilities could only be implemented as rooftop and facade applications. In these solar power plants, a 10-year purchase guarantee was given for overproduction. The FiT determined for this purchase guarantee was calculated over the active energy cost. Businesses or citizens would be able to generate electricity without the obligation to obtain a license or establish a company. However, there is a condition about not exceeding connection capacity (Resmi Gazete, 2019).

The common point of these regulations is that consumers meet their electricity needs from their own generation facilities that are closest to the consumption point. In this concept, it is aimed to integrate small-scale production facilities into the national economy and to ensure their effective use in order to provide supply security (Güngör, 2019). Furthermore, one of the most important decisions paving the way for the prosumer system was ‘net-metering’. Net metering assures that the excess electricity produced during the day will be compared with the electricity consumed when there is no production. After, at the end of the month, production and consumption are matched. If the generation is excessive, the payment will be taken from the state based on how much electricity was given to the network, and if the consumption is excessive, the payment will be made to the state at the end of the month. This was a step that would directly reduce the depreciation time (Şenoğlu, 2020). Finally, production and consumption in facilities must be located in the same distribution area. It will detect the amount of electrical energy supplied to the network on an hourly basis from the installed meter data (GÜNDER, 2019).

In addition to legal infrastructure, another important issue is physical infrastructure. In terms of capacity, important information was presented in the “Five and Ten-Year (2024-2029) Regional Connectable Capacity Report” published by TEİAŞ (2019). According to the report, Turkey will add an additional capacity of 20,818 MW by the end of 2024 and a further 6,453 MW by the end of 2029. Thus, a total of 27,271 MW of regional capacity will be created in nine of the 15 transmission regions. In the 58 provinces where regional capacities are not provided, there will be additional 50 MW of capacity for each on a provincial basis for possible generation investments from 2019-2024. So, a total capacity of 2,900 MW will be provided to these 58 provinces (TEİAŞ, 2019).

5.3 CURRENT SOLAR PV PROSUMERS OUTLOOK OF TURKEY

In order to make prosumer systems more widespread, there must be increased interest and action. Important results have been reached in the "Turkish Public Preferences for Energy" study that was conducted by the Kadir Has University Center for Energy and Sustainable Development (CESD, 2019). Solar energy was people's first choice in terms of providing electricity at equal prices or regardless of the price. Meanwhile, the potential of solar energy is quite high and could meet this interest. Turkey ranks second in Europe after Spain in its geographic potential to produce solar energy (Çetinkaya, 2013).

According to the analysis of the SHURA Energy Transition Center, the total electricity production potential of rooftop solar PV systems that could be installed in buildings in Turkey is estimated at 14.9 GW (SHURA, 2020). The potential of solar energy capacity is almost 3 times higher than Turkey's current installed solar power, meaning it could produce 22 TWh of electricity per year. These systems can, moreover, meet the electricity needs of 17% of public buildings in Turkey, when analyzed by considering cooling, lighting, ventilation and partial heating and hot water. Approximately 70% of the total potential power of rooftop solar PV systems can be obtained from residential buildings which is 15-16 TWh. However, considering the leveled electricity generation cost of these systems for households, it is 30% to 50% higher than the current electricity tariff. Only 30% of the total technical potential in all buildings reaches grid parity. Rooftop solar PV systems for buildings still have difficulties dealing with the grid price. It still requires a substantial reduction in initial costs to speed up installations (SHURA, 2020).

According to the statement of Energy and Natural Resources Minister Fatih Dönmez at the 7th Meeting of Kayseri Anatolian Solar Producing Electricity in February 2020, during the nine-month period starting from May 10, 2019, industry subscribers made

1207 solar power system applications with an installed capacity of 862 MW. Additionally, there were 1218 applications with an installed capacity of 12 MW from residential subscribers received. There were 5,944 rooftop applications with a total installed capacity of 1,544 MW. At the end of 2019, 252 MW of rooftop solar was installed through GES by February 2020 (Haktanıyan, 2020).

In addition, a new tariff has improved the outlook for renewable energy. The Turkish Parliament passed the "Green Tariff" application, also known as the "Renewable Energy Tariff (YETA)", in February 2020. This mechanism was specially designed for individuals and institutions who want to use electricity produced only from renewable energy sources. Since this tariff was passed out of environmental concerns, it allows that the cost may be slightly higher when considering current energy installation costs. However, investment costs are expected to decrease with the support and incentives given to the renewable energy sector, which will be reflected in the prices over time. YETA will become more attractive over time as energy costs decrease (NTV, 2020).

Additionally, the Ministry of Energy and Natural Resources announced that it aims to have an additional 10,000 MW of installed rooftop solar PV by 2027, of which 4,000 MW is planned as residential roofs and 6,000 MW as roofs for industrial and commercial consumers (Küçükkaya, 2019). In the light of this information, although the share of solar energy in electricity generation is still small considering overall consumption, the investment outlook is promising, especially since investment is expected to rise despite changing market conditions.

6. DISCUSSION FOR INCREASING PV PROSUMERS IN TURKEY

Generating consumable energy and selling surplus energy to the network to create a commercial model are two important elements of the prosumer concept. In this regard, three new trends in prosumerism are evident: ensuring self-consumption with renewable energy sources, realizing energy management with digitalized systems, and creating commercial benefits with integrated technologies. Solar energy has become the leading source of this prosumer ecosystem thanks to its modular structure, simple system design, and reduced investment cost. (PVP4GRID,2018) In Turkey, after the amendment in May 2019, investment has been directed towards rooftop solar and self-consumption. (Resmi Gazete, 2019) Yet there is still a long way to go, and the selected case studies in the thesis will be a guide.

First, the cost of solar panels has decreased by about 80% in the last 10 years, consequently driving down investment costs (BNEF, 2018a). However, in recent years, Turkey has witnessed a sharp rise in the dollar exchange rate (Investing, 2020). Although this situation has increased investment costs again, the increase in electricity prices is parallel to the rise of dollar exchange rate (EPDK, 2020b). This parallelism is seen in Figure 6.1 and Figure 6.2. While the increase in exchange rate in the last two years was around 50%, electricity prices also increased by around 40%. For this reason, the increase in the dollar exchange rate will not depreciate investment. Considering this parallelism, it is possible to say that consumers who provide self-consumption from their own resources will be less affected by price fluctuations in the market.

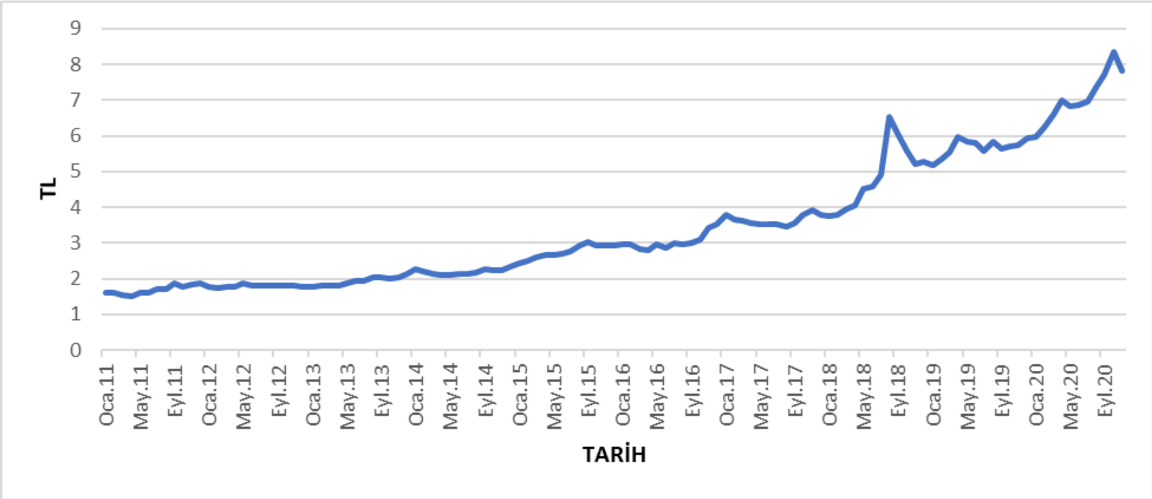

Figure 6.1: U.S. Dollar Exchange Rate, 2011-2020
Source: Investing, 2020

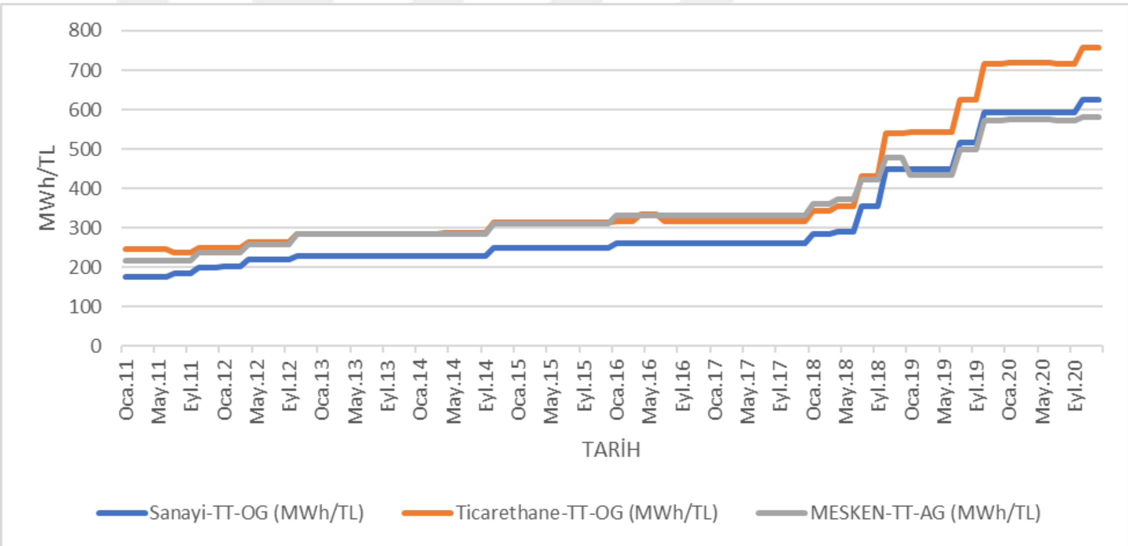

Figure 6.2: Electricity Prices by Consumer Profiles for Ten Years (Active Energy + Distribution Fee - TL Based)
Source: EPDK, 2020b

In 2020, the energy sector is affected by Covid-19 like other sectors. As it mentioned before, during the COVID-19 pandemic, it is seen that electricity demand fell much less compared to the demand for other types of energy. The reason is the consumption of electricity in residential buildings is increased due to curfews and restrictions (Robinson and Keay, 2020). That makes solar energy investment in residential building more important for roof-top installations. However, each user may not have opportunity to build a solar system on his own roof to utilize this potential. Considering the type of housing in Turkey, it is seen certain problems in roof top solar installation. Firstly, the roof is common use area for all household. One owners or tenant cannot use it just for own benefit. The size of roof could not enough to meet all the people needs in the multi-apartment building. Another problem is while solar energy is affordable for one user, on the other hand, it can be an expensive investment for the other user. At this point, the *mieterstrommodell* in Germany case can be considered as a solution because it allows third parties to install rooftop solar in multi-residential buildings and sell the generated electricity to homeowners or tenants (Solar Power Europe, 2018).

Considering Turkey's current conditions, growing population and urbanization since the 1950s have increased the need for housing. This has led to the spread of irregular urbanization and the multi-apartment model, remaining the dominant housing model today (Çiftçi, 2020). From 1964 to 2019, 2.5 million multi-apartment buildings (16.2 million flats) were built. During this period, 75.9% of the annual building production was in multi-apartment buildings. In these buildings, the roof is a common-use area, and a tenant cannot use it for his own profit. In addition, even if there is a joint decision from the apartment management regarding the installation of a roof solar system, tenants and some property owners may not want to finance or be able to afford it.

However, unlike in Germany, it is illegal in Turkey for third parties to sell unlicensed electricity generated by installing solar energy on building rooftops to property owners or tenants through energy supply contracts. Therefore, the first step towards generating more rooftop solar and prosumerism is to establish a legal basis for third party companies to supply energy. This application can be implemented swiftly with smart meters without using the existing network. The second step is to apply a FiT for surplus electricity, as in Germany. Tax reductions and government subsidies will also increase the attractiveness of investment. As mentioned before, in the *mieterstrommodell*, those who do not want to use this system in the same building can opt out. The financing burden and operational risks thus lie with third parties, not on prosumers. Therefore, tenants can also benefit from this system. Overall, this win-win situation will help improve the difficult economic situation in Turkey.

Adaptation to the *mieterstrommodell* or tenants' electric model will not be difficult. Although it is not yet possible to implement this model with energy supply contracts, already used energy performance contracts comply with the current legislation. Energy performance contracts are similar to the tenant electricity model in some respects. They provide financing by using the savings obtained from energy efficiency projects like rooftop solar installation. Basically, technical and operational risks are taken over by the energy services companies, who guarantee performance (EYODER, 2020). Thus, as in the *mieterstrommodell*, rooftop solar energy systems are installed, operated and financed by the third parties. The difference is that energy is not sold; instead, companies get a share of the savings. This model is mostly used by industrial consumers (Keskin, 2020). In the realization of this application, the infrastructure of Energy Efficiency Consultancy (EVD) companies, which are the basis for energy service companies, can also support the tenant electricity model. However, the opportunities offered by energy performance contracts are limited when compared to the tenant electricity model. Therefore, it is necessary to establish a legal, regulatory basis for providing electricity to multiple users and that can be applied for unlicensed electricity generation.

In the tenant electricity model, solar energy investments are oriented towards self-consumption. However, another important pillar of the prosumer concept is the ability of consumers to manage their production and to commercialize their surplus, enabling prosumers to become active market players. No matter how it is analyzed, electricity consumed from solar PV will bring profit to users as investment. The current government support facilitating investment is also critical. However, after the May 2019 legal regulations, prices of excess electricity have remained relatively low compared to the previous FiT. These further underscores the need to incorporate different models that might commercialize the production, consumption, and trade of energy. P2P energy trading in the Australian case sheds light on this point.

In Turkey, there is a distinct difference between the purchase price of electricity from the grid and the selling price to the grid. As an example, the active energy electricity cost of residential subscribers was 39.27 kr/kWh in the fourth quarter of 2020 for low-voltage, single-term, single-time price in the activity-based tariff.[1] This was the price that prosumers sold electricity. However, when it is purchased by the consumer, a 21.23-kr/kWh distribution cost is added, which adds a 5% electricity consumption tax, a 1% energy fund, 2% TRT tax, 18% value-added tax as costs. Consequently, consumers pay a price of 77.10 kr/kWh for electricity (EPDK, 2020b).

The above section illustrates how a P2P energy-trading system can be more advantageous. Electricity can be purchased from prosumers at a higher price than the active energy cost and sold to consumers for a lower price than the grid. In Table 6.1, residential subscribers 1 through the activity-based tariff is taken as an example. A similar scenario was then created by looking at the Australian case. However, the difference between buying and selling prices in Turkey is not as high as in Australia. Considering this situation, a scenario was created for Turkey in the Table 6.1

In the case of Australia, as it mentioned before, PV prosumers are usually paid 7c/kWh for returning surplus power to the main grid, but the consumers are charged 25c/kWh. Power Ledger's P2P project agreed to pricing of 20c/kWh for power purchased via blockchain platform. Prosumers get 75% of the electricity charges, and the utility company gets 25% (Andoni et al., 2019). In Turkey there are different types of electricity subscribers. The main ones are industrial, commercial and residential subscribers. Residential subscribers are the people who using electricity just for meet the household electricity needs. In the scenario prepared for Turkey, PV prosumer which is residential subscriber 1 pay 21.23-kr/kW returning surplus power to the main grid. However, it charges consumers 77.10 kr/kWh. If a P2P project agree to pricing of 61,69 kr/kWh, it provides 20% discount to consumers like in the Australian case. Prosumers get 75% of the profit of electricity charges, and the utility company gets

[1] Cost of this subscribers charged according to tariff of fourth quarter of 2020 for low-voltage, single-term, single-time price in the activity-based tariff. This type of subscribers will be referred to as residential subscriber 1 in the following sections.

25%. As it seen in Table 2, in the P2P trade prosumer sell the electricity to 56,08 kr/kWh, and utility company takes 5,6 kr/kWh from this transaction.

Table 6.1: Possible profit scenario of P2P energy-trading-based residential subscriber in Turkey

Active Cons. Cost	Prosumer Electricity Saving Price[1]	The Cost the Consumer Pays for Electricity Within P2P Trading[2]	Consumer Profit Range	Sale Price of Prosumer Within P2P Trading[3]	Prosumer Profit Range	Transaction Fee of System Developers Within P2P Trading[4]	Developer Profit Range
39,27 kr/kWh	77,1012 kr/kWh	61,68096 kr/kWh	20%	56,08 kr/kWh	43%	5,6 kr/kWh	9%

[1] Network price including taxes and distribution cost.

[2] Scenario which is 20% cheaper than the network.

[3]Scenario Where Prosumer Takes 75% Of Profit

[4]Scenario Where Developer Gets 25% Profit

Turkey does not have any regulations and thus needs a legal framework for executing P2P trading in electricity. According to the unlicensed electricity regulation, it may start to make trials on this subject in a village or site independent from the grid in the near future (Güven, 2019). However, this kind of off-grid systems limit the range of P2P systems. Certain steps must be taken by the state for application in on-grid. To start, the role of platform providers for P2P trades should be defined clearly in the law. For the development and expansion of the system, respective parties should gain legal access to trade on the electricity grid. In short, the distribution system operators (DSOs) should enable P2P trading. The government should also subsidize network charges where electricity is shared over the public network. Ultimately, P2P energy trading is a complex operation that relies on modern communication technologies. Hence, the adaptation of new technologies like smart meters should also be subsidized. In the light of these study, the steps that need to be taken by Turkey are listed at Table 6.3.

Table 6.2: Comparison of Turkey, Germany and Australia in terms of case studies

	Case studies	Current condition of Turkey
Case of Germany	Roof of multi-apartment buildings has a high potential for PV installation with 3-4 TWh	Roof of apartment buildings has a potential for PV installation with 15-16 TWh
	There is a FiT that supports solar energy.	There is a FiT that supports solar energy.
	There is a suitable legal infrastructure for the tenant electricity model which is called Mieterstrommoedell.	There is no suitable legal infrastructure for the tenant electricity model.
	The 3rd party can sell the electricity produced by solar PV from the building roofs to the residents of the building with **energy supply contracts**.	The 3rd party cannot sell the electricity generated by solar PV from the roofs of the building to the residents with energy supply contracts, but can provide this service with **Energy performance contracts** and get a share of the savings.
	PV installation of up to 100 kW is allowed for households on the Mieterstrommodell for self-consumption. However, renewable energy surcharge (EEG surcharge) must be paid.	Unlicensed installation can be made up to 10 kW for household use and an exemption of income tax and VAT are provided to prosumers
	The surplus of production can be sold to the grid.	The surplus of production can be sold to the grid.
Case of Australia	High differences between the returning surplus power to the main grid and the charge for consumers	High differences between the returning surplus power to the main grid and the charge for consumers.
	There is a legal basis for P2P power trading	There is no a legal basis for P2P power trading
	There is a technical infrastructure for P2P power trade via blockchain which conduct by Power Ledger Company	There is no a technical infrastructure for P2P power trade.

Table 6.3: Legal and physical process for increasing PV prosumers in Turkey

	What Turkey needs?	**How Turkey succeeds it?**
Legal Necessities	'Tenant electricity model' which applied for multi apartment buildings should be implemented in Turkey like mieterstrommodell in Germany	A legal infrastructure should be established for the model where 3rd party institutions can realize PV installation and electricity sales to roof of different buildings behalf of the prosumers
	The commercial benefits of the operators who will implement the tenant electricity model should be considered.	Tax cuts should be provided for 3rd party operators to make it easier for them to bid below the tariff price.
	Government support should be provided for solar installations that will meet the higher electricity consumption of consumers and enable it to be commercialized.	For residential electricity subscribers, the 10 kW limit in the unlicensed electricity installed capacity should be increased to 50 kW.
	In addition to selling excess electricity to the grid, it must be able to trade electricity directly between other consumers and prosumers.	A legal framework should be established to ensure the P2P energy trading and distribution companies in Turkey should be included in this mechanism.
Physical Necessities	Physical infrastructure that will allow the realization of additional productions from solar PV should be established.	Transformer capacities should be increased for solar power installations.
	A physical platform should be created where P2P energy trading will be provided.	Blockchain technology must be integrated into energy trading.
	Blockchain technology requires a certain level of technological integration and digitalization. These must be accessible to the prosumers.	Smart meters for calculation and smart trading devices (micro computing servers) must be made available to the prosumer with support of government incentives.

7. CONCLUSION

Due to climate change, the energy transition from fossil fuels to renewable resources has become inevitable. As a result of developments in the field of renewable energy technologies, installation costs have dropped sharply in the last ten years, and it is predicted that this decrease will continue in the future. Among renewable energy sources, solar power has emerged as the most competitive and has the largest share in the rise in installed capacity to produce power. Due to the modular structure of solar energy, it plays an important role not only as utility scale but also in self-consumption with rooftop installations. In this way, the number of prosumers who produce the energy that they consume has also increased.

In Turkey, the amendment of Unlicensed Electricity Generation Regulation in the Electricity Market entered into force in May 2019 in order to support renewable energy investments that encourage self-consumption. Thus, the prosumer concept has come to the fore of the agenda. While solar energy is generally experiencing an upward trend, PV prosumers are still not ubiquitous. For this reason, new models should be created by examining examples of how other countries have increased and integrated prosumers into their energy systems.

Prosumers, besides producing the energy that they consume, are also active players in the energy market. For this reason, the German and Australian cases should be considered examples for Turkey to emulate. *Mieterstrommodell* in Germany has created the possibility for people living in multi-unit apartments to be prosumers, which is the predominant residential situation for people in Turkey. In addition, this model not only benefits from utilizing apartment roofs to generate power but also leaves the installation, finance, and operational risks to third-party companies instead of prosumers. The Australian model also commercializes excess electricity after self-consumption is met. Instead of selling excess electricity to the grid, it provides P2P energy trading, which can provide even greater profits to producers and savings to consumers. Surplus electricity is sold to the grid through the active energy price in Turkey. This price is almost half of the total price for which the electricity is sold. P2P energy trading thus offers a more profitable price and enables prosumers to increase their profits and reduce their depreciation time. If legal regulations and physical capabilities are developed that can encourage greater implementation of P2P trading in Turkey, the country can meaningfully grow its solar PV prosumers as well. In this context, the steps to be taken by Turkey, can be listed as follows.

- Tenant electricity model should be applied in Turkey. To achieve this, a legal infrastructure should be established for the model where 3rd party institutions can realize PV installation and electricity sales to roof of different buildings behalf of the prosumers. In addition to this, tax cuts should be provided for 3rd party operators to make it easier for them to bid below the tariff price.
- Legal and physical infrastructures should be established for P2P energy trade via new regulations and integration of blockchain system in energy sector.
- To integrate the new commercial models for residential prosumers, the 10 kW limit in the unlicensed electricity installed capacity should be increased to 50 kW.
- In the digitalization process, the devices and systems such as smart meters and micro computing servers should be subsidized by the state so that prosumers can access high technologies.

The two models studied in the case have been operating since 2017. In order to elaborate the analyzes in the following years, the capacity data added as a result of mieterstrommodell and P2P energy trade should be analyzed in the countries. The annual additional Solar PV capacities for self-consumption which established before 2017 and after 2017 should be compared. In that context, long term effect of these models to growth rate of prosumer should be calculated via Simple Linear Regression. Moreover, number of case studies and best practices should be increased and scope of the current studies must be extended. Especially, energy cooperatives which also become popular model for solar PV investment for self-consumption, should be another topic in the further studies. Finally, the current study has gaps in the areas such as off-grid systems, solar energy for lighting or agricultural watering. The thesis mostly takes the urban prosumers to center, but rural prosumers also examined in the future direction.

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CURRICULUM VITAE

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Academic Background

- KADIR HAS UNIVERSITY (2017-Cont.)
  Energy and Sustainable Development (MASTER)

- MARMARA UNIVERSITY (2011-2016)
  Political Science and International Relations (BACHELOR)

Work Experience

- İTÜ ÇEKİRDEK (2020 - Cont.)
  Expert, Incubation and Acceleration Programs
    - Business Development
    - Process Management
    - Strategic Planning
    - Training Coordination

- PİER ENERJİ (2019-2020)
  Business Development Specialist
    - Feasibility Study
    - Project Design
    - Supply & Demand Analysis
    - Engineering, Procurement, and Construction

- İNFOLOJİ GROUP (2017-2018)
  Business Development Assistant Specialist
    - Project Management
    - Strategic Planning
    - Problem Analysis
    - Solution Development

- GAS & POWER / PETROTURK.COM (2016-2017)
  Business Development Assistant Specialist

- International Energy Research
- Sectoral Reporting
- Energy Analysis
- Media Monitoring

- EUROPEAN PARLIAMENT (2014-2014)
  Intern Research Assistant
  - Sectoral Research
  - Reporting
  - Strategic Planning

- NATO - SHAPE (2014-2014)
  Intern Research Assistant
  - Open-Source Intelligence Report
  - Actor Analysis
  - Regional Research

Personel Skills

- Language
  - English

- Design
  - Illustrator
  - Photoshop

- PV Analysis
  - PV*Sol
  - PVSyst

- Modelling
  - Sketchup
  - Autocad

PROJECT & ORGANIZATIONS

- MODERATOR | Kadir Has University - CESD Energy Talks, 2019
- MODERATOR | Youngsummit'19 – Energy and Environment Summit, 2019
- SPEAKER | BiGenc Talks, 2018
- SPEAKER | Grad. Student Conference on Energy and Sustainable Development, 2018
- ORGANIZER TEAM | Turkish Defense Industry Summit, 2018
- ORGANIZER TEAM | Istanbul Water Congress and Fair (WATERIST), 2018
- ORGANIZER TEAM | Istanbul Transportation Congress and Fair (TRANSIST), 2017
- ORGANIZER TEAM | Young Turkey Summit (GTZ), 2017
- ORGANIZER TEAM | Turkey Energy Summit, 2017