GRID-CONNECTED PHOTOVOLTAIC SYSTEMS FOR FUEL STATIONS: A COMPLETE TECHNO-ECONOMIC ANALYSIS

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ABSTRACT

GRID-CONNECTED PHOTOVOLTAIC SYSTEMS FOR FUEL STATIONS: A COMPLETE TECHNO-ECONOMIC ANALYSIS

The purpose of this study, beyond being an engineering practice, is an attempt to overcome a bottleneck that has not been overcome so far with scientific methods and to use the power of science for the benefit of the environment, the public, fuel distribution companies, petrol stations and almost every part of the society. Due to rapid changes in in terms of technology, efficiency, environmental sensitivity, consumer preferences, cost structure and legal base, this study is investigating and making suggestions for oil station companies regarding on-grid photovoltaic applications.

Successful management of the process depends on effective calculation including, system requirements considering local solar radiation and financials from many aspects. Considering that, many fuel station owners cannot effectively approach the technical, bureaucratic, and financial aspects of photovoltaic applications and that academic studies that will guide the interested parties in a package form are not sufficient, the importance of this study will be more clearly demonstrated. Information obtained through the literature review, applying the engineering economics models and also with a widespread field study including petrol stations, solar material supply and installation companies, health and safety company and bank. It has been tried to set a user's manual for concerned parties both in, academia, oil & solar sector and financial system in Turkey.

Keywords: Environmental Sensitivity, Oil Stations, Solar Sector, Photovoltaic Applications, Green Petrol Station

ÖZET

ŞEBEKE BAĞLANTILI FOTOVOLTAİK DESTEKLİ AKARYAKIT İSTASYONLARI: TAM TEKNO-EKONOMİK ANALİZ

Bu çalışmanın amacı, bir mühendislik uygulaması olmanın ötesinde, bugüne kadar aşılamayan bir darboğazı bilimsel yöntemlerle aşmak ve bilimin gücünü çevre, kamu, akaryakıt dağıtım şirketleri, benzin istasyonları ve toplumun hemen hemen her kesimi yararına kullanmaktır. Teknoloji, verimlilik, çevresel duyarlılık, tüketici tercihleri, maliyet yapısı ve yasal altyapıda her geçen gün yaşanan hızlı değişimlere ayak uydurabilmeleri gayesi ile akaryakıt istasyonu şirketleri için şebekeye bağlı fotovoltaik uygulamaları hakkında araştırma yapmakta ve önerilerde bulunmaktadır.

Sürecin başarılı yönetimi, yerel güneş radyasyonuna bağlı sistem gereksinimlerinin ve uygulama finansallarının etkin hesaplanmasına bağlıdır. Birçok akaryakıt istasyonu sahibinin fotovoltaik uygulamaların, teknik, bürokratik ve mali yönlerine etkin bir şekilde vakıf olmadığı ve ilgililere paket halinde yol gösterecek akademik çalışmaların yeterli olmadığı dikkate alındığında, bu çalışmanın önemi daha anlaşılır olacaktır. Çalışma sırasında kullanılan bilgi ve araçlar, literatür taraması, mühendislik ekonomisi modellerinin uygulanması ve ayrıca akaryakıt istasyonları, güneş enerjisi tedarik ve montaj şirketleri, sağlık ve güvenlik şirketi ve banka gibi alanlarda yapılan geniş bir saha çalışması ile elde edilmiştir. İlgililer için bir kullanım kılavuzu oluşturulmaya çalışılmıştır. Türkiye'de yapılan ve yapılacak olan bu ve benzeri çalışmalar, akademik değerinin yanı sıra petrol, güneş enerjisi, finans gibi sektörlerde de fayda sağlayacaktır.

Anahtar Kelimeler: Çevre Duyarlılığı, Akaryakıt İstasyonları, Solar Sektör, Fotovoltaik Uygulamalar, Yeşil Petrol İstasyonu

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CHAPTER 1

INTRODUCTION

One of the most basic needs of developing humanity and civilization is energy. While increasing population, developing technology, complex processes and the accelerating world make life easier and increase efficiency at exponential rates, the need for energy to meet these trends is increasing at a similar rate.

This infinite situation and increasing needs increase the energy demand in parallel with the accelerated speeds. Energy is becoming more valuable every day. In addition, the stocks of raw materials required for traditional methods used in obtaining energy are decreasing day by day. The calculations made with existing technologies predict that these stocks may be depleted in the near future (Månberger 2021).

Unfortunately, the use of traditional methods, especially the energy obtained by fossil fuel consumption, are not the only raw materials stocks that are being depleted. The carbon emissions that occur during both the production and consumption of fossil fuels clearly contradict the idea of a sustainable environment and civilization, and traditional methods of obtaining and using energy consume our world, so to speak. Today, most countries have signed the Kyoto Protocol (Barker 1985) to combat global warming and climate change, which are the main problems posed by this depletion and unsustainability.

The countries that have signed the Kyoto Protocol have promised to reduce the release of carbon dioxide and other gases causing the greenhouse effect (Methane (CH_4), Nitrous oxide (N_2O), Sulphur hexafluoride (SF_6), Perfluorocarbons (PFCs) and Hydrofluorocarbons (HFCs) in line with certain criteria and targets, and to increase their rights through carbon trade where they cannot reduce these gases. Within the scope of this protocol, the objective in terms of the amount of carbon they emit for each country is the emission levels in 1990.

The greenhouse gas emission rates of the world and Turkey according to the data published by The World Bank are shown in Figure 1.1. and Figure 1.2.

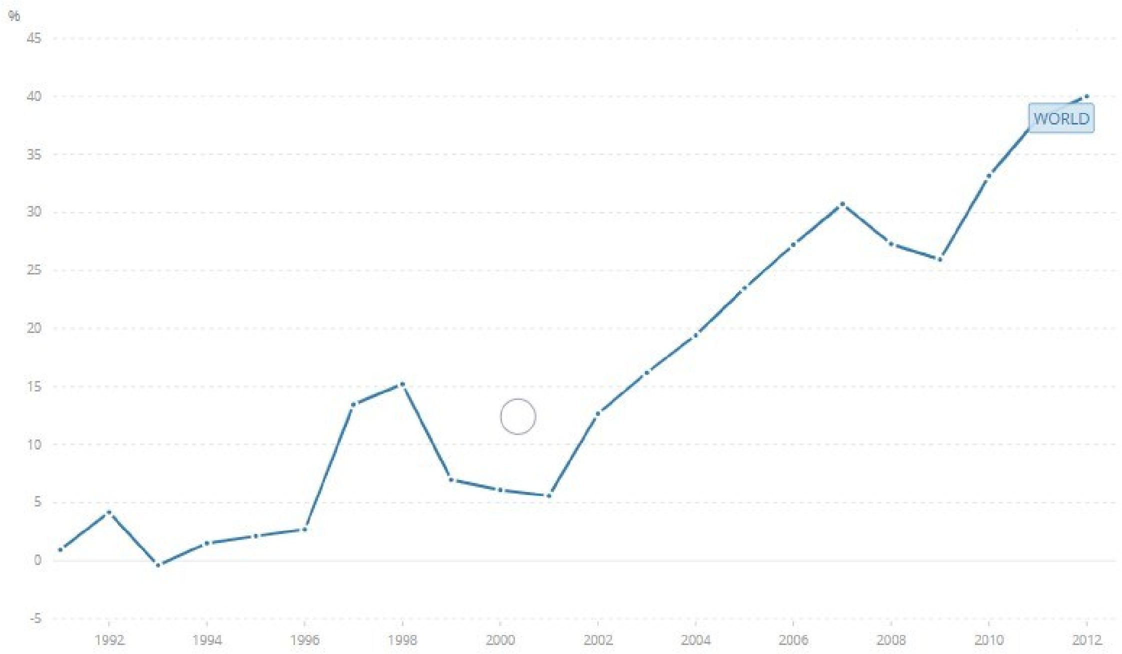

Figure 1.1. Greenhouse Gas Emission Rates of The World
(Source: The World Bank Group 2016)

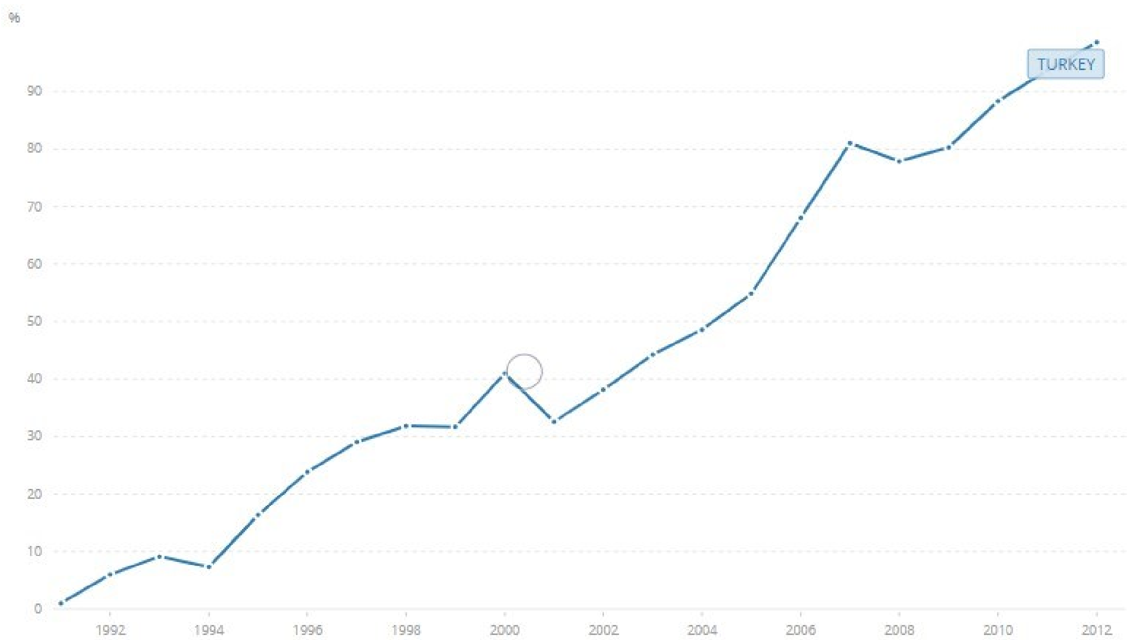

Figure 1.2. Greenhouse Gas Emission Rates of Turkey
(Source: The World Bank Group 2016)

It seems that the shortest way to reduce the use of fossil fuels and to meet the increasing energy demand mentioned in the beginning, within the boundaries of environmental sensitivity and in the context of our level of development, is renewable energy. Increasing the use of renewable energy sources is seen as the most accurate way to reduce greenhouse gas emissions (Bayraç 2010). It is a known fact that renewable energies emit much less carbon than fossil fuels.

Among renewable energy sources, wind and solar energy systems have the least greenhouse gas emissions and are the most efficient energy production methods in terms of other environmental sensitivity parameters. It can be said that wind and sun are among the cleanest energy sources.

In recent years, clean energy sources have attracted more attention from researchers, governments, policy makers, companies and the general public as a result of the major structural changes faced by the global electricity industry.

Solar photovoltaic (PV) systems, which are one of the few cleanest sources and sourced from the sun that creates life in our world, are known as a safe and advanced technology among other renewable energy systems. Today, photovoltaic systems have become an important part of the total energy supply in many countries, especially in Europe and Asia, with both quantitative and qualitative aspects (Pietzcker 2014).

On the other hand, developing environmental regulations and taxes negatively affect the energy use costs obtained from fossil fuels. Due to the increasing costs, company owners, operators and energy investors are looking for alternative energy production sources to meet their energy needs. For many industries, energy, especially electricity consumption costs, is one of the main items in the total cost calculation and has a direct impact on profitability.

This situation has been reversibly reduced by technological advancements and especially the mass production of photovoltaic systems in China and made these systems more accessible and suitable. Decreasing panel costs also reduce production costs and increase the trend to this field. The processes are becoming easier and more manageable for small investors every day (Figure 1.3.).

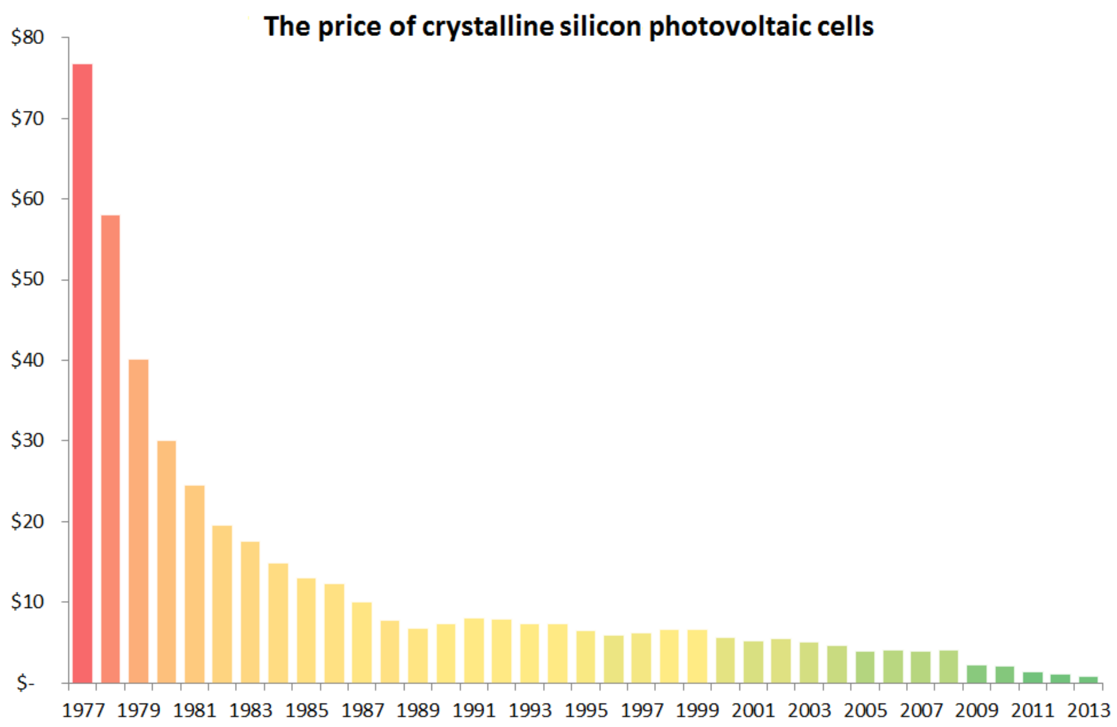

Figure 1.3. The Price of Crystalline Silicon Photovoltaic Cells
(Source: Woodhouse 2019)

It is of course very important for Turkey, which has a developing economy, to increase energy production, to manage it correctly and to become a self-sufficient country in terms of energy. In fact, considering that Turkey's current account deficit is mainly caused by energy, it would be appropriate to say that every contribution to the management of this process will be at the top in terms of public priorities.

Given the developing economy of Turkey, increasing local and global competition and the rapidly changing world, energy management is one of the first few issues to be focused on in all sectors. For all these reasons, there is also a general strategy of government support for the use of renewable energy resources in Turkey (Berksoy 2018).

The fuel distribution sector, on the other hand, is under pressure from rising taxes and decreasing profit margins in addition to all the conditions of competition and change mentioned above, and perhaps the most important problem in the long term is the energy nature relationship itself and the social responsibility environment caused by the negative effect of fossil fuels on this relationship. The responsibility to face the antipathy caused by environmental sensitivity for the industry is on the shoulders of the fuel stations that are the defenders of this sector.

Given these considerations, every possible opportunity to prove social responsibility for the sector, every cost-preventive factor and every new opportunity for additional income should be carefully evaluated for strategic management. All these gains are very valuable in terms of marketing the development of renewable energy systems.

Fuel stations mostly have high financial credibility due to their long-term agreements with distribution firms. On the other hand, there is a ten-year government purchase guarantee for electricity produced from renewable energy sources for investors in Turkey and also various specialized financial models for renewable energy investments. Considering all these parameters such as large roof area, attractive investment opportunity for renewable energy sources, high electricity consumption, environmental intensive attention, high reliability and state support, integrating photovoltaic systems into their businesses in order to meet their own electricity consumption and generate additional income is becoming more of a requirement than an opportunity for fuel stations.

However, it appears that solar energy systems are showing exponential development in Turkey and the sector in question has not been able to start an integration parallel to this development in recent years. The main reason for this is that some engineering problems, bureaucratic problems, marketing problems and financial problems that need to be overcome with innovative solutions have formed a bottleneck in terms of these applications.

First of all, there is a great commercial opportunity and synergy paradigm in the application of photovoltaic systems to fuel stations in Turkey with an academic, then strategic and systematic approach.

In the following part of the study, the necessary steps and a clear plan have been set forth to make this investment a turnkey package for the investor by addressing the problems one by one.

Beyond being just an engineering practice, this study is an initiative for overcoming the bottleneck with scientific methods and aims to use the power of science for the benefit of the environment, the public, fuel distribution companies, stations and almost every segment of society.

CHAPTER 2

AIM OF THE STUDY

In today's world, energy is one of the most important and decisive needs. The uninterrupted and sufficient continuity of energy supply has a great importance for both individual and collective life. Trying to meet this energy need based solely on the consumption of fossil fuels not only pollutes the world more every day and depletes existing resources but is also inadequate in terms of meeting the developing and digitalizing world’s needs. In order to meet the energy demand in the most effective way and in harmony with the environment, the short-term solution is to further expand the use of renewable energy resources and to effectively develop the methods of benefiting from these resources.

The most important features that distinguish renewable energy sources from original and other energy sources are that they are in harmony with the environment, sustainable and generally widespread, and that especially solar and wind-based systems do not need any raw materials.

Solar energy is accessible all over our planet, albeit at different levels. It does not emit carbon dioxide and only produces, without consuming any resource or requiring intensive business activity. The installation area required for solar energy production is almost all areas that are inactively waiting. Roofs are awaiting, empty with great promise for the future.

Considering everything that has been explained so far and the relevant regulation in Turkey, at some point, the elements required to benefit from solar energy are electricity consumption, an appropriate roof area, the initial necessary investment and of course the sun. The starting point of this project is to utilize the opportunity presented with the combination of fuel stations having large roof areas above the pumps called canopies, the high investment and working capital they have and credibility associated with this, their electricity bills, which are quite high and have a significant place among the cost items, and the high solar irradiation levels for the benefit of Turkey and humanity. Each fuel station is a potential solar field with its roof structure, which is flat, generally shadowless due to urban planning and gets sun during the day with full efficiency. With the right calculations and engineering knowledge, the daily electricity needs of an average fuel station can be met through these panels.

The project aims to convert solar energy into electrical energy to meet the daily electrical needs of the converted facility. It is even possible to make additional profit from solar electricity that will vary according to the size of the facility. The laws and regulations regarding the renewable energy market in Turkey make this possible.

Increasing electricity prices and falling solar panel costs have made the worldwide use of photovoltaic systems increasingly advantageous.

Thanks to this project, fuel station enterprises will be able to achieve a significant reduction in their costs (11-17% on average) with a rational and rapidly returning investment, and of course, they will be able to increase their profitability accordingly. This positive contribution will provide an increase at similar rates on the operating value, and in fact, secure its return when the investment is made. Almost every financial business will support this type of project and provide various financing opportunities. After solar energy panels are activated with appropriate financing solutions, the amount paid routinely for the electricity bill on a monthly basis will cover the financing of the investment.

In a sense, the aim is to develop a systematic system that can start with zero equity resources, pay itself off and contribute to the value and reputation of the business from the first moment. This project, which can cover the initial investment cost in an average of 5-6 years according to the loan term and the size of the project, will provide an absolute profit to the owner for the remaining average of 20-25 years.

There are over 13,000 fuel stations (EPDK 2020) throughout Turkey, and the annual electricity consumption of these stations is 1500 GWh (EPDK 2020), it will be possible to make a positive contribution of 0.25% to the total electricity need of the country (TÜİK 2019). The positive effects of this situation on the current account deficit and carbon emissions will be significant.

Considering the digital transformation that the energy sector in general and the fuel sector in particular will experience in the coming years, the project will be an important step for the beginning of this transformation on the basis of business and sector. As will be explained in the later stages of the project, the solution of many parameters that currently constitute an obstacle to photovoltaic applications in fuel stations has been focused on, and a paradigm change has been aimed in this area, so to speak. It should also be considered that fuel distribution companies have increased their interest in the issue in recent months and are looking for a solution.

2.1. World Oil Market and Future Forecasts

Petrol is a substance that has been used for many years by humanity for a variety of purposes. The formation of petrol has spread over a very long period of time. It is known that animal and plant wastes, which sank to the bottom of the seas many years ago, turned into petrol after a number of chemical reactions under high pressure and temperature. This formation process requires a lot of time and depends on many variables. The ambient temperature and pressure characteristics required for petrol formation directly affect the way the necessary bacteria work in petrol formation (Tissot 2003). Petrol is an oily substance that can be found mostly in liquid form and in various colors. Dense and easily flammable, petrol is a mixture of hydrocarbons naturally found on earth in solid, liquid and gaseous form. The word petrol is derived from the Latin words "petra" and "oleum". Petra means "rock" in Latin, while the word oleum means "oil". The colour of crude petrol may vary depending on the place and content it is extracted from. The reason why the colour of the petrol varies is the variety of hydrocarbons in the content and the difference in the mixture ratios. The average crude petrol consists of 83-87% by weight of carbon and 12-15% of hydrogen. Nitrogen, oxygen and sulphur (N, O, S) elements are generally found in less than 5% by weight in petrol (Bayraç 1999).

Compositions such as density and the amount of sulphur determine the quality of the petrol. Low petrol density makes the treatment process easier and allows more petrol products to be produced as a result of this process. Petrol with low density is called light petrol. The low amount of sulphur in the petrol composition indicates the petrol is more efficient (Tissot 1984). There are more than 150 types of crude petrol in the world according to their density and sulphur amounts.

The API gravity definition, developed by API (American Petroleum Institute) and based on specific gravity, is one of the most appropriate measurements in the classification of petrol all over the world (Galina 2016). Fossil fuels, including processed petrol, are not only used as energy raw materials, but also serve many purposes every day in the world. Fossil fuels are among the raw materials produced by the main ingredients used in sectors such as paint, plastic, medical, cosmetics, iron and steel, and aluminum, which are also needed by most industries. As a result of the processing and treatment of crude petrol, fuel gas, liquefied petroleum gas (LPG), naphtha, normal gasoline, super, unleaded, paraffin, solvent, jet fuel, gas petrol, diesel, heating fuel, fuel oil, road construction material, mineral oil and similar products are obtained. Apart from different fields it is used in, petrol is also the most basic raw The petroleum market has some unique features. Since petrol markets are globally sensitive, the supply-demand balance may also vary. Production is planned in order to control the petrol price, taking into account that the demand cannot increase quickly under normal conditions. Petrol markets around the world are traded in large volumes. The investment policies implemented by companies operating globally can be very effective on the balances in the world economy. The political approaches of their countries can also be effective in the international investment decisions of these large companies (Yücel 1994).

Since petrol exploration and production processes require large investments and expensive technologies, organizations in the sector are always obliged to follow international technology changes. Each country has its own legal regulations on petrol that will make a difference for that country (Öztürk 2017).

Countries with petrol reserves want to utilize this important resource with the highest efficiency and profitability. Importer countries, on the other hand, try to procure this resource at the least cost. Another important factor that forms the characteristics of the market is the characteristics of trading countries (Ercan 1996). The reason why the petrol market is complex, and dynamic is that there are many factors that affect each other. These factors are political, economic, socio-cultural and technological. Due to the capital intensity and large scale of the petrol industry, the companies in the petrol industry create a great economic power and can implement strategies and policies locally and globally.

In 1960, OPEC (Organization of Petroleum Exporting Countries) was established to protect the interests of petrol exporting countries. With the increasing growth rate of the world economy after 1960, the commitment to petrol has increased, which has led to an increase in OPEC's bargaining share. Due to the Arab-Israeli War of 1973, the first petrol crisis shook the petrol security structure around the world and had a great impact on the markets. In the period after the petrol crisis, the market balances have changed and countries that import petrol have also started to turn to alternative energy sources. After the shock caused by the petrol crisis on developed countries, some radical measures were taken to determine the adaptation policies required in a similar crisis period, to put them into action quickly, and especially to reduce the dependence of the economy on monopoly petrol. As a result of new studies, IEA (International Energy Agency) was established by OECD countries on November 15, 1974 (Soysal 2003). The International Energy Agency conducts detailed-data analysis on energy production and use planned today and in the future. With the analyses made, the situation of global energy markets and the determinants of the dynamics of these markets are determined. Within the scope of the analyses, the production costs and potentials of resources, the development of the energy market and energy prices, government policies and climate changes are examined. As a result of the analyses done in recent years, a very rapid increase is projected for energy demand and use. The use of fossil fuels to meet these increasing rates will also rise and maintain its use with other energies. It is predicted that the dominance of fossil fuels among other energy sources will continue (Nicola 2006).

Table 2.1. Oil Reserves by Countries (Source: Bayraç 1999)

Country	Million Barrels
Venezuela	300.9
Saudi Arabia	266.5
Canada	169.7
Iran	158.4
Iraq	142.5
Kuwait	101.5
United Arab Emirates	97.8
Russia	80.0
Libya	48.4
Nigeria	37.1
United States of America	36.5
Kazakhstan	30.0
China	25.6
Qatar	25.2
Brazil	12.7

According to the published petrol reserve data and future projections, it is predicted that petrol will meet the energy needs for many years to come. With the increasing population, the increased need for energy leads to increases in petrol use in countries with medium and low levels of development. No matter how much energy the developing renewable energy technologies provide, they will not be a solution to this energy demand for many years

2.2. Fuel Sector in Turkey

Turkey cannot meet its own petroleum and natural gas needs due to insufficient resources. In Turkey, where 50 billion cubic meters of natural gas and 40 million tons of petrol are consumed annually, approximately 10-12% of these amounts are produced within the borders of the country. Turkey continues to consume 92% of petrol and 99% of natural gas depending on foreign sources (TUIK 2018).

Diesel is generally used as fuel-oil from countries such as the gulf countries, Algeria and Norway. In Turkey, despite being a country with an entirely developed refinery system, the change of crude petrol in domestic currency creates a chain price interaction between fuel product prices and fuel input sector costs. In countries that do not have their own crude petrol resources, imports affect many variables such as the country's foreign trade, balance of payments, exchange rates, money supply, employment and inflation.

The effects of the fuel economy on the current account deficit are determined by the relationships between inflation, exchange rate, and crude petrol barrel price increases, as well as being affected by the excessive increase in energy use resulting from increased investment expenditures due to the high growth rate. Import invoices of the foreign-dependent economy vary within the framework of these effects. In terms of growth rate, Turkey is on an important route with characteristics similar to the Asian Pacific region, especially growing economies such as India and China, in terms of energy consumption indicators.

Turkey's producible petrol reserve is known as 334.5 million barrels. In the absence of new discoveries, it is thought that the remaining renewable crude petrol reserve has a life of approximately 19 years (Ercan 2019). The natural gas reserve is 3.7 billion cubic meters and has a life of 9 years.

As of the end of 2018, 5 refineries (6 licensed refineries), 97 distributors and 12,828 fuel dealers operating in the petrol market are licensed from EMRA. There are 92 distributors and 10,701 auto gas stations operating under license in the Liquefied Petroleum Gases (LPG) market.

According to TURKSTAT data, 54.2% of the total 22,865,921 vehicles registered in traffic as of 2018, consists of automobiles, 16.4% of trucks, 14% of motorcycles, 8.2% of tractors, 3.7% of trucks, 2.1% of minibuses, 1% of buses and 0.3% of special purpose vehicles. According to the type of fuel used, the number of cars using petrol, diesel and auto LPG varied by -1.0%, 7.3% and 1.7% in 2018 compared to 2017, respectively (Akademi 2019).

The fuel sector in Turkey serves an average of 4 million vehicles and 8 million people every day. The fuel dealer network in Turkey is the third largest network in Europe after Germany and Italy. The fuel sector, which grows at an average rate of 7% each year, is ranked 6th among European countries with an annual fuel sale of 35 million tons. The income of the sector, excluding indirect taxes, is also affected by the change in petrol prices in addition to consumption. In the last 5 years, its share in GDP has been realized as 3.1% on average. The aviation and maritime sectors also have a large share in the growth of the fuel sector in Turkey. There is an average annual fuel consumption of 4.5 million tons in the aviation sector and 3 million tons in the maritime sector (Bilge 2018).

When Turkey is examined in terms of the number of vehicles per person, it is 150 vehicles per 1000 people. This rate is behind other European countries due to high automotive prices. Measures taken against unregistered fuel with the growth in energy & infrastructure, transportation, construction and agriculture sectors, which have been of great importance in the growth of the country in the last 7 years, have increased diesel sales by an average of 10% each year (IEA 2019).

2.3. Importance and Development of Renewable Energy

After the petrol crisis that occurred in 1973, the importance of energy began to be better understood all over the world. After this date, countries took important steps towards diversifying energy resources and using alternative energy sources, especially the countries that import energy have sought various policies for the sustainable use of energy. By the 2000s, the search for alternative energy gained great momentum and studies on renewable energy began to increase.

In today's world, energy and meeting the existing energy needs has gained great importance. The ever-increasing global demand for energy and the rapid consumption of traditional energy resources all over the world are forcing countries to seek new sources of energy. The dilemma caused by the energy demand and excessive fossil fuel consumption both increases the acceleration and slope of trends in negative environmental factors and increases the pressure on innovations for alternative energy sources.

Along with the rapidly rising world population, energy consumption increases day by day. Trying to meet this energy need only based on the consumption of fossil fuels is polluting the world more and more every day and depleting its limited resources. The solution to the need for energy lies in popularizing and increasing methods of renewable energy. Renewable energies are basically the unleashing of potential energy in solar-generated resources. The main renewable energy methods used in the world are solar, wind, geothermal, hydro, biomass and wave energies. Each type of renewable energy varies according to its usage area.

Hydroelectric energy is the conversion of mechanical energy from flowing water into electrical energy with the help of turbines. Many rivers and dams around the world produce electricity with hydroelectric technology.

Wind energy is the most advanced renewable energy method. Electricity is produced with the help of turbines turning in the wind and generators. Many countries of the world have wind turbines both on land and on the sea. The source used for wind energy is the continuous winds of the region where the power plants are installed. They are in different classes according to wind speeds and directions and the turbines to be installed are determined according to these characteristics.

Geothermal energy, which has been used by humanity since ancient times, is the conversion of the earth's natural heat into energy. Geothermal energy used in areas such as heating, electricity production and drying technologies also contributes to the production stages in industries.

The sun, which is known as the most important energy source of the world, also directly and indirectly creates other renewable energy sources. Since it has a direct effect on the world as a resource, the sun is anticipated to become an alternative to fossil energy sources in the future.

Biomass is a mass of non-fossil organic matter of biological origin. Biomass refers to the substance produced from living organisms (Pamir 2003). Traditionally, biomass is a known and used energy source from the discovery of fire to the present day. The use of biomass in the modern sense has been in the 21st century. Biomass energy is transformed into energy sources such as biogas, bioethanol, biodiesel, biomethanol, bio dimethyl ether, and biooil in modern applications (Australian 2016). It is widely used in the production of biodiesel, bioethanol and biogas.

Productivity levels have increased considerably with studies on renewable energy technologies for many years. What distinguishes renewable energy from original and other energy sources is that it does not need any raw materials. The sun is always an unlimited source, the wind always blows, the cities always produce organic waste. Although it is slower and more laborious than other energy productions, its benefit for the environment is great. No carbon dioxide is emitted and production is done without consuming any source.

Reserves such as fossil fuel-based petrol, coal and natural gas, which are consumed in the same way as the current consumption parameters, tend to be depleted within 100 years (Üçgül 2010). As a result of the unbalanced distribution of fossil resources worldwide, external dependence on energy possesses great economic loss for most countries. In addition, renewable energy types are very important in terms of reducing carbon emissions that harm the environment, there is no need to import because they are domestic resources, and therefore reduce external dependence on energy.

Renewable energy technologies, which are determined according to the type of resource available, have been one of the most studied sectors by humanity in the recent years due to the benefits they yield. Although the use of increasing renewable energy technologies promises hope for a clean future, energy consumption from fossil fuels has been a stable primary energy source for many years (Figure 2.1.).

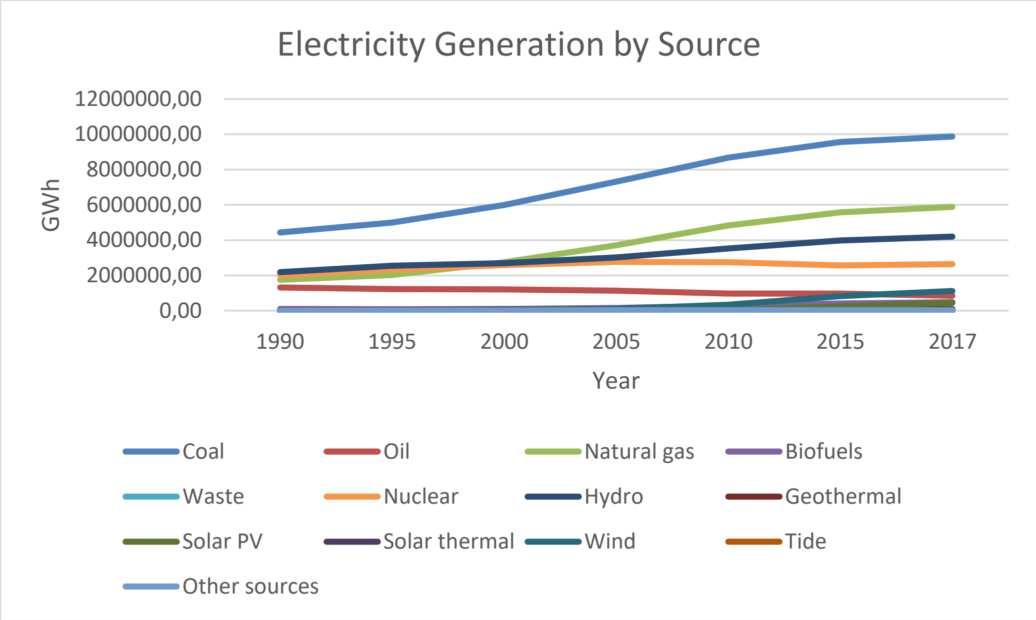

Figure 2.1. Electricity Generation by Source (Source: Akova 2008)

2.4. Solar Energy in Turkey

Geographically, Turkey is a country in the Northern Hemisphere between 36-42° north latitudes and 26- 45° east longitudes. The solar energy potential of Turkey, thanks to its geographical location, makes Turkey much more advantageous than many other countries in terms of solar energy. Although Turkey is located in the solar belt, the acquisition and use of solar energy is much less than predicted. Therefore, solar energy, which is among the renewable energies, should be implemented effectively and sustainably as an important solution alternative in meeting energy needs in the near future.

The General Directorate of Renewable Energy (YEGM) is responsible for the identification and evaluation of all energy resources in Turkey. This institution is located within the Ministry of Energy and Natural Resources (MENR). YEGM also conducts studies on renewable energy sources and prepares the groundwork for popularizing renewable energies.

The use of photovoltaic systems should be expanded as an important step in solar energy in Turkey. Developing technologies are effective in increasing the use of photovoltaic systems. Thanks to the reduction of costs and the increase in productivity of photovoltaic systems in recent years, there has been an increase in their use, and this is expected to rise in the future. Over time, the goal is to gradually increase the capacity and reach a total licensed and unlicensed PV (photovoltaic) plant installed power of approximately 15 GW in the next 5 years (mgm.gov.tr).

YEGM, which conducts studies on the effective and efficient use of solar energy, has published a "GEPA (Turkey Solar Energy Potential Atlas) Album" to determine the potential of solar energy production (Figure 1). According to Turkey's Solar Energy Potential Atlas, the total annual sunlight time is 2737 hours (daily total is 7.5 hours), and the total annual solar energy received is 1527 kWh/m², that is, 4.2 kWh/m² in total per day.

Turkey has a high solar energy potential of 110 days per year and if the necessary investments are made, Turkey has the potential to produce 1100 kWh of solar energy on average per square meter per year. Table 1 shows the distribution of Turkey's solar energy potential and sunlight duration values by regions (Kılıç 2011).

Table 2.2 Solar Energy Potential by Regions (TEİAŞ 2020)

Region	**Total Solar Energy (kW/m^2-year)**	**Effective Solar Time (hours/year)**
Southern Anatolia	1.46	2,993
Mediterranean	1.39	2,956
Eastern Anatolia	1.37	2,664
Central Anatolia	1.31	2,628
Aegean	1.30	2,738
Marmara	1.17	2,409
Black Sea	1.12	1,971

While the southern parts have the highest values, these values decrease as we go north. In the part of Turkey covering 63% of the surface area, the working rate of solar water heating systems is 90%. In many parts of Turkey, it is known that solar water heaters can operate at full efficiency through 70% of the year. In many provinces, water heating systems are provided with solar energy systems. Also, in some industrial applications, the use of photovoltaic batteries in electricity production with volume heating applications is becoming increasingly widespread with decreasing costs (mgm.gov.tr).

Within the scope of increasing the share of renewable energy sources in the electricity supply, the installed power of the plants based on renewable energy sources, including June 2020, has reached 38019 MW. The installed power based on solar energy is known as 6166.6 MW. These values represent the sum of licensed and unlicensed production capacities. The distribution of unlicensed installed power values by sources is shown in Table 2.3.

Table 2.3. Unlicensed Power Capacity According to Sources (Source: Tetra Tech 2018)

Source	Installed Capacity (MW)	(%)
Solar	5,883	92.4
Natural Gas	331	5.2
Biomass	76	1.2
Wind	71	1.1
Hydro	9	0.1

Solar energy systems are the most suitable and widespread method of electricity production for both small businesses and individual use. Thanks to reduced installation costs, the use of PV systems has increased rapidly. To date, Turkey has installed a total of approximately 6 GW of solar energy capacity, most of which are field applications of less than 1 MW. By comparison, Germany's solar installed power, which is Europe's leader in this field, is 45 GW. A recent study estimated the solar capacity of Turkey's roofs as 200 megawatts (MW) and the market potential as 4 GW for 2017 (Falvo 2018).

2.5. Renewable Energy Regulation

The Regulation on Unlicensed Electricity Generation in the Electricity Market published by the Official Gazette of the Republic of Turkey provides the manufacturer with a wide range of information on what kind of procedures renewable energies can be applied in the scope of at small and medium-sized enterprises. The purpose of the regulation is to determine the procedures and principles to be applied to the persons who can produce electricity in electricity markets, in the places closest to their consumption points, to meet their electricity needs from their own generation facilities, to bring small-scale generation facilities into the national economy, and to determine the effective use of small-scale generation resources, without the obligation to obtain licenses and establish a company with minimum grid loss.

Within the scope of this regulation, the procedures to be applied on unlicensed electricity generators giving the surplus electricity they generate to the system, the transfer of production facilities procedures and the rights and obligations of the operator are explained in detail.

Renewable energy generation facilities are implemented within the scope of the procedures, standards and incentives determined by YEKDEM (Renewable Energy Resources Support Mechanism) established by the government. These incentives and procedure system started with the YEK Law No. 5346 issued in Turkey in 2005 through the YEKDEM mechanism. With YEKDEM, the aim is to increase the number of production facilities based on renewable energy sources in Turkey, to reduce the need for fossil fueled environmentally harmful production facilities and to reduce foreign dependence on energy.

The electricity produced by the relevant generation facilities within the scope of YEKDEM is guaranteed to be purchased at a fixed price for a maximum of 10 years. These prices to be applied to the facilities are determined by the YEK Law and are as follows; 7.3 US cent/kWh for hydroelectric and wind energy-based generation facilities, 10.5 US cent/kWh for geothermal energy-based generation facilities, 13.3 US cent/kWh for biomass and solar energy based generation facilities.

In addition to these incentives provided by YEKDEM, the regulation on 'Supporting Domestic Components Used in Facilities Generating Electricity from Renewable Energy Sources' provides additional incentives to production facilities based on renewable energy sources that use a certain level of domestic components in their facilities. With this application, the facilities are encouraged to use domestic production parts and components at a high rate. The number of incentives varies according to the source type of the facilities and the rate of domestic components they use.

Article 5 of the Regulation states that the production facility should be within the same distribution zone of other production facilities and consumption facilities owned by the persons who will establish. Within the scope of this article, the obligation of the installed power increase in cases where the capacity is not sufficient is specified.

The PV generation facilities to be newly installed within the scope of the Regulation shall be provided with grid connections by including those up to 400 kW in the low voltage class and those over 400 kW in the medium voltage class (Law No.6331).

The generation facilities to be connected from the low voltage level shall not exceed 50 percent of the power of this transformer if they will transmit through the transformer of the grid operator. If the transformer belongs to the applicant, the capacity in question is the maximum transformer power. While the applications were rejected based on missing and incorrect documents in the periods before the regulation, they can now be declined without even rejecting information, so it has become very important to prepare the application documents very carefully and completely.

Within the scope of Article 11, the facility application to be produced is evaluated in accordance with the procedures and principles of the institution to be authorized by the ministry. Production facilities based on solar energy can only be done as roof and facade applications (Law No.6331).

As stated in Article 19, for solar energy systems after the connection agreement has been made, it is necessary to provisionally accept within 2 years if the connection is at medium voltage level and within 1 year if the connection is at low voltage level. Sometimes this is interpreted as ready for provisional acceptance, but the regulation is quite clear on this issue, provisional acceptance should be done, and the documents received should be submitted to the relevant institutions. If there are 15-20 days left before the expiry of the period, it must be ready for temporary acceptance and temporary acceptance should be done urgently.

The installation of SCADA ‘Supervisory Control and Data Acquisition’ monitoring systems is mandatory for systems over 50 kW. The generation plant may not be operated with a power greater than the agreed power in the connection agreement. If the generation facility is operated at a power greater than the agreed power in the connection agreement, the penal conditions in the Connection Agreement to the Distribution System for Unlicensed Electricity Generators shall apply (Law No.6331).

For electricity energy consumed in the facilities belonging to one or more real and/or legal persons in the same tariff group and connected to the same connection point or whose electricity energy consumption can be measured with a single common meter, their consumption can be combined to establish a production facility or facilities in the scope of this Regulation.

CHAPTER 3

STRATEGY AND METHOD

Increasing environmental sensitivity within the framework of technological and sociological trends in the world within the framework of developing technologies is important in many sectors. Considering the intense initiative, will and tendency towards electric vehicles, especially in the automotive sector, the use of renewable energy in the fuel sector has a meaning far beyond the cost advantages it will provide today. Photovoltaic systems, which provide electricity production from solar energy in particular, are a much more efficient, accessible and sustainable option in lower capacities due to many factors such as the fact that they do not need a special operating methodology and process, that periodic maintenance processes are costless and effortless, and that they are easy to apply in terms of zoning.

Considering the current technology level of a solar power plant and the regulations in force, the only three factors that it will need are self-consumption, the necessary structure area and the first investment capital. Considering the geographical location of our country and the surrounding countries and accordingly the radiation levels, it is possible to say that the systems in question are even more advantageous throughout the country.

Fuel stations have all three of the above-mentioned requirement factors in abundance. The relatively high and significant amount of self-consumption in total cost, the large, flat and perhaps most importantly constructively applicable roof areas above the canopy over gas station markets and fueling pumps, and finally, the low percentage size of the solar energy system compared to the total company value or operating capital make this sector suitable for self-consumption solar energy systems.

Many projects assembly and application companies operating in the solar energy sector work with zero or very small inventory in supply chain management and supply materials on a project basis. Therefore, as the application shrinks, the purchase prices and freight costs per piece increase. Also, engineering and project services, which constitute a small percentage in large projects over 200kW, appear as a cost element up to 50% in small systems between 80kW-10kW.

For this reason, it has become necessary to reconsider the supply chain and project designing services paradigms in order to perform PV applications in fuel stations. As a result of the preliminary agreement with IBT Solar, which is planned to be a business partnership, the continuity of the supply chain and the use of local products as much as possible have been agreed, and in addition, working styles have been determined in principle with many local panel producers. With this method, material and freight costs for a 20kW system have been made equivalent to the costs for a 200-300kW system.

Although almost every financial institution has some instruments related to solar energy investments, even financial institution branch officials do not have practical knowledge on this subject, let alone in presenting these instruments to the end user (fuel stations for our project). Even if the owner of a fuel station decides to take an individual PV system initiative, they face serious difficulties in reaching credit-based financial solutions.

As a result of the preliminary agreement reached with the Turkey Finance Participation Bank for PV applications in fuel stations, sample studies for 100% financing of 20-25-30-35-40-45-50-60-70-80 kW projects have been prepared and approval and allocation processes have been accelerated so they can be carried out from a single source. Upon the request of the investor, if the investor has the demand and the desired credit sufficiency (such a sufficiency is not in question for the fuel stations), a financing solution can be produced quickly in the project package.

The fact that the financing is included in the solution package can be considered another practical requirement.

There is a detailed procedure to be carried out with the regional distribution company for on-grid unlicensed under 5 MW solar energy systems. Effective follow-up of such a procedure by players outside of he solar energy sector causes serious inefficiency in terms of both cost and time. The difficulty of bureaucratic procedures has also been a serious obstacle for fuel distribution companies (Shell and Petrol Ofisi) to step back in their initiatives.

On the other hand, since almost all the existing solar energy companies focus on large projects in grid systems, they do not have the human resources capacity and process management models to follow the processes of dozens of applications at the same time. Within the scope of our project, it is clear that the staff of university graduates (business, economics, accounting and public administration) will focus on bureaucratic processes in a concentrated manner, which will increase according to the needs, and considering the experience to be gained over time, it will reveal a significant increase in efficiency in this field of operation. Even just the improvement to be achieved in bureaucratic processes can be considered justification for PV applications in fuel stations in itself.

In addition, an organizational chart focused on relations with bureaucracy will contribute to the necessary experience and knowledge for the international expansion in the subsequent stages.

Considering the marketing of systems, as mentioned before, almost all of the companies operating in the solar energy sector are focused on systems above 200kW. Also, there is a heavy burden of knowledge and experience brought to the proposer of a project that will fundamentally affect the electrical and safety infrastructure of the station, impacting the utility rights, operating systems, profitability structures, investor profile, relevant legal regulations, national and international structures of distribution companies, occupational health and safety requirements arising from the fuel itself and explosion protection elements and many other sector specific issues. Therefore, a practice specifically focused on the development of grid-linked solar energy systems in fuel stations promises a full focus as well as a multidisciplinary approach.

Considering all the above-mentioned requirements, PV applications in fuel stations that are currently idle and can contribute 0.5% to Turkey's electricity consumption. Besides the package approach for fuel sector holds opportunity for expanding into neighboring countries and additionally promises to make a significant contribution to environmental sensitivity in Turkey.

3.1. Service Pack Solution

Solar Station is an organization that plans to carry out projects suitable for potential investors with a package solution that includes many services. In photovoltaic system-oriented solar power plants, there are basically many problems and separate solutions to each problem. In addition to innovative solutions, there are also traditional solutions for basic engineering problems.

Panel and inverter selections, which are the main products of PV systems, will be determined according to the planned location and system requirements and will be provided as a result of the agreements with the partners in the supply chain.

The wiring and construction systems that provide the connection of the panels shall be determined by using appropriate measurements with separate projects and shall ensure that the projects are implemented. The static calculations of the canopy and management buildings where the systems are to be installed will be examined and, where necessary, the necessary building reinforcements will be made with the construction company, which is a business partner.

The risk will be minimized by integrating the insulating connection materials required for the security of the systems with the system and the fire detection and protection systems will operate simultaneously with the system. Minimizing the risk factor in jobs done in dangerous areas is very important for preventing occupational accidents. During installation and after installation, each station will have its own occupational safety specialist and system controls will be done at regular intervals.

The maintenance and cleaning of the systems shall be provided with a high degree of care and maintenance shall be done by support teams. Along with occupational safety training to be provided to the fuel station employees, detailed information about the system components and risk factors will be conveyed to the employees.

3.2. Engineering Problems and Solutions

Photovoltaic systems are an attractive form of application for fuel stations in every aspect. PV applications will provide a definite return for station owners thanks to both high electricity consumption levels and available space amounts. The fuel sector has been meeting the energy needs of humanity for many years. Due to the developing automotive sector, fuel stations are growing day by day. It is possible for these stations to generate electricity in the quantities they consume with PV systems.

In addition to all positive features, there are some problems that need to be solved. With the explosion protection principles and calculations included in the legislation of the Ministry of Transportation, the Ministry of Family Labor and Social Policies and the international HSE (Health-Safety-Environment) standards of the fuel distribution companies are considered, the high voltage on the roof area (although it may vary according to the connection methods in PV systems, it may be up to 1000V) may create dangerous situations. To date, no general engineering solution has been produced for this problem, and as a result of the calculations in individual applications, only the stations where the roof height can carry the safety values to the highest level have been put into practice. Especially due to this obstacle, the initiatives taken by Shell and Petrol Ofisi companies within themselves have remained unavailable until now, but they had the chance to implement it only in three stations. In the enterprises undertaken by various solar energy assembly and application companies independent of fuel distribution companies, results could only be achieved in five stations. Currently, there are only eight stations in our country that use on-grid systems that fulfil their self-consumption with solar energy. One of these (Shell-Güzelyalı) can only partially provide for its self-consumption due to the aforementioned problem.

The possibilities of using water, air and fuel vapor insulating cable connection apparatus used by IBC Solar-Germany (IBT Solar subsidiary in Turkey), one of the providers in PV applications modelled in this project, in underwater cabling, without creating a high cost, have been investigated, tested and their suitability has been approved. Although this solution is simple, it definitely solves the explosion protection problem, which has not produced an effective solution so far.

Another engineering problem is that the static calculations of some canopies built before 2000 cannot bear the static load that the panels will create within the safety coefficients. With the cooperation and studies conducted with the Izmir-based EnArt Company, a steel dressing model has been developed for the strengthening and project designing of the construction in terms of static and dynamic aspects. Sample studies have shown that this method, which is relatively cost and time effective, is an ideal analysis in terms of bearing the desired load within safety limits and also ensuring compliance with responsible zoning regulations.

As a result, one of the factors that make PV applications necessary in fuel stations is that the two main engineering problems have been solved as summarized above. These engineering solutions have largely not been overcome in developing neighboring countries as well as in our own country. In this context, PV applications in fuel stations will be able to contribute to the Turkish economy with the chance to expand internationally.

3.2.1. Explosion Protection

Accidents that occur in man-made systems and cause much loss of life or injuries, significant damage to buildings and loss of public reputation are frequently experienced in our country. One of the measures that need to be taken to reduce the negative consequences of these is to prepare an Explosion Protection Document.

ATEX, which entered into force as an "Explosion Protection Document" in our country, is named after the French-origin phrase "ATmosphères EXplosibles", that is, "Explosive Environments" and is a document that should be prepared in every workplace with the risk of explosive environment.

The purpose of the Explosion Protection Document is to prevent the formation of an explosive environment, to ensure the health and safety of the employees, and to take measures to reduce the harmful effects of the explosion in case of a possible situation. When we set out with this idea, the explosion protection document should be prepared before the activities that pose a risk of explosion start.

Fuel stations are among the high-risk workplaces due to the presence of flammable materials. The environment formed by flammable gas, steam, powder, fiber (fiber, wire, yarn) or volatile flammable solids by mixing with air under atmospheric conditions is called explosive atmosphere and the spread of flame continues spontaneously after the explosive atmosphere is ignited.

The environment formed by flammable gases or flammable substances in the form of vapor by mixing with air under atmospheric conditions is called explosive gas atmosphere and the spread of the flame continues spontaneously after ignition. Places that have or are expected to have an explosive gas atmosphere, require special care for construction and installation and the use of special tools are called hazardous areas. A non-hazardous area is where explosive gas atmosphere is not expected to occur, special care is not required for construction and installation and special tools are not required.

Facilities in which flammable materials are processed or stored, must be designed and established in such a way that the flammable material does not leak for any reason and does not spread to a large area if it does leak. Facilities like this shall be operated and maintained as such that they will not cause any flammable material leakage even in normal and abnormal jobs during the operation phase. The necessary precautions should be taken to ensure that leakage does not occur and does not spread to a large area when it occurs, taking into account the continuity and intervals of the leakage.

Process sections and equipment that discharge flammable substances or cause flammable substances to leak should be examined and the necessary designs and corrections should be made to reduce the probability of leakage, frequency and spreading distance by redesigning such process sections or equipment with consideration for the possibility of flammable substances discharge frequency and spreading distance.

Classified hazardous zones may not apply in operating situations outside of normal operation, such as commissioning and non-routine maintenance. It is expected and accepted that in such activities outside of the normal work are carried out with a safe working system. Normal and routine maintenance work must be considered in the zone classification.

It is not always easy to decide, as a result of a short survey and control just looking at a facility or plant project, that the parts of that facility will be divided into 3 zones (0, 1 and 2) according to the risk group and be included in the site classification. Zone 0 is the region with the highest risk and Zone 2 is the region with the lowest risk. It is rare that a simple control of the facility or examination of the plans can achieve a decision on the hazardous areas. More often, it is necessary to examine with a more detailed approach the assumptions of explosive gas atmosphere formation. In order to calculate where the flammable gas or steam will discharge (leak) and with this possibility of discharge, how long the discharge will last the necessary assessments should be made looking at the descriptions of constant, main and secondary discharge sources. Once the degree, amount of discharge, structure, speed, ventilation of the environment and other factors have been determined, there will be solid and necessary information to calculate the probability of creating an explosive environment in the atmosphere around the source of discharge. The type and size of the explosive environment can be calculated with this information. This approach requires detailed examination of each part of the process equipment that contains a flammable substance due to its own or process conditions and constitutes a source of discharge. The method and methodology for how to classify areas containing explosive gas atmosphere are described below.

Before the area classification is made in a facility, the equipment plans, tool single line, work and process flow plans of the facility should be prepared. Such plans must be prepared before the plant is commissioned. Various types, different locations and large number of potential discharge points should be taken into account when making the evaluation and the entire facility should be considered when drawing the boundaries of the hazardous area. Control systems that are planned and installed according to a "Functional Safety" standard, such as batch sequence control and discharge system, may have an effect that reduces the potential for the generation of discharge sources and/or the amount of discharge. Therefore, such control systems should be considered in the hazardous zone classification. Previous experience gained in the same or similar facilities should also be carefully evaluated and taken into consideration when making a site classification. It is not enough to make a site classification by determining the zone 1 or zone 2 distances by considering only one potential flammable material discharge source. If there is documented evidence or experience with the design and operation of the plant under consideration, these reinforce the preferred site classification. Zone classification done based on experience gained in the industry or new evidence outside of this should be reviewed and corrected from the beginning.

There are also some risks for photovoltaic panels installed on canopy and management buildings. The ignition levels of volatile vapors pose significant risks to PV systems. Fire-protected fasteners are used for the safety of PV systems. No lack of precaution should be considered in terms of fuel stations and the security of these systems is ensured by using ex-proof materials with insulation properties used in underwater systems. The height of the canopy should be a maximum of 5 meters for steam protection. During installation and after the completion of the connection of the systems to the grid, the stations must be regularly under the control of occupational safety experts.

3.2.2. Fire Security

Although solar energy systems seem to be more attractive and easier than other energy systems, they do have some risks. Fire hazards and precautions in solar energy systems vary according to the type, power and location of the solar energy system. Flammable material, air and heat source are required for a fire to occur. The fire may occur either due to technical deficiencies or errors during the installation and operation of the facility or due to an external factor. There are different fire protection methods for each different threat, and the points to be considered when installing systems should be handled one by one.

The most important cause of fire in PV systems is electrical failures. The main ones are the arcs formed as a result of electric arc, short circuit, grounding error and reverse current. This and faults such as cable insulation problems, module cracks or incorrect connection can cause ignition of flammable materials. At the same time, incorrectly installed DC and AC inverters are among the main causes of many fires. Any faulty connection or breakage in the connections can be transformed into an electric arc due to the current and can be emitted with the help of air. This problem, which is an important risk in power lines, is one of the most important points to be considered in PV systems due to high current and high voltage. DC arcs cannot be extinguished on their own and their temperature can reach about 3000 degrees. At this temperature, the metals may melt and cause combustion of the flammable materials in the vicinity. There are three types of arcs in electrical systems. Serial arcs are arcs that occur as a result of connector error or disconnection while the system is generating current. This is why, it is necessary to have fire insulation in PV systems (Manzini 2015).

Parallel arcs are mostly formed by disruptions in insulation. The fact that DC circuits are very close to each other at different poles in the two contactors causes arcs. Insulation material between the two cables can be damaged by an animal gnawing, UV damage, loosening, cracking, humidity, air coming in or freezing. Arc formation can be observed in places where damage is seen. The arcs in the ground are formed due to an error in the insulation system. In arc welding risks, general triggers can be listed as poor solder connections, loose connections, grounding leakage, defective insulation and corrosion.

In order to prevent system errors, the quality of the materials selected for the system and the maintenance of the installed system are very important. Compatibility of DC closed-circuit systems with NFPA 70 in PV systems that has potential of more than 80V electricity will ensure that possible damages are minimized. Unlike other systems, the products used in system installation should be the systems preferred by the approved organizations rather than protection measures in PV systems.

One of the most important points to be considered in system installation is the components of the system to be installed. Systems complying with international standards such as IEC 61730 and/or ANSI/UL 1703 should be used in the modules of the PV panels being used. Modules to be used must have undergone TÜV Rhineland tests or FM approval (TCV 2003)

IEC 61730-1 safety norm is the standard for determining the flammability values of plastic materials in PV systems. Reverse current test, bypass diode test, ground continuity test and wet current test are also required for the safe installation and use of the system. The tests to be performed on the distribution boxes for photovoltaic systems have been determined in accordance with the standard numbered EN 50548.

Non-combustible material should be preferred for the module frame and fittings. There should be sufficient free space on roofs where the system is installed in accordance international standards to facilitate firefighters' response to fire.

EN 13501 and ENV 1187 standards are used for roofs and there is no norm in Europe that can be applied to every EU country. Within the framework of these standards, fire retention of building materials and parts, resistance to air fires and radiation temperature are determined. Another standard to be taken into consideration in PV systems is to determine the lightning and overvoltage behavior for power supply systems numbered IEC 62305.

Cables compatible with weather conditions and UV rays must be selected. Cables that comply with UL 4703 standards and have high fire resistance should be used. In order to protect the system cables from wear and tear and weather conditions, it is recommended that the cables are passed through metal guards. It is necessary to position the cables on the roof in a way not to damage the building in case of a possible fire. Firewalls can be created according to the location and status of the system. Direct contact of cables and connectors with membrane materials on the roof must be prevented. Cables must be wrapped with fireproof materials. Due to the additional loads to the roof, these materials must be light materials.

Care should be taken to make sure the main DC cables to the inverter do not pass through the building, otherwise the necessary measures should be taken. The inverter has to be kept in an area that will not be affected by weather conditions. If possible, it is recommended that the inverter be kept in a non-flammable area protected by a fire detection system. It should not be mounted on flammable materials such as inverter wood or polyurethane sandwich panel. It is recommended that DC disconnector fuses be used between the PV generator and the inverter. PV systems must be installed by authorized personnel and regularly maintained by these authorized persons. Problems with the cables during this maintenance may need to be checked with the help of a thermal camera.

When using solar energy, which is a renewable energy source, to provide the energy consumed in buildings, the use of building surfaces is inevitable. In these situations, it is becoming more popular to use photovoltaic systems that can convert solar energy into electrical energy on building surfaces. Photovoltaic systems are used in roof elements as building surfaces. Roof components are a major factor in the emergence and spread of fire. Roof elements carry risk in terms of fires that occur in the outdoor environment reaching the indoor environment or fires occurring in the indoor environment reaching other units of the building. When fires occur in buildings, roof components are important for extinguishing work and safe evacuation. Therefore, it is necessary to establish fire safety measures to ensure the safety of life and property in the use of photovoltaic systems in buildings.

The presence of high voltage and high current in photovoltaic systems is one of the factors that may cause fire and up to standard fire safety precautions should be observed. It is necessary to determine the risks and transfer them to the design process. In this case, it is necessary to know the reaction classes of the panels to the fire, to know the toxic gas and drip properties of the panels during the fire, to determine whether the system components are approved within the framework of national and international standards, to evaluate the fire loads that the panels will bring to the building systems, to examine the materials to be placed around the panel, and to consider the objects that may fall from the roof.

Evaluating and eliminating the risks ensures the safety of the property, safety of the users and the teams that respond in case of a possible fire. This also prevents the fire from rapidly growing and facilitates the fire response process. It is necessary to close the electrical circuit system in case of a possible fire, to take flammable materials out of the fire area, to have safe and sufficient areas for fire response, and to have the appropriate extinguishing system assemblies available.

In photovoltaic systems used as roof elements, there are many important points to be noted. Module construction of photovoltaic system elements adapted to the building and fittings should be chosen from non-combustible materials. It is expected that the air well and roof finish material on the lower surface of the panel will be constructed in a way to prevent the emergence and spread of fire. It is necessary to determine the areas where the extinguishing teams can move properly on the roof and to make it easier for fire response during the fire. It is necessary to keep the electrical cables away from flammable materials and to support them with non-flammable elements in the passage of structural elements (use of passive fire arresting elements). In case of a possible fire, it is appropriate to disconnect the system from the electricity and inactivate the panels. It is necessary to prevent the fire from spreading to the neighboring buildings. The construction of compartments and firewalls should be handled and evaluated for this purpose.

Something that causes the switches and cables to overheat is the conductors not being correctly screwed into the connectors. Poor contact may cause an electric arc. As a result, the temperature of the cable with poor contact is higher than expected and increases the risk of fire. There may be loosening in the connections due to temperature changes, so the necessary maintenance of PV systems must be carried out every year. First of all, the lines destroyed or affected by the fire should be closed and other circuits should not be touched. Cutting off electricity to all volumes is not recommended. Only the section with fire should be de-energized. Thus, lighting is provided in other sections, the operation of the water pumps continues, the elevators are not between two floors, and the work of the fire brigade units in the smoke-filled rooms becomes easier. Overhanging cables is dangerous and they must never be touched. All iron parts in the fire zone may be under tension. Therefore, not only electrical cables and devices, but also gas and water pipes, roof gutters and iron fences should be avoided.

Electrical shock caused by the removal of a fuse under load poses a serious risk and may cause the equipment to be destroyed. The DC circuits must be de-energized before any intervention is made. During the fire, changes in electrical installations must be carried out by qualified persons. Only in emergencies, that is, if human life is involved or if it makes the extinguishing process difficult, cables under low voltage can be cut or shorted. Only persons who have participated in the extinguishing process in high-voltage facilities should enter the scene under the supervision of authorized specialist personnel.

The perimeter of lines that have fallen on the ground is dangerous. Therefore, the lines that have fallen to the ground should not be approached more than 10 m until the electricity administration authorities release this area. The installations must be checked by a specialist before the electrical installation can be re-electrified.

Fires in the electrical installation can also be extinguished with water by leaving sufficient safety distance. The extinguishing agent to be used must be selected according to the place in which it will be used. In places such as information processing and automation rooms and electricity distribution centers, gas extinguishers that will not damage the circuits with dust or excessive cooling can be used. Carbon dioxide extinguishers can be used in electrical rooms. In general, the plan should be to prevent the passage of the fire to other parts instead of saving the place where the fire has occurred and the place where the fire has occurred should be sacrificed. It should be kept in mind that large areas can be damaged while trying not to damage a small part.

If chemical dry powder or carbon dioxide is to be used, it should be responded with at a distance of at least 0.5 m from low voltages. In normal extinguishing processes, the fire is not approached any further. It is possible to say that carbon dioxide and dry powder devices can be used, especially at 220 V voltages. For high-voltage lines ABC powders can only be used by leaving the distances that are applicable when spraying water on domestic installation lines that are out of voltage. If carbon dioxide is used on high-voltage installations, the distances given below from which water is to be sprayed should be taken as a basis.

When extinguishing with water, the distance between the extinguisher and the electrical part is very important. In low voltage installations, it does not pose a risk if the installations are responded to from a distance of 0.5 m with the spraying nozzle, 1 m with the 12 mm direct nozzle with the steel pipe, and 3 m in the open installations. Response should be from a distance of 2 m to 30,000 V voltage, 3 m on 110,000 V voltage, 4 m to 220,000 V voltage and 5 m to 380,000 V voltage with squirting lance in high voltage lines. Water should be sprayed at a distance of 5 m at 30,000 V voltage, 6 m at 110,000 V voltage, 7 m at 220,000 V voltage and 8 m at 380,000 V voltage with direct nozzle with steel pipe with a diameter of 12 mm. In low-voltage and high-voltage lines; if a nozzle with a steel pipe greater than 12 mm is to be used, the distance to stay from the voltage lines should be increased by 0.25 m for each mm above 12 mm in diameter. If the B nozzle with a diameter of 22 mm is to be used, the distance to be left must be additionally 2.5 m longer.

Antifreeze, foam, or liquids that can conduct electric current can only be sprayed on lines that are not under voltage. If foam is to be used, the distances applicable to water can be taken. However, if air foam that forms a conductive ground is used this should be in installations that are not under voltage.

Fire brigade units should be informed about the energy and electricity sources in the building. In buildings with GES, building electrical plans should be kept hanging in places that are easy to see. DC lines have to be laid in a fire-protective manner. Compliance with high quality standards is critical to all system elements.

Metal ladders used to reach the point of response in particular, pose a great danger at a fire and accident site. Especially extension, turning and displacement in the ladder support can cause serious accidents. The ladders must be able to stand at least 1 m from the contact points, and portable ladders must not be used in unstable places. Caution should be exercised against the possibility that the end of the ladder can easily come close to air lines under tension due to the loads on freestanding ladders or the wind shaking it. Wet clothing and transmission power tools should not come into contact with unclosed voltage lines.

There may be danger of death in the event of contact with installations under voltage. In order to prevent the person assisting the victim from being shocked, the electrical current should be cut off first. If the power does not go off or there is no experienced person who can turn it off, the casualty should be moved away from the cable and machine with support from a well-insulated object (dry wood, dry clothes, rubber ground). Open body parts should not be touched with bare hands, dry blankets and clothes or gloves should be used. In high-voltage lines, it is dangerous for anyone other than the experts of the electricity administration to approach the victim. After the victim is removed from the power line, the resuscitation process should be performed immediately, and extra attention should be given to removing the clothing parts from the person. Water, carbon dioxide or extinguishing blankets can be used to extinguish burning clothes. It may even be useful to wrap the victim with a blanket or jacket in emergencies. Powder extinguishers can also be used, but halogenated extinguishers should not be used as they may cause inflammation.

Innovative solutions can be more effective than traditional solutions in many situations today. Early warning and immediate intervention are very important in life issues such as fire. Since solar energy systems contain very technological, modern and sensitive technologies, they are fire sensitive systems.

The procedures to be followed in case of fire response should be explained in detail to the persons in the solar energy areas during the system installation and authorized teams should be established for first response. They must be trained on the extinguishing types to be used during the fire response and what the fire brigade teams that will stop the fire need to do in order to close the system and prevent the spreading of the fire. Detailed inspections have to be made of the systems by the competent authorities before installation and the connection stages to the grids have to be checked precisely.

3.2.3. Construction

Photovoltaic power plants that provide electricity production from solar energy should be mounted on grounds with robust static properties. In order for solar energy plants to have a long life, there are static calculations to be made regarding the ground on which the photovoltaic power plant is to be built. In terms of construction structure, photovoltaic power plants are divided into two categories depending on whether they are installed on the ground or a roof.

Regardless of the solar plant’s construction type, the calculation values of the loads to be used in the dimensioning of TS 498 building elements and the design and construction rules of TS 500 reinforced concrete structures must be complied with. In the installed photovoltaic solar power plants, it is possible to use both aluminum and steel products as construction materials. The roof material used in fuel stations is an aluminum material called sandwich panels. Such roofs can be called trapezoid roofs. These materials are lightweight and very strong materials. The connections of construction materials to be installed on sandwich panels are more advantageous than tile-type roofs. Since the connection points will be fixed on flat plates, the connection points will be more solid.

In flat roof installation, a vertical triangular sub-construction made of lighter material similar to the floor assembly is used to give the necessary slope to the solar panels. The static calculations of the building should be done by the building's own architect while the roof is being installed and systems should be created that are suitable for this static calculation and will not put force on the roof. The thickness of the profiles being used should be considered. No anchorage is done to prevent damage the concrete structure of the building, because the water leaking from the holes causes the concrete or steel construction to corrode. The feet are usually fixed by placing weights on them.

Tile roof mounting and the types of fixing hooks used on the trapezoidal roof are different. On the tile roof the wood under the tile is stabilized and a fixing hook is used accordingly. It is easier to mount on a trapezoid roof. The profiles are easily fixed to the trapezoid, making assembly easier. When we consider Aluminum Constructions, there are products called 6000 series, which are used in Photovoltaic Solar Power Plants in our country and all over the world, and it should be noted that the most used version of these aluminum material products is the 6063 series. In the static calculations of this product group, which we consider to be the most suitable for anodization as a chemical composition, it is necessary to pay attention to horizontal and vertical inertia moments. Not every aluminum construction or every steel construction can be used for a photovoltaic solar power plant.

The solid core has a direct impact on the other materials that are to be used. To achieve this, the core material to be used in the infrastructure must have a service life for at least 25 years. First of all, a calculation should be made to determine whether a “piling” or “mounting on concrete bases” application is more beneficial according to the land and climate conditions in the infrastructure. What should be noted here is that choosing aluminum carrier systems will ensure thermal compatibility with panel frames made of aluminum. This prevents both micro cracks that may occur as a result of thermal expansion and increases efficiency by dissipating the heat of the system. Another point to be noted is the carrier system design. Within the framework of the current regulations, the design should be made with consideration for the nature conditions of the region where the system will be installed. The operations performed during the installation are directly affecting the life of the infrastructure. It is absolutely necessary to use competent personnel. In addition, welding should not be used at any stage of the installation. Even the smallest part used must be carefully selected and assembled. On the other hand, another important issue is the bolts used in the joining of carrier materials. Corrosion or deformation that may occur in the bolts in the future will affect the efficiency of the plant.

3.2.4. Radiation Maps

Turkey has a high potential compared to many countries in terms of solar energy potential due to its geographical location. Approximately 170 million MW of energy comes to the solar world per second. The region that benefits the most from solar energy is the part of the equator between the 35° north and south latitudes. This region is called the "Earth Sun Belt". Considering that Turkey's annual energy production is 100 million MW, the solar energy that is born in a second is 1.700 times the energy production of Turkey. According to the study conducted by using the sunshine time and radiation intensity data measured in the years 1985-2018, available in the General Directorate of Meteorology, it has been determined that the average daily total sunshine time of Turkey is 6.8 hours and the average total radiation intensity is 1.311 kWh/m^2-year (3.6 kWh/m^2 daily). Turkey has a high solar energy potential of 110 days and if the necessary investments are made, Turkey can produce 1.100 kWh of solar energy on average per square meter per year (mgm.gov.tr).

Table 3.1. Average monthly sunshine duration in Turkey 1985-2018 (Source:https://www.mgm.gov.tr/kurumici/radyasyon_iller.aspx)

	Sunshine Duration (hours/day)
January	3.3
February	4.2
Marc	5.4
April	6.7
May	8.2
June	10
July	10.7
August	10.2
September	8.6
October	6.2
November	4.6
December	3.0

From the southern latitudes to the northern latitudes, the intensity of global solar radiation decreases. In other words, as expected, the change in radiation exhibits a parallel appearance to the latitude. While global solar radiation intensity has the highest values in the southern regions of Turkey, it has the lowest values in the northeast. It appears that the distribution, which varies in parallel with the latitudes, deteriorates slightly on our northeast regions. This is a natural result of the fact that the region has very high mountains and the general atmospheric circulation that affects Turkey.

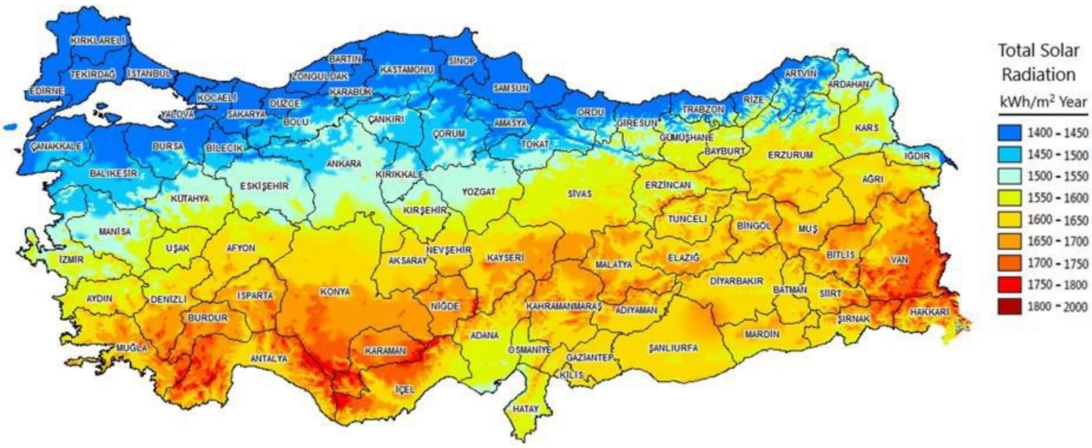

Figure 3.1. Turkey Solar Radiation Map (Source: TC Ç.Ş.İ.D.B. 2021)

Solar radiation values vary in many situations. The measured values are greatly affected by short- and long-term changes in time, sky condition, location, sunshine time changes depending on clouding status and the most efficient operating temperature.

3.2.5. Calculation Method

The design of a PV system will have many parameters and design criteria might be slightly different for each case. Many components that affect the system performance must be taken into account.

For fuel stations, shading of PV panels becomes very important if it is located close to a residential area. One of the biggest factors that create a negative effect in photovoltaic system performance is shading of PV panels. Since PV systems generate electricity depending on the amount of sunlight they receive, the power output decreases when a shadow falls on a panel. Intuitively, the power output of the panel will decrease proportionally to the shaded area, but this is not exactly the case. Studies have shown that only one of the 36 cells in a small solar module can reduce the power output by more than 75% (https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html).

The current passing through a cell line for a given radiation level is constant. When a solar panel is shaded, the current decreases throughout the entire array. In this case, each cell in the cell line has to work in the current set by the shaded cell. This prevents unshaded cells from operating at maximum power. Therefore, a small amount of shading can have a dramatic effect on the power output of a solar panel. Similar principles also apply to interconnected PV modules. If even a single module is shaded, the current output from the entire module array may be excessively reduced, potentially resulting in a significant loss of power output. There are a number of different approaches that can be applied in PV system design to reduce shading losses.

The modules connected in series form the arrays and the arrays can be connected in parallel to an inverter. The current across all modules of an array must be the same and the voltage of the parallel arrays must be the same. A shaded module in an array can significantly reduce the array's power output. However, a shaded module in an array does not reduce the power output of a parallel array. Therefore, by grouping shaded modules into separate arrays, the overall power output of the array can be maximized.

Shaded and non-shaded modules must be in separated parallel sequences (Figure 3.2.). Thus, the unshaded arrays can provide a higher current and power output.

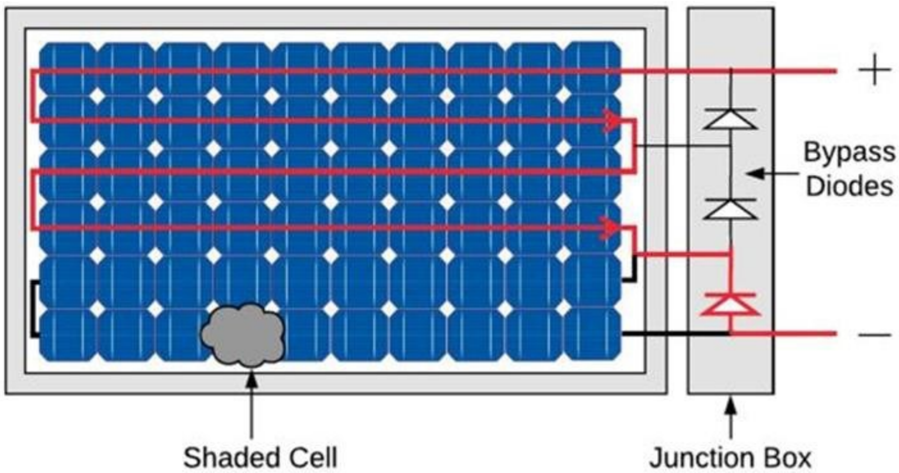

Figure 3.2. Bypass Diode in PV Module (Source: Fraas 2014)

Bypass diodes are a module that allows the module to “bypass” the shaded regions of the module. Using bypass diodes, the high current of unshaded cell lines can flow around the shaded cell line. However, this means losing the output of the bypass cells. While it is theoretically ideal to have a bypass diode for each solar cell, due to cost reasons a typical solar module achieves three bypass diodes by effectively grouping cells into three series of cells. There are also types with 4 and 6 bypass diodes according to different solar panel types.

Since the systems planned to be installed for fuel stations are on-grid systems, battery group products are not available in the system. The capacity of the system is determined based on the monthly average electricity bill. The main objective of the project is to provide PV electricity matching the amount used by the fuel stations. The data generated for the devices used in an average gas station and consuming electricity are shown in Table 3.2. The daily average electricity consumption amount obtained from the data in the table has been determined as 162.13 kWh. This value is 4,863.9 kWh monthly and 59,177.45 kWh annually.

Efficiency in PV systems is a very important factor in determining the size of the system and the components of the system.

The current-voltage (I-V) properties of the PV cell are important for the capacity of the system and the maximum points of the system. Under a constant light intensity, the current through the resistor is measured against the voltage between the ends of the PV cell by changing a variable resistor between open circuit and short circuit states. It is also possible to measure V_{oc} and I_{sc} values by operating the PV cell in the dark, like a diode with the help of an external DC supply source, or under illumination of a light source for which intensity can be changed.

The open circuit voltage (V_{oc}) of a PV cell is the voltage measured from the cell ends when the current flowing through the cell is zero. Open circuit voltage (V_{oc}) is the voltage seen at the cell ends when the current passing through the cell is zero. The short-circuit current (I_{sc}) of the PV cell is the current passing through the cell at zero voltage and under lighting. In the ideal case where parallel resistance effects are neglected, they are equal to the current generated by light and depend on the radiation intensity.

The Filling Factor (FF) is a variable used to define the maximum output power of a PV cell based on open circuit voltage and short circuit current. As the series resistance increases, the FF value decreases, and FF is determined with the formulas Eqs 3.1. and Eqs 3.2. The value of the filling factor is a measure of the ideality of the PV cell. In an ideal PV cell, it is desirable that the filling factor should be close to 1.

The Filling factor is approximately 80% for a normal silicon PV cell. It (FF) is another variable that determines the general behavior of a PV cell.

Table 3.2. Petrol Station Electrical Equipment List (Source: Basut Petrol 2020)

Device No	Device Name	Piece	Power(watt)	Peak Power (watt)	Average Power (KW)	Total Power (KW)	Hour per Day	Daily Consumpt. (KW h)
1	submerse pump	8	1,200	396	2.66	12.77	5.00	13.30
2	pressure pump	1	2,000	660	0.55	2.66	5.00	2.77
3	dispenser pump	3	1,200	396	0.60	4.79	3.00	1.80
4	dispenser pump	1	1,200	396	0.20	1.60	3.00	0.60
5	cleaner	1	2,000	660	0.22	2.66	2.00	0.44
6	tea center	1	2,000	660	2.44	2.66	22.00	53.64
7	compressor	1	1,500	495	0.50	2.00	6.00	2.99
8	tv	1	200	66	0.18	0.27	16.00	2.84
9	ice-cream freezer	1	1,000	330	0.78	1.33	14.00	10.86
10	water freezer	1	1,000	330	0.44	1.33	8.00	3.55
11	b. freezer	1	1,000	330	0.44	1.33	8.00	3.55
12	air conditioner	3	1,500	495	2.00	5.99	8.00	15.96
13	little freezer	1	100	33	0.07	0.13	12.00	0.80
14	computer	3	150	50	0.60	0.60	24.00	14.36
15	automation 1	1	100	33	0.13	0.13	24.00	3.19
16	automation 2	1	100	33	0.13	0.13	24.00	3.19
17	wash machine	1	400	132	0.04	0.53	2.00	0.09
18	booster	3	200	66	0.13	0.80	4.00	0.53
19	signs	3	250	83	1.00	1.00	24.00	23.94
20	mobile heater	1	1,200	396	0.40	1.60	6.00	2.39
21	oil machine	1	1,500	495	0.33	2.00	4.00	1.33

$$P_m = V_{mp} * I_{mp} \quad (3.1)$$

$$FF = P_m / (V_{oc} * I_{sc}) \quad (3.2)$$

Where:
V_{mp} = voltage at maximum power
I_{mp} = current at maximum power
P_m = maximum power of the system

FF= filling factor
V_{oc} = open circuit voltage
I_{sc} = short circuit current

The maximum power point can be determined by continuously increasing the resistance load in a constant irradiated PV cell from zero (short circuit) to a very high value (open circuit). At the maximum power point, the V × I value is high. At this point, the PV cell produces the highest electricity at its radiation level. The output power is zero in both the short-circuit and open-circuit limit values. The maximum output power that the PV cell can produce is equal to the area of the rectangle with the maximum area that can be drawn within the I-V curve of the cell. A high-quality single crystal silicon PV cell can produce 0.60 V open circuit voltage (V_{oc}) at a cell temperature of 25°C. If the sunshine conditions are good and the air temperature is 25 °C, the cell temperature will most likely be close to 45 °C and the open circuit voltage will decrease to 0.55 V per cell. With this type of PV cell, the voltage value decreases at an acceptable level until it approaches the short-circuit current (I_{sc}). If the cell temperature is 45 °C, the maximum power value is typically generated by 75-80% of the open circuit voltage (in this case 0.43 V) and 90% of the short circuit current. This value can reach up to 70% of the product of $V_{oc} \times I_{sc}$. Although the short-circuit current (I_{sc}) from a PV cell is approximately proportional to the illumination, the open-circuit voltage (V_{oc}) may decrease by only 10% when the illumination decreases by 80%. In low-quality PV cells, the voltage value decreases faster with increasing current. The power of PV cells should be given not only as the product of $V_{oc} \times I_{sc}$, but also with load curves.

The maximum power point of a PV cell changes depending on the incoming radiation. For example, the accumulation of dust on PV modules reduces the maximum power value.

Maximum power value, panel area and sunshine times are used when calculating efficiency in PV solar energy systems; Eqs 3.3 and Eqs. 3.4.

$$\eta_{PV} = \frac{P_m}{\text{Solar Panel Area} * \text{Sunshine Time}} \qquad (3.3)$$

$$\eta_{sys} = \eta_{PV} * \eta_{inv} * \eta_{cable} \qquad (3.4)$$

where;

η_{PV} = efficiency of photo-voltaic module/s

P_m = maximum power of module/s

Sunshine Time = daytime with effective radiation level
Solar Panel Area = total non-shaded module/s surface area

η_{sys} = efficiency of total photo-voltaic system

η_{inv} = efficiency of inverter/s

η_{sys} = efficiency of total photo-voltaic system

Elin Plus ELNSM6612M-293Wp PV panel has been selected as an example for the modeled system. The specifications of the panel are given below.

Table 3.3. Features of PV Panel ELNSM6612M-293Wp (Source: solaravm.com/400-watt-gunes-paneli-144-hucreli-elin-sirius-monokristal)

P_{mp}	395.00 Wp
V_{mp}	40.28 V
I_{mp}	9.81 A
V_{oc}	49.12 V
I_{sc}	10.14 A
Module Efficiency	19.92%
External Dimensions	1979*1002*40 mm

Table 3.4. 395W Panel Annual Production Calculated with Formula by Regions

Region	**Sunshine Duration (hours/year)**	η_{sys}	**395 W Panel Production (kWh/year)**
South Anatolia	2,993	2,956	608.4
Mediterranean	2,956	75.2%	596.4
East Anatolia	2,664	74.9%	557.0
Central Anatolia	2,628	74.8%	552.3
Aegean	2,738	75.0%	566.2
Marmara	2,409	74.3%	494.3
Black Sea	1,971	73.6%	454.9

The electricity that the solar panel can generate is directly related to the sunshine times. The solar radiation per square meter directly affects the production of the panels. The system efficiencies calculated with the "PVGIS Estimation" (PVGIS-

Interactive Maps, 2020) program and the annual energy production according to the regions are shown in Table 3.5 according to the reference solar panel values.

Table 3.5. System Capacity Needed for Example Station

Region	**Consumption/Production (kwh per panel)**	**# of Panels Needed**	**System Capacity (kwP)**
South Anatolia	973	98	38.7
Mediterranean	992	100	39.5
East Anatolia	1,062	107	42.3
Central Anatolia	1,071	108	42.7
Aegean	1,045	105	41.5
Marmara	1,197	120	47.4
Black Sea	1,301	131	51.7

3.2.6. Material Selection

The photovoltaic effect was observed firs time in 1839 by French physicist Alexander Edmond Becquerel while working on Becquerel platinum layers. In 1873, Willoughby Smith discovered photoconductivity in selenium and this went down in history as the first photovoltaic apparatus. 1877 Scientists W.G. Adams and R.E. Day found in their scientific studies that solids can also have a photovoltaic effect. In 1883, the scientist Charles Fritts developed a 1% efficient photovoltaic cell (Erturk 2018). In 1946, for the first time, Russell Ohl patented the modern PV solar panel. In 1954, -6% efficient silicon PV cells were made in Bell Laboratories (Fiducia 2019).

The solar panel converts the solar rays falling on it directly into electrical energy. Direct current begins to form in the solar cells on the panels due to solar rays. For conventional first-generation solar cells, the starting raw material is silicon. Boron and phosphor are used to generate p (positively charged) type and n type (negatively charged) regions, and eventually a photodiode.

The most commonly used solar panels are monocrystalline and polycrystalline silicon and thin film (amorphous Si or CIGS) panels. As the names suggest, Monocrystalline and polycrystalline are both solar cell types made of crystalline silicon. In individual or commercial solar power plant installations, almost all panels are crystal solar panels. The crystalline silicon solar panels are known in industry simply as "Mono" or "Poly" panels. Both monocrystalline and polycrystalline solar cells are very similar in terms of performance. The a-Si thin film is a completely different technology. It is much less efficient and therefore uses much more roof space, but relatively cheaper. CIGS thin film cells provide comparable efficiencies to polycrystalline silicon.

Monocrystalline cells are formed from a single continuous crystal structure. They are made by the Czochralski method, in which a silicon crystal 'seed' is placed in a molten silicon container. The seed is then slowly withdrawn with molten silicon forming a solid crystal structure around the seed known as the ingot. The solid crystal silicon ingot that is formed is then thinly sliced into wafers. The Czochralski process results in a large cylindrical ingot. Four edges are cut to make silicon wafers. A significant part of the original silicon ends as waste.

Polycrystalline or multicrystalline is a newer technology and varies in the production process. The polycrystalline also starts as a silicon crystal 'seed' placed in a molten silicon container. However, instead of pulling the silicon crystal seed as with monocrystalline, the silicon container is simply allowed to cool. This creates unique edges and grains in the solar cell. Polycrystalline cells are less efficient compared to monocrystalline silicon, but they are cheaper and have become the dominant technology in the residential solar panels market. With evolving technologies, polycrystalline is now very close to monocrystalline cells in terms of efficiency.

The thin film cells are made by depositing photovoltaic material on a flexible solid surface. The most common thin film PV materials are amorphous silicon, cadmium telluride (CdTe), and copper indium gallium selenide (CGIS). Depending on the technology, the thin film module prototypes have achieved efficiency between 7-13% and the production modules operate at approximately 9%. With the studies conducted in the laboratory environment, yield values have reached up to 22% (Fiducia 2019).

Due to their market size, monocrystalline solar panels was preferred in this thesis. Since monocrystalline solar panels are made of the highest-grade silicon, they have the highest efficiency rates. New panels convert more than 22% of sunlight into electricity.

Monocrystalline silicon solar panels also save space. Since these solar panels give the highest power outputs, they require the least amount of space compared to all other types.

Monocrystalline panels have a long life; most solar panel manufacturers provide a 25-year warranty for their products. Both types of crystalline solar panels are likely to last longer than the 25-year warranty lives, as silicon being a very inert and stable material.

Monocrystalline solar panels tend to be more efficient in warm weather. Temperature has a direct effect on current transmission in semiconductors. While low temperatures do not adversely affect efficiency, high temperatures significantly reduce efficiency. However, this distortion of the output is less severe in monocrystalline panels than in polycrystalline solar panels (Ercan 2019). In practice, the difference is very small. The level at which each solar panel production decreases as the temperature increases is called co-temperature and is published according to the characteristics of each panel.

Another important component of PV systems is inverters. Inverters are power electronics circuits that provide alternating current to the load from direct current input. Inverters are responsible for providing AC current at the desired amplitude and frequencies. DC current sources such as PV panels, battery packs, fuel cells, or the outputs of rectifiers fed from an alternative source can be used as the inverter input. Inverters used in solar energy systems are either on grid and disconnected. Grid-connected inverters supply the energy to the interconnected system according to the voltage level and frequency of the grid. On the other hand, disconnected inverters perform power conversion between battery groups and consumers (Kröger 2010). Grid-connected inverters can be classified as arrays and centers according to their application areas. Many parameters have to be evaluated in the selection of inverters. The parameters commonly used in the selection of the inverter are the power of the photovoltaic system to be installed, the condition of the installation surface and the region in which the photovoltaic system is installed. The power of the photovoltaic system being installed, the consumers or the companies that will commercialize it, the permissions granted, and the state of the installation area will determine the dimensions of the system. Considering that the area dimensions that can be installed in fuel stations is 300 m^2 on average, the system capacity to be installed would be approximately 50 kW. On the other hand, factory roofs have an installation area up to MW level. In this context, the use of array inverters in small systems, the use of array and central inverters in MW-sized commercial and power plant applications and the use of central inverters in large power plant applications are suitable.

Inverters differ not only in their connection to the grid but also according to the waveforms they use. For the loads that show resistance, such as a simple induction load, a motor, or a bulb, square wave (Modified sinus) inverters perform better than sinus inverters. Most modified inverters have a system or algorithm called "Maximum Power Point Tracker". This algorithm, which was developed to achieve maximum efficiency, automatically adjust the output based on input and load in the system. As the name suggests, it allows the power obtained in certain periods to be sent to the load by following the peak value (Roberto 2009).

Although MPPTs have some technical differences according to their usage areas, their operation is generally the same. If we consider solar MPPTs, the angle of sun rays falling to the surface during the day is constantly changing. Accordingly, the amount of beam absorbed by the solar panel (photovoltaic cells) will change, the energy obtained will always be different in the interval. However, in order for the system to function correctly, increasing or decreasing irregular power cannot be applied directly to the load.

These power needs to be regulated. MPPT starts a series of operations by detecting the moments when the different power values obtained at different time intervals using the complex algorithms running on a microcontroller. First, the DC voltage taken from the photovoltaic cells is converted to AC. After that, different voltage and current values are converted back to DC according to the current system power requirement. The main purpose here is to ensure that the maximum power is transmitted from the photovoltaic cell to the load (system). The inclusion of MPPT in PV solar energy conversion systems increases the output power of the system and thus, the solar panels are used at the highest efficiency and less panel usage is provided and the solar panel investment costs are reduced.

It should be known that the slightest shadow factor falling on the panels will affect the overall performance of the system and cause large energy losses in the 25-year working period. It is necessary to pay attention to the factors that create shadows, especially in roof applications. Satellite dishes, lightning rods and similar items that will create shade on the PV panel should be avoided. If working on a surface with a high number of shade-generating factors, smaller, powerful and/or inverters with a high number of MPPTs should be selected. The installation of photovoltaic panels facing south in the northern hemisphere provides higher energy production. Using different inverter or different MPPT circuits of the same inverter will minimize the energy losses that may occur if there is an obligation to install at different orientation and at different angles on the installation surface.

Since the weather conditions vary daily, monthly and seasonally, it is necessary to design the system to be installed for high performance throughout the year. The part that concerns the photovoltaic system in changing weather conditions is solar radiation and temperature changes. Due to the annual temperature differences of Istanbul and the fact that Konya is not the same, the number of series connected panels to be used in the systems for these two locations will vary. The voltage of the panels decreases with the increase of the outdoor temperature and the panel voltages increase with the cooling of the outdoor environment. In this case, it should be noted that the inverter to be selected is in the MPPT voltage range. Especially inverters with a narrow MPPT voltage range should be carefully designed in areas with high seasonal temperature differences.

3.2.7. Maintenance and Repair

In order to maintain maximum efficiency in photovoltaic panels and to avoid major financial losses caused by lack of maintenance and environmental conditions, periodic maintenance of solar panels must not be neglected. Several points that pose potential risks for PV systems must be addressed during regular maintenance and repair stages.

Insulation errors are the most common problems in PV systems. Insulation errors are usually caused by incorrect and loose connections made during the EPC period; the cables were laid tight, that the corners of cable trays damage the cables, and that rodents damage the cables by gnawing them etc. Insulation errors cause short-circuits and failure or deactivation of devices such as inverters. After the fault has been eliminated, performing an insulation test according to the IEC 62446-2016 standard is required. Cable insulation is required to be above 2 Ohm at least and cable insulation values must be consistent with each other. When performing maintenance on the damaged cables; if the cables are underground, it is necessary to lay new cables, and if the cables are above ground, cables must be repaired. Rodents can damage DC cables by gnawing at them, as they hide in underground ducts and make their nests close to warm cable ducts in winter. In such cases, as part of the maintenance and repair works, spraying should be done in the SPP area and rodents should be made to leave the SPP area.

Inverters are one of the most important components of solar systems. Maintenance and repair work of inverters that convert direct current to alternating current must be carried out according to the procedures specified in the equipment manufacturers' maintenance manuals. The mounting connections or ventilation systems of the inverters differ according to their brands. In case the string inverters are connected incorrectly or not at the appropriate torque value, terminal burns occur in the connections over time. In central inverters, especially the cleaning of the air filters and the maintenance of the fans must be done every year. Ventilation, cleaning and maintenance of the inverter cubicle are very important in central inverters. Overheating problems occurred in the switches used in solar power plants can only be eliminated by performing necessary maintenance works in a proper way. Performing thermal tests and visual inspections of all connections at least once a year at the SPP site will prevent possible fire risks and production losses.

The most common problems occurred in solar panels are hotspot in cells, diode failures in junction boxes and cable failures in junction boxes. It is observed that the panel efficiency falls below the nominal efficiency rates due to these reasons, especially in the summer months. Incompatibility (mismatch) observed in the connectors can cause the connectors to malfunction. Due to incompatibility problems, the connectors burn and pose a fire risk for the PV system site. Problems related to periodic (preventive) maintenance can be detected and fixed. It is compulsory that thermal imaging carried out within the scope of periodic maintenance be performed by competent personnel and under the conditions specified in IEC 62446-2016 standards. Otherwise, erroneous analysis can be made, and wrong conclusions can be reached.

Failures occurred in medium voltage systems that connect SPPs to the electricity grid cause significant production losses in SPPs. The fact that the repair / supply periods especially for transformers and breakers can be up to a month, shows how big the risk is. In order to prevent malfunctions in transformers and breakers, it is compulsory that periodic maintenance be carried out by expert personnel. Testing transformer protections during maintenance works is of great importance. Phase failure can easily occur in transformers without protection that might be caused by the power variations in the grid. In case phase burns occur in the transformers, it must be sent to and repaired at the factory. It is recommended that oil-gas analysis be carried out and conversion ratio and winding resistances be measured in oil-immersed transformers. Measuring contact transition resistances in breakers is also of great importance in detecting possible arc formations.

Relays are equipment in energy systems that protect the system from abnormal conditions. The deterioration of the quality of the energy supplied from the grid or of the energy in the system above certain tolerances can damage the systems. Relay coordination must be performed in the field in order to prevent this situation. Otherwise, the power variations received from or given to the grid may cause unexpected malfunctions and explosions. Whether the hierarchical breaker protections are working according to the relay coordination in the impacts received from the grid can be understood by checking whether the relay settings are made correctly.

The main reason for all these malfunctions is the fact that the professional preventive maintenance works are not carried out or that the maintenance performed by non-specialized personnel without complying with the standards. SPP investments are long-term investments that generate income for investors for a minimum of 25 years. In this long process, maintenance and repair services not only prevent financial losses that may occur in investments, but also provide more production returns than expected, make investments more feasible and reduce return time on investments. For this reason, investors should consider maintenance and repair activities not as an additional cost, but as an investment tool that should be addressed and that can provide additional income as well as preventing financial loss. Otherwise, it will be inevitable to experience malfunctions that will cause much more costs than the amounts in the budgets allocated for maintenance and repair works.

3.2.8. Occupational Health and Safety

Although the risk assessments made by the risk assessment team determined in accordance with the risk assessment regulation at the fuel and LPG service stations, which are defined as extremely dangerous workplaces in accordance with the risk assessment regulation, are valid for 2 years, the risk assessment is completely or partially renewed considering the possibility that new risks that may arise in different situations affect the whole or a part of the workplace.

Situations where new risks may arise can be listed as follows: Relocation of the workplace or changes in the buildings; changes in the technology applied in the workplace, in the materials and equipment used; changes in the production method; occurrence of work accident, occupational disease or near-miss event; a change in legislation regarding the threshold values of the working environment; that risk assessment is deemed necessary as the results of the work environment measurement and health surveillance; the emergence of a new danger originating from outside the workplace and affecting the workplace.

Since fuel and LPG service stations are classified as extremely dangerous workplaces, emergency plans are valid for 2 years. It is required that employees selected as members of emergency teams to be sent to appropriate training. Emergency drills should be conducted once a year. It must be ensured that employees get a training program on occupational health and safety that consists of at least 16 hours per year. The topics of the training to be provided for employees can be listed under four main headings (Occupational Health and Safety Regulation in Construction Works, 2014). General topics include basic training. Information on labor legislation, legal rights and responsibilities of employees, workplace cleanliness and order, legal consequences of work accident and occupational disease should be provided for employees at the start of employment period.

Information on health measures to be taken are of great importance among the basic training topics that should be provided for the employees working in places with high risk factors such as fuel stations. The topics in basic health training are as follows: Causes of occupational diseases, principles of prevention of disease and implementation of prevention techniques, biological and psychosocial risk factors, first aid, harms of tobacco products and passive exposure.

Training to be given to employees on technical issues should include the following topics: Chemical, physical and ergonomic risk factors; manual lifting and transport; flaming, explosion, fire and fire protection; safe use of work equipment; working with vehicles which have monitor; electricity hazards, risks and precautions; the causes of work accidents and the application of protection principles and techniques; safety and health signs; use of personal protective equipment; occupational health and safety general rules and safety culture; evacuation and rescue.

While evaluating the characteristics of working environment, environmental measurements, noise, dust, lighting, pressure vessels, electrical internal installation, grounding, underground tanks, lightning rod etc. should be done on time in accordance with the provisions of the regulation to which they are subjected.

The rules related to Occupational health and safety (OHS) are specified in the relevant regulations published under the authority granted by Article 30 of Occupational Health and Safety Law dated 6/20/2012. Provisions related to working at heights in the OHS legislation are generally specified in following two regulations: Regulation on Occupational Health and Safety in Construction Works, Regulation on Health and Safety Conditions in the Use of Work Equipment.

Regulation on Occupational Health and Safety in Construction Works, published in the Official Gazette dated 10/05/2013 and numbered 28786, is the regulation containing the most comprehensive provisions regarding working at heights. This Regulation includes the definition of working at height, the rules to be followed in the work at height, the details of the technical measures to be taken with references to the relevant standards, and the provisions related to scaffolding systems.

In the Regulation on Health and Safety Conditions in the Use of Work Equipment published in the Official Gazette dated 04/25/2013 and numbered 28628, general issues regarding the use of work equipment in temporary works performed at height, special provisions regarding the use of hand ladders, special provisions regarding the use of scaffolds, and special provisions regarding the work performed using ropes are regulated.

One of the most important requirements in the prevention of occupational accidents is that the works are done by competent and adequately trained people. Employees who do their jobs properly and in accordance with the relevant procedures and methods will reduce work accidents to a great extent. For this reason, it is of great importance for employees to receive vocational training related to the work they are expected to do at the time their employment start and throughout their working life, and to receive training related to occupational health and safety principles (OHS) and to their specific working environments, in order to carry out their work in a healthy and safe manner.

Article 17 of the Law No. 6331 requires that employees receive training; the Regulation on the Procedures and Principles of Occupational Health and Safety Training Provided for Employees published in the Official Gazette dated 05/15/2013 and numbered 28648, and the Regulation on the Vocational Training of Persons to be Employed in Works Classified as Dangerous and Extremely Dangerous published in the Official Gazette dated 07/13/2013 and numbered 28706 contain detailed principles on this regard. In addition, the "Communiqué on the Occupations Requiring Vocational Qualification Certificate Issued by the Vocational Qualification Institution" has made the Vocational Qualification Certificate compulsory for various fields of occupations.

Although the hazards and risks that may be encountered during working at height are largely clear, the characteristics of the work equipment used during work, issues related to installation and personal protective equipment etc. may cause some hazards and risks to be overlooked. For this reason, it should be ensured that the training to be given to the employees covers all processes from the installation of the equipment and access to the work area to the completion of the work. In determining the topics, issues such as the nature of the work to be done, the environment in which the work will be carried out and the physical condition of the structure, the activities simultaneously carried out in the same environment, the work equipment planned to be used for working at height, the personal qualifications of employees, their knowledge and experience levels, and possible emergencies are at the forefront.

Falls can be basically divided into two classes as falls on the same level, and falls from heights due to the height difference. Considering the impact effect caused by the height difference, falls from heights has more serious consequences and is frequently occurred in works and workplaces where work at height is done. The fact that the fallen person fell approximately 5 m after one second and approximately 20 m after two seconds reveals the increase in speed and therefore the high impact that will occur during the impact. For this reason, especially fall-from-height type work accidents are accidents with a high probability of serious consequences or death. Taking necessary safety measures is a very important factor in preventing employees from falling frequently. There are also health-related factors that need to be considered, some of which can be corrected. The factors that cause the fall most frequently are weakness of the lower body, problems related to gait and balance, use of psychoactive drugs, postural dizziness, poor vision, problems with feet and/or shoes, advanced age, fatigue, muscle weakness, previous falls, chronic diseases such as diabetes, arthritis etc., and fear of falling/heights.

Regarding the work at heights, there is a provision in the Regulation on the Health and Safety in Construction Works as follows; "It shall be ensured that the work to be done is planned and organized in advance and that the issues related to falling from height are included in the emergency plan (EPDK 2019).

Personal fall arrest systems (PFAS) are fall arrest systems that stop free fall and limit the effects of the fall on the worker. Personal fall arrest systems prevent the employee from uncontrolled falling from heights and reduce the effects of falling. PFASs shown in Figure 3.3 generally consist of 3 basic components: anchors, body harness and connectors.

Figure 3.3. Basic Components of a Personal Fall Arrest System

Personal fall arrest systems are used for work that employees carry out their work on unprotected edges or on unstable platforms (suspended scaffolding, etc.). In order to minimize the impact of the fall on the employee and the oscillation at the stop, the system should be constructed in such a way that the height of the fall is kept to a minimum. All components of the system must be visually inspected before each use and worn-out parts must be replaced. Attachment of connectors to guardrails and scaffolding components should be avoided as much as possible and more suitable anchorage points should be preferred. Considering the possibility of any emergency, the employee using the PFAS should be checked /accompanied by another employee. PFADs are systems designed to stop a fall only once. In case of any fall, all components of PFAD must be examined in detail by a competent person. Unless a report is prepared and signed as a result of the examination, indicating that it is not damaged and can be reused, the PFAD in question must be removed from use.

It refers to the distance between the employee and the ground before the fall, which is necessary for an employee using PFAS to stop without hitting any object or the ground in case of a fall (Figure 3.4). Distances recommended in the relevant standards as:

Maximum Fall Distance= 2m+1m (Safety distance)

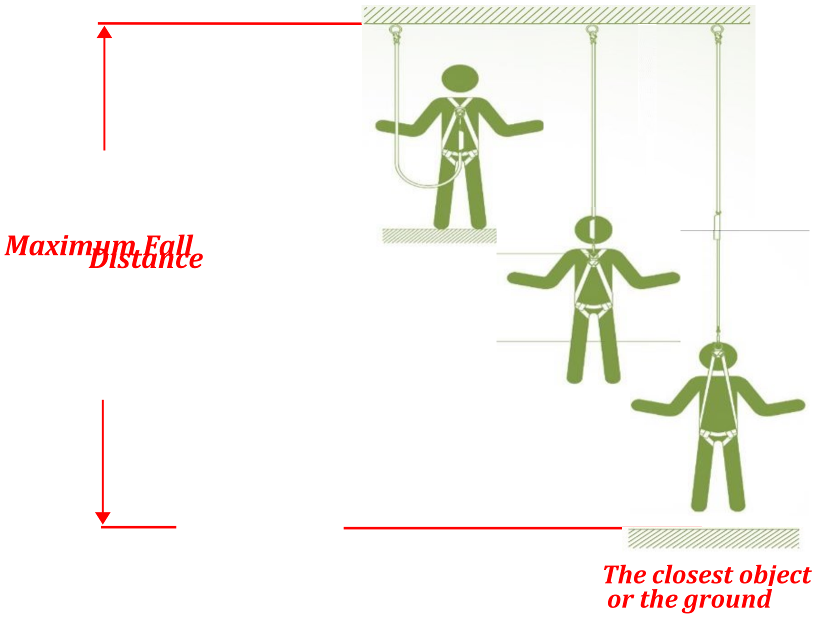

Figure 3.4. Full Body Harness, Connection Components and Energy Absorber

Employees who are required to use PFAD must be given necessary information and necessary training about the correct use and fastening of full body harness, inspection, maintenance and storage of equipment, correct anchor selection and application, and emergency procedures. After the training, whether the employees use the equipment safely or not should be checked by performing hands-on training, and these works should be carried out through competent personnel.

The most serious danger in the use of PFAS is the danger of swinging as illustrated in Figure 3.5. This is also called the pendulum effect. There may be a risk of swinging in two ways as a result of determining the wrong anchor point or not taking additional precautions. First is hitting an obstacle on the swing path or a structure to which the system has been anchored, as a result of falling from an unprotected edge; and the other is hitting the ground as a result of the rope breaking caused the rope rubbing against the building edge, or due to the long rope. The areas where PFAS will be used should be evaluated well, and when there is a risk of swinging, the use of PFAS should be reviewed or additional measures should be taken.

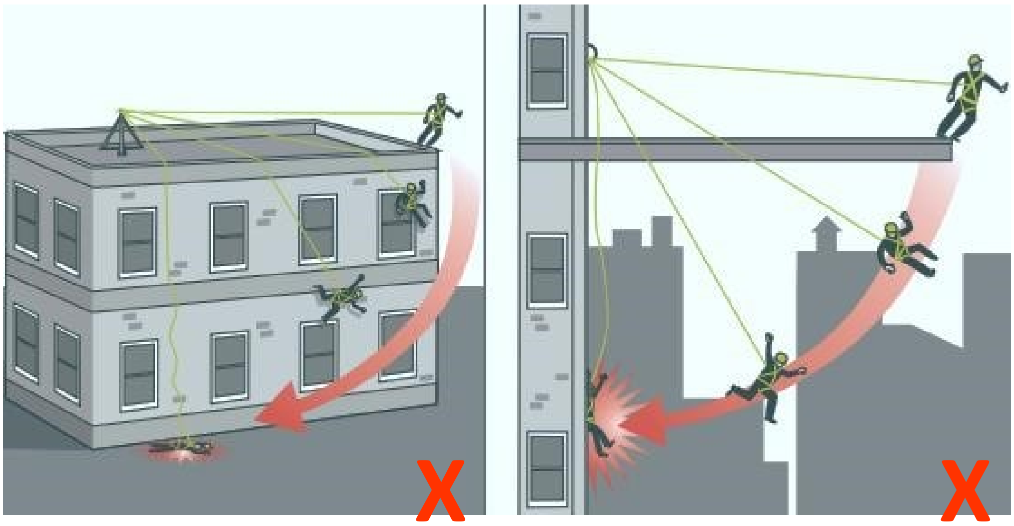

Figure 3.5. Swinging Risk

Working at heights equipment is the equipment that can be moved horizontally and/or vertically or are fixed and that is used to enable the necessary access and thus to perform the jobs that require working at height. Access equipment used during work at heights and the standards they must comply with are classified as follows; Scaffolds (TS EN 12810, TS EN 12811), Ladders (TS EN 131-1), Mobile elevating work platforms (TS EN 280:2013+A1), Mast climbing work platforms (Facade platforms) (TS EN 1495+A2), Mobile access and working towers (TS EN 1004, TS EN 1298). Considering the work to be performed, the most suitable equipment must be selected. It should be ensured that operators and users have received training. Manufacturer's instructions must be followed in each use.

3.3. Bureaucratic Problems and Suggestions

For photovoltaic systems that are planned to be implemented for fuel stations, there are certain procedures that the user is required to follow. For the designed on-grid unlicensed solar energy systems below 5MW (GES Solar Energy Systems Magazine September 2020), there is a detailed procedure that must be implemented with the regional distribution company. For players outside the solar energy industry, effectively following such a process causes serious inefficiency in terms of both cost and time. The difficulty of bureaucratic processes has also been a serious factor in fuel distribution companies taking a step back in their initiatives.

On the other hand, since almost all existing solar energy companies focus on large projects in on-grid systems, they do not have the enough human resources capacity and process management models to follow dozens of procedures at the same time. Electricity production processes are subjected to many procedures in our country. The procedures with which both electricity distribution companies and local grids require the investors to comply with have deterrent effect on investors.

Bureaucratic challenges are one of the major obstacles that slow down renewable green energy investments. These difficulties make the investor tired and prevent them from investing. Among those who are willing to invest in this field, there are many investors who took a step back and decided not to make investment because of these obstacles and difficulties. Therefore, minimizing these procedures will certainly benefit our country, as it will reduce dependence on imported energy. Because of the fact that the project approval and acceptance processes take too long due to the bureaucratic reasons, SPP installations in Turkey are progressing slowly compared to other countries. If the reason why we are in the last places in the electricity produced from solar energy although our country is at the second place in the world in terms of production of hot water with the sun and it is exposed to very good sun rays is questioned, it will be found out that main reasons are bureaucratic problems.

In order to develop in the field of energy, the obstacles to renewable energy should be eliminated, and procedures and bureaucracy should be reduced in this context. For example, the rule requiring the approval of roof static project by the municipality and amendment of construction permit and zoning permit should be removed for SPPs or it should be simplified specifically for SPPs. Because the implementation of the standard zoning and construction permit procedure require a lot of unnecessary losses. As in Europe, most of the powers and responsibilities should be transferred to the signatory engineer, the founding company and the investor. The capacity allocated to transformers by TEİAŞ should be increased. The fact that new capacity is not allocated claiming that the transmission lines are inadequate and that the sun is an uncontrolled power is among the biggest technical shortcomings in Turkey at the moment. Especially in places where consumption is high, SPP will not load the grid, on the contrary, it will reduce the load and energy losses of the grid.

The cancellation of the investment incentive certificate for panels has caused an unbelievable cost in this sector (the average is 300-400 USD / kWp in the world, while it is around 500-600 USD / kWp in Turkey) (EPDK, Elektrik Piyasasında Lisanssız

Elektrik Üretim Yönetmeliği, 2019) and therefore has dealt a major blow on the future investments in the sector. It would be better to give support to the domestic manufacturer, such as the support given by the Chinese state, rather than preventing them from using imported panels. Because the process has started to resemble the process experienced in automobile industry. In such cases, domestic manufacturers are unable to develop technology and cannot compete with the world. The foreign currency to be spent for imported panels will be amortized in a short time, and even less foreign currency will be paid to foreign countries in the short run, as the most important reason for Turkey's current account deficit, energy imports, will decrease as a result of energy production with domestic sources such as solar and wind. For small, house type SPP facilities installed on the roof, the process should be simplified like home electricity subscription as in developed countries. Germany and Australia, where millions of small facilities are installed on roofs are examples of this. Unfortunately, there are only a few of this kind of facilities in Turkey. Because the same procedures and bureaucracy applied to large facilities are also applied to these facilities. In this type of facilities, SPP does not create load on the grid, on the contrary, reduces the load and energy losses of the grid. In this context, approximately 15000 fuel stations within the target scale within the scope of the project have the potential to contribute significantly to the development of our country in this field.

Photovoltaic systems to be implemented at fuel stations will be subject to the laws and regulations applicable to on-grid, unlicensed solar energy systems below 5MW. The list of the legislation is as follows:

- Electricity Market Law No. 6446
- Law No. 5346 on the Utilization of Renewable Energy Sources for the Purposes of Generating Electrical Energy
- List of Information and Documents to be Submitted in Unlicensed Production Applications and Requests (Official Gazette dated 21 May 2019)
- Distribution System Connection Agreement / Distribution System Usage Agreement Statement for Licensee-Free Electricity Producers (Official Gazette dated 26 June 2012)
- Distribution System Connection Agreement for Unlicensed Electricity Producers

- Distribution System Usage Agreement for Unlicensed Electricity Producers
- Occupational Health and Safety Law No. 6331
- Turkish Commercial Code No. 6102
- Turkish Code of Obligations No. 6098
- Regulation on the Protection of Employees from the Dangers of Explosive Environments published in the Official Gazette dated 30 April 2013 and numbered 28633
- Petroleum Market Law No. 5015
- Petroleum Market License Regulation published in the Official Gazette dated 17 June 2004 and numbered 25495
- Regulation on Technical Criteria published in the Official Gazette dated 10 September 2004 and numbered 25579

CHAPTER 4

PROJECT FINANCIALS

Fuel stations are businesses that generate high returns for investors in the long term. However, the electrical appliances used at the stations affect the individual profitability of stations. SPP investments require higher investment costs than residential projects in enterprises such as fuel stations. On the other hand, there is a government-supported 10-year purchase guarantee for the electricity to be generated by PV systems. The initial installation costs of the system differ in terms of system sizes, which are determined according to the suitable roof areas of the fuel stations and their electricity consumption. As the system capacity grows, the cost per kW decreases. Assuming the PV system capacities to be applied for fuel stations between 30-120 kWp, the initial installation costs vary between 900-1200 $/kWp per kWp.

The investor can amortize the initial installation cost with the prices provided by the purchase guarantee between 5-7 years. The amount required for the investment can be obtained from banks at interest rates specific to renewable energy systems. Supports to renewable energies enable investors to obtain positive returns. During the lending phase, banks establish a trust relationship with the investor based on the production expectations of the immovable in the proposed project. The life of the installed system varies between 20-25 years depending on environmental conditions. After the system has amortized its own investment amount, it will continue to generate electricity for the investor for many years. Installation cost is the ultimate problem for the investor to overcome. A PV system project designed based on proper calculations will create a safe environment for banks and guarantee the reliability of the system for the investor.

In this context, possible risks should be properly determined at the first, and then these risks should be eliminated as much as possible with the financial foresight tools to be used. The possible risks are considered with a scatter chart as shown in Figure 4.1.

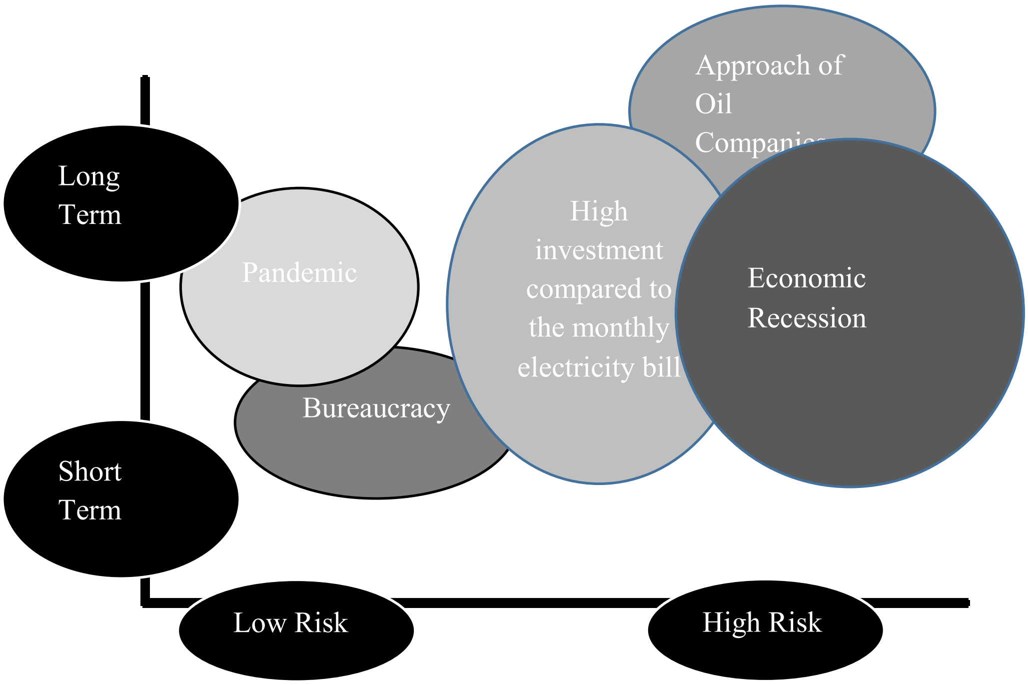

Figure 4.1. Risk Scatter Chart

- Coverage risks:
    - The fact that photovoltaic applications in the fuel sector have not been systematized yet,
    - The fact that the entire photovoltaic market is focused on large projects,
    - Lack of awareness about the added value of the investment,
    - High investment cost compared to monthly electricity bill.
- Institutional risks:
    - The fuel distribution companies' willingness to lay claims to the project model and the procedural processes in establishing the solution partnership ground.
- Strategic risks
    - Economic recession
    - Pandemic
    - State of the competition
- Planning risks
    - Points that may have not been considered during planning,

The financial parameters to be used to eliminate these risks and their calculations will be discussed in the following three sections.

4.1. Financial Problems and Suggestions

Financial analysis is the most important process related to the implementation of photovoltaic applications in fuel stations. The financial analysis process aims to identify problems and provide projections for solutions. In this section, base parameters to be used for the financial analysis process will be defined, and an imaginary solar station investment will be studied so that these parameters are understood better. In order to make the calculation more understandable, real values have been taken as basis, and taxes and expenses that may arise from the use of financial instruments have been ignored.

4.1.1. MARR (minimum attractive…) / IRR (internal rate of return)

Return ratio is the interest rate paid on the outstanding balance of borrowed money, or the interest earned on the unrecovered balance of an investment or loan (where the last payment or receipt equates the balance to zero with interest). Return ratio is expressed as a percentage per period.

MARR is the lowest return ratio that will lead to acceptance of a proposed investment alternative. MARR can be determined using following three methods: MARR can be taken as a rate equal to the interest rate paid by a local savings bank. In this case, MARR becomes the opportunity cost of money, and represents the cost of the opportunity lost due to not depositing the money in the bank. For most operators, the savings bank rate will be lower than the overall rate of return they earn on their investment. Thus, MARR can be taken equal to the current average return rate of the company's total investments. MARR may be intentionally taken higher than the bank's interest rate or the average return rate of the company's investments. In this case, MARR can be determined based on the company's long-term profit targets (to achieve the desired future growth rate). The aim is to encourage to look for more profitable new ventures. MARR can also be taken as a large ratio to consider the high degree of risk that investments may pose. Since it is aimed to prove that PV application is a high-yield investment for the fuel station, the third alternative mentioned above was taken as the basis while making the calculations. In Turkey, corporate income tax is applied gradually based on the total annual gross earnings of the enterprises. Again, an average rate was taken as the basis for the application in order to make the calculations simple and easy to understand.

Table 4.1. Annual Interest & MARR & Corporate Income Tax

Real Interest	**1.1%**
MARR	**5.0%**
Corporate Income Tax	**25.1%**

PV panels will eventually experience loss of efficiency over the years; therefore, at the end of their predicted life of 25 years, they have an efficiency rate equal to 75-80% of their initial efficiency rate. This parameter should also be considered in the calculations.

Table 4.2. Annual Production

Year	**Production (kwh)**	**Year**	**Production (kwh)**
0		14	47,657
1	54,309	15	47,181
2	53,766	16	46,709
3	53,228	17	46,242
4	52,696	18	45,779
5	52,169	19	45,322
6	51,647	20	44,868
7	51,131	21	44,420
8	50,620	22	43,976
9	50,113	23	43,536
10	49,612	24	43,100
11	49,116	25	42,669
12	48,625		
13	48,139		

The electricity sales price has increased by 4.7% on USD basis in the last five years (TÜİK 2019 Inflation Report). However, it was assumed that this trend would not continue in the long term and there would be no increase on USD basis, therefore, the current price of electricity which is 0.11 USD/kwh was used.

Table 4.3. Electricity Price (Source: Gediz Elektrik 2021)

Electricity price (USD/kwh)	**0.11**

When the costs related to the photovoltaic application connected to the system at a fuel station is under question, two basic and simple cost elements to be calculated are initial investment cost and annual costs of the system. The first of these elements and the most important in terms of quantity is the initial investment cost. The initial investment cost is also divided into items such as project cost, bureaucratic transaction costs, material costs, assembly costs and control costs. While cable, PV panel, inverter, transformer and assembly costs are included in the material expenses, occupational health and safety expenses, fire control expenses and SCADA program expenses are included in the control expenses (IBT Solar System Offer 2021).

Table 4.4. Cost Summary (Source: Solar İstasyon 2021)

Costs Summary Table (USD)	
Project Cost	2,500
Bureaucratic Procedures	800
Material Cost	19,500
Installation Cost	8,700
Control/Test Costs	1,800
Total Initial Investment	33,300
Insurance Cost	90
Maintenance Cost	170
Total Annual Expenses	**260**

Considering that it will be the most used method in practice, it was assumed that 50% of the initial investment would be made with loans, and additionally, 6% annual loan cost and ten-year repayment period were taken as basis in the calculations. In addition, in accordance with the current legislation, loan interests to be made were recorded as an expense on an annual basis.

Table 4.5. Credit Conditions (Source: Türkiye Finans 2021)

Credit Conditions (USD)	
Total Credit Amount (USD)	16,650
Loan Instalments (Years)	10
Annual Credit Interest	6%

Other parameters to be included in the main financial statement are as follows:

DC: Depreciation Cost expresses the reduction in the value of a fixed asset due to wear and tear. Tangible fixed assets are allocated to the accounting periods in which they are used and recorded as expense. The depreciation period specified in the income data law for solar energy systems is 20 years.

SV: Scrap Value is basically a term used in finance in relation to depreciation. It is the predicted value of an asset at the end of its predicted useful life. In calculations, it will be taken as 5% of the initial material investment at the end of the period.

NCF: Net Cash Flow is the net income after deducting all expenses such as taxes, principal and interest payments, insurance expenses from the income obtained from the operation of any economic asset. It is the positive difference between cash inflows and outflows generated in an investment project.

NPM: Net Profit Margin measures how profitable a business is after deducting all costs, expenses, and taxes. In other words, it is the ratio that shows how much net profit is obtained from a unit of sales.

NCP: Net cash balance or position refers to the amount of cash that a project already has and the amount of net cash flow it has received at the end of a period of time.

NPV: Net Present Value is a method used when comparing investments or trying to understand the value of an investment.

A simple method is used to show through a single figure whether an investment is profitable or loss-making by converting (discounting) each of the expenses and incomes of the investment over time to its present value at an interest rate appropriate to the risk level of the investment.

The general formula (Eqs 4.1.) for calculating the net **current value** of a regular money flow will be observed below

$$\mathbf{NPV}(t, N) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

(4.1.)

where;

NPV = (net present value)

N = number of periods

t = current period

i = real interest on period (MARR could be applied)

Real interest (Table 4.6.) or MARR (Table 4.67) could be used within the NPV formula, depending on the strategy set.

Table 4.6. NPV Calculation According to Real Interest

Year	NCP (real interest) (USD)	Year	NCP (real interest) (USD)
0	-16,650	13	14,505
1	-15,015	14	18,818
2	-13,350	15	23,138
3	-11,650	16	27,468
4	-9,912	17	31,806
5	-8,131	18	36,154
6	-6,301	19	40,512
7	-4,418	20	44,880
8	-2,475	21	48,844
9	-467	22	52,814
10	1,611	23	56,792
11	5,903	24	60,777
12	10,200	25	64,771
NPV (USD)			**346,915**

Table 4.7. NPV Calculation According to MARR

Year	NCP (MARR) (USD)	Year	NCP (real interest) (USD)
0	-16,650	13	14,903
1	-15,664	14	18,818
2	-13,935	15	23,138
3	-12,171	16	27,468
4	-10,366	17	31,806
5	-8,517	18	36,154
6	-6,618	19	40,512
7	-4,663	20	44,880
8	-2,647	21	48,844
9	-564	22	52,814
10	1,593	23	56,792
11	5,965	24	60,777
12	10,430	25	64,771
NPV (USD)			**131,483**

IRR: The internal rate of return is the expected annual amount of money, expressed as a percentage, which the investment can expect to generate at and above the cap rate for the company (Internal Rate of Return) (Young 2003).

The word "internal" means that the figure does not take into account potential external risks and factors such as inflation. The IRR is also used by financial professionals to calculate expected returns on stocks or other investments, such as the yield-to-maturity on bonds. The rate of return excludes potential external factors and is therefore an "internal" rate. It is possible to evaluate projects by comparing IRR with MARR.

IRR values are calculated on below table (Table 4.8.). MS Excel is able to calculate IRR values directly by using the formula "**internal_rate_of_return**" on values of net cash flows in years.

Table 4.8. Internal Rate of Return <> MARR Comparison

Period (years)	**IRR**	**MARR**	**Investment (Yes/No)**
10	**3%**	5%	No
15	11%	5%	Yes
25	14%	5%	Yes

MARR value was initially accepted as 5%, when compared with the IRR rates:

- For 10 years → MARR > IRR → Investment is not acceptable if a 10-year assessment is made
- For 15 years → MARR < IRR → If an evaluation of 15 years is made, the investment is acceptable
- For 25 years → MARR < IRR → If an evaluation of 25 years is made, the investment is acceptable

4.2. Price Sensitivity

As can be understood from the explanations and calculation tables provided in the previous section, the economic efficiency of an on-grid photovoltaic system at a fuel station depends on many parameters; however, electricity prices are the one that has the highest volatility among these parameters.

Electricity prices not only change on an annual basis against the Turkish Lira due to the inflationary environment, but also show high volatility in terms of US Dollars over the years. In the last five years, there has been a 4.7% change in prices in USD terms; for the last ten years, this change has been around 11%. It is possible to say that this volatility is due to global reasons such as oil prices, as well as local factors such as the fact that the share of power plants operated with fossil fuel is very high in Turkey's power plant stock. For these reasons, it would be useful to measure the sensitivity of the project in terms of price sensitivity in order to determine whether it is applicable in terms of fuel stations. Sensitivity analysis investigates the effect of the change in the coefficient values determined in a linear programming problem on the optimal solution of the problem. It is investigated that the coefficients in the created model are not fixed and to what extent they will change in later periods and affect the optimal solution. If it foreseen that there will be a difference in the optimal solution as a result of this change, the problem should be re-solved. In the sensitivity analysis, the value changes in the objective function and constraint coefficients and source values and the change in the optimal solution when a new variable and a new constraint are added are examined. Normally, it is possible to find the effects of any change in resources or constraints by resolving the linear programming model.

However, this way of resolving is often unnecessary because of a different optimal solution containing the same basic variable. Therefore, the sensitivity analysis aims to determine the effect of such a change through the optimal solution table without re-solving, İf the effect of price sensitivity on investment decision is analyzed over NPV and IRR values.

Table 4.9. Sensitivity Analysis

Electricity Price (USD/kwh)	NPV MARR (USD	Electricity Price (USD/kwh)	IRR (15 Years)	electricity price (USD/kwh)	IRR (25 Years)
	131.483		**11%**		**14%**
0.165	479,360	0.165	24%	0.165	25%
0.160	444,572	0.160	23%	0.160	24%
0.154	409,785	0.154	22%	0.154	23%
0.149	374,997	0.149	20%	0.149	22%
0.143	340,209	0.143	19%	0.143	21%
0.138	305,422	0.138	18%	0.138	20%
0.132	270,634	0.132	16%	0.132	18%
0.127	235,846	0.127	15%	0.127	17%
0.121	201,058	0.121	14%	0.121	16%
0.116	166,271	0.116	12%	0.116	15%
0.110	131,483	0.110	11%	0.110	14%
0.105	96,695	0.105	10%	0.105	13%
0.099	61,908	0.099	8%	0.099	12%
0.093	27,120	0.093	7%	0.093	11%
0.088	-7,668	0.088	5%	0.088	10%
0.082	-42,456	0.082	4%	0.082	8%
0.077	-77,243	0.077	2%	0.077	7%
0.071	-112,031	0.071	1%	0.071	6%
0.066	-146,819	0.066	-1%	0.066	5%
0.060	-181,606	0.060	-2%	0.060	4%
0.055	-216,394	0.055	-4%	0.055	3%
				0.049	1%
				0.044	0%
				0.038	-1%

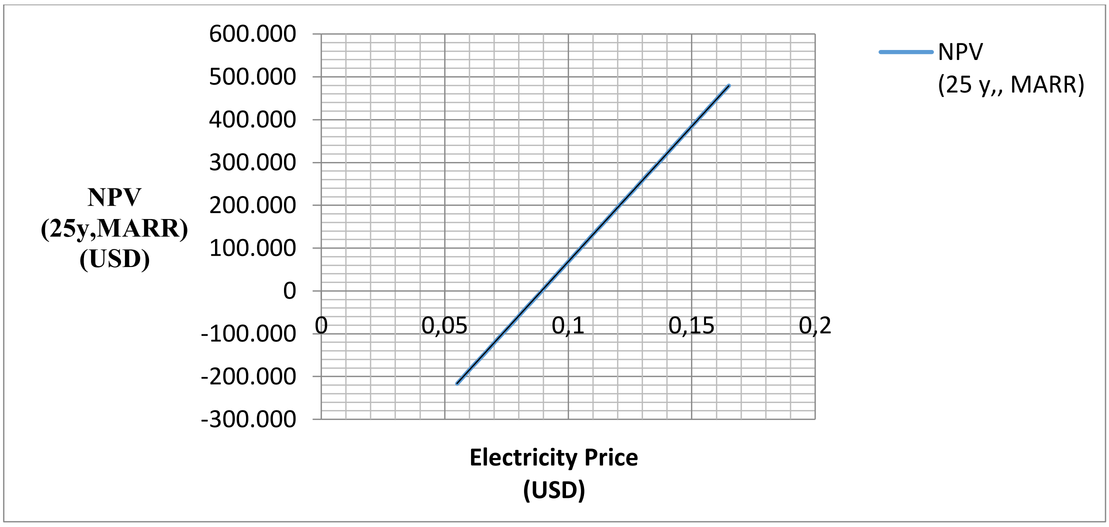

Figure 4.2. Sensitivity Analysis: Net Present Value → Electricity Price

Based on the NPV value calculated according to the 25-year investment period and the desired MARR value; the electricity price decreases to the level of 0.088 USD per kWh, the investment loses its economic attractiveness. Besides **slope** of the above graph (Figure 4.2.) shows the statement that 1 USD cent increase on electricity price (USD/kwh) also raise the value of the project around **63,250 USD** (according to net present value).

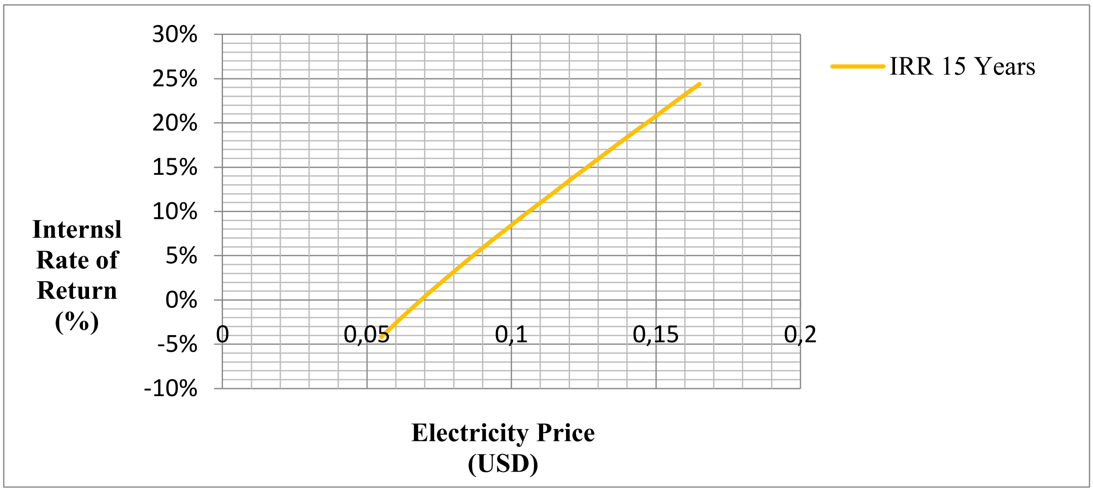

Figure 4.3. Sensitivity Analysis: IRR 15 Years → Electricity Price

Based on the IRR value calculated according to the 15-year investment period: If the electricity price decreases to the level of 0.066 USD per kWh, the investment loses its economic attractiveness.

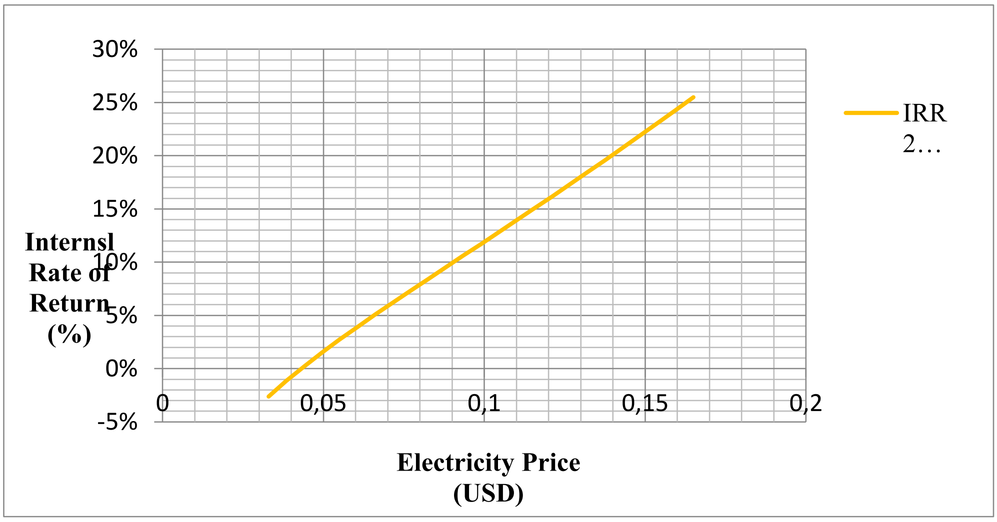

Figure 4.4. Sensitivity Analysis: IRR 25 → Electricity Price

Based on the IRR value calculated according to the 25-year investment period; If the electricity price decreases to the level of 0.044 USD per kWh, the investment loses its economic attractiveness.

4.3. Levelized Cost of Electricity

The Levelized Cost of Energy (LCOE) is a method used to calculate the unit energy cost of power generation plants. The energy unit price is calculated by taking into account the initial investment cost, operating and maintenance costs, and fuel costs. Thus, the minimum price at which the energy must be sold can be calculated in order not to make a loss.

Levelized energy cost can be compared to the payback method, but not how long it takes to recoup the initial investment; The lowest energy unit price (kWh/₺) that should be applied in order to make a profit during the estimated life of the power plant is calculated. Thanks to LCOE, it is possible to compare different power generation plants and even electrical energy storage methods by calculating the cost per unit of energy (Park 1990)

Basically, unit energy price is obtained by dividing all expenses on an annual basis by the electrical energy produced in a year. It can be calculated with many different approaches and formulas. One of the most common levelized energy cost formulas is Eqs 4.2.

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

(4.2)

where;

It = Initial Investment Cost (USD)

Ft = Annual Fixed Expenses (USD)

Mt = Annual Variable Expenses (USD)

Et = Plant Power (kW)

t = Estimated Life of the Plant (years)

The initial investment cost covers the costs incurred until the plant reaches the operational stage. Operation, maintenance and repair cost, personnel, spare parts, operation etc. on an annual basis. It includes expenses and can be divided into two as fixed and variable costs. The estimation of these expenses is made per kW and if the calculation is requested; ET, which is in the denominator in the first formula, is subtracted from the formula so that the cost per kW values can be calculated.

Especially for renewable power plants, governments may offer opportunities such as financial support or credit discounts as incentives. If such incentives are desired to be taken into account, they can be added to be subtracted from the initial investment cost. Capacity factor is the ratio of the energy produced by a power plant in a certain period to the energy it can produce at full capacity. Therefore, the capacity factor estimation has an important place in the calculation. There are 8760 hours in a year, multiplied by the power plant power and capacity factor to get the energy produced in a year.

The average unit cost of the energy to be used in the next 25 years at each fuel station that will join the Solar Station family is as follows:

LCOE = (24.419+3.698) / (34*2569*25*0. 92*0.55) =2.5 USD Cent/kWh

- Average electricity unit price 16 USD Cents ($0.16 – Commercial Tariff)
- **Reduction rate** in electricity costs of the station = 1-(2.5/16) **= 84.34%**

The monthly net decrease in the electricity costs of the station

= (0.16-0.025) *11 ₺/USD * 122 kWh * 30=5433 ₺ (Basut Petrol Study)

Stations which implement the Solar Station concept will save 84.34% in electricity costs starting from the first month following the implementation with current prices.

4.4. Return on Investment

Return on Investment (ROI) is the data showing the return on investment. Basically, ROI shows how much return an investment provides to the investor, that is efficiency (Altaş 2011), and whether the investment in question should be proceeded (Eqs. 4.3.)

ROI = (Return on Investment – Investment Cost) / Investment Cost (4.3)

ROI is one of the most important data for investment with the Conversion Rate. Undoubtedly, if the ROI rate is above 100% there is monetary profit/return. A ROI of 180% indicates that for every 100 USD invested, the investor earns 180 USD in return. If this ratio is 80% instead of 180%, it means that there will be a return of 80 USD for 100 USD invested, which means there is a loss of 20%.

In today's competitive environment of commercial companies, sector diversity is increasing, and as a result, different business opportunities that provide profitability have started to develop. However, for the sustainability of the success of the companies, it is very important to make a profit, to eliminate the risk factors and to achieve concrete results.

The ROI measurement tool is important as it enables the commercial enterprises to create their strategy by measuring their investments. In terms of the continuity of commercial enterprises, it is necessary for these enterprises to make a profit. The defining features of the frequently used ROI tool are as follows:

- It is sophisticated and a frequently used measuring tool.
- It allows measuring the profitability indicator of an investment.
- It enables to learn the earning in return to the investment made.
- It is easy to interpret and analyze.
- It supports the profitability and growth of companies.
- It is used to determine the loss and gain based on the amount of investment.
- It is expressed in percentages.

Examining the ROI calculations in terms of the fuel station where photovoltaic application has been performed will enable us to better analyze the project outputs. Different ROI values for real interest and MARR values will be calculated based on the financial analysis table.

Table 4.10. Return on Investment According to Real Interest & MARR

ROI (real interest)	2,084%	**ROI (MARR)**	790%

Table 4.11. Breakeven Period for Sample Project

Year USD	0	1	2	3	4	5	6	7	8	9
NCF	-16,650	1,818	1,830	1,846	1,866	1,890	1,919	1,953	1,991	**2,035**
NPM		44%	45%	46%	47%	49%	51%	53%	56%	**59%**
NCP (real interest)	-16,650	-15,015	-13,350	-11,650	-9,912	-8,131	-6,301	-4,418	-2,475	**-467**
NPV	**346,915**									
NCP (MARR)	-16,650	-15,664	-13,935	-12,171	-10,366	-8,517	-6,618	-4,663	-2,647	**-564**
NPV	**131,483**									

Due to low annual operating cost (only insurance and maintenance / control cos) project balance in terms of NCF (net cash flow) is on positive side starting from year one after initial cost at starting point (Table 4.11.). Also net annual NPM (net project margin) is starting with 43.8% at year one and go up to 387.4% at year 20. Positive effect of depreciation end at year 20 and NPM goes on with a slow decrease to year 25 and ends with the margin of 243% (Table 4.12.)

NCP (net cash position) calculation is made in two ways; with real interest (1.1%) and with MARR (5%). If the observation is made according to NCP (net cash position), for both NCP calculation, project balance turns to positive in year 9 **.** That means **project breakeven period is 9 years** (Table 4.11.)

Table 4.12. Period for Sample Project – Following Years

Year USD	**10**	15	20	22	25
NCF	**2,084**	**4,114**	**3,923**	**3,433**	**3,325**
NPM	61.8%	382.2%	387.4%	244.5%	243.0%
NCP (real interest)	**1,611**	**23,138**	**44,880**	**52,814**	**64,771**
NCP (MARR)	**1,593**	**23,872**	**46,460**	**54,719**	**67,141**

4.5. Financing Model

Many financial institutions can provide loans under favorable conditions and with payment-free periods up to 2 years within the scope of solar energy loans for the purpose of financing unlicensed electricity generation projects from solar energy. The fact that unlicensed electricity generation projects are supported by the government with legal regulations, and that there is a purchase guarantee for 10 years at the tariff determined for the excess electricity generated and not used by the relevant supplier company increases and facilitates the bank support in this field. (IBT Solar 2021) .


Proje

35,1 kWp ÇATI ÜSTÜ LİSANSSIZ FOTOVOLTAİK GÜNEŞ ENERJİSİ SANTRALİ- BASUT PETROL GES

Teklif No

PV-SI-2020-E0001

URLA / İZMİR

ÇATI ÜSTÜ FOTOVOLTAİK GÜNEŞ ENERJİSİ SANTRALİ KURULUMUNA İLİŞKİN FİYAT TEKLİFİ

Figure 4.5. Title Page for Sample Project Offer (Source: IBT Solar 2021)

1 TEKLİFİN KAPSAMI

35,1 kWp kurulu güce sahip PV-GES'in; projelendirme, ürün tedariki, kurulum ve montajını, şebeke bağlantısı ve senkronizasyonunu,
devreye alınmasını, sistem performans parametrelerini ve garanti hususlarını kapsar.

2 FİYAT

YÜKLENİCİ'nin bir fotovoltaik santralinin temini için bütçe teklifi aşağıdaki gibidir:

33.300,00- Dolar

(Yazı ile: Otuz Üç Bin Üç Yüz Dolar)

Anahtar teslim bütçe fiyatı, **35,1 kWp** 'lik proje kapasitesine dayalı olup, aşağıdaki birim fiyatına tekabül etmektedir.
950,00 -Dolar/kWp

(Yazı ile: kWp başına Dokuz Yüz Elli Dolar)

Katma değer vergisi (KDV) hariç olup, fatura tutarına ayrıca dahil edilecektir.

Figure 4.6. Price Page for Sample Project Offer (Source: IBT Solar 2021)

IBT SOLAR

SOLARİSTASYON

BASUT PETROL GÜNEŞ ENERJİ SANTRALİ PROJESİ ÜRÜN LİSTESİ

Doküman No: SI000003

Ürünler-Hizmetler	Marka	Açıklama
Saha Şantiye Harcamaları, Lojistik & Banka & İdari Masraflar		
All Risk Saha İnşaat Dönemi Sigortası	IBT SOLAR	1 Proje için yapılacaktır.
SGK Ödemeleri	IBT SOLAR	1 Proje için yapılacaktır.
Saha Şantiye Kurulması	IBT SOLAR	1 Proje için yapılacaktır.
DC Üretim Sistemi & DC Kablolama		
Fotovoltaik Güneş Panelleri	Schmid Pekintaş / Elin Solar / Smart Energy	325 Watt Monocrystalline Güneş Paneli
1x6mm² Solar Kablo	Prysmian veya muadili	Teklifimiz 1500V'a kadar dayanımlı Prysmian'ın H1Z2Z2-K' modeline göre verilmiştir. TEDAŞ MYD
DC Kablolama / DC Kabloların Altyapı Aksamına Sabitlenmesi	IBT Solar Tyco	şartnamelerine uygun şekilde IBT Solar standartlarında yapılacaktır.
MC4 Konnektörler	Fronius	Tyco marka yüksek standartlı konnektörler kullanılacaktır.
İnverterler		35 kW Inverter kullanılacaktır.
Haberleşme ve Takip Sistemi		
İnverter Haberleşme Sistemi	Fronius	Uzaktan İzleme Sistemi
IBT SOLAR Scada RTU İzleme Sistemi	Schneider-Wago	IBT Solar'ın özel geliştirdiği yazılım ve yüksek kalite pano kullanılacaktır. Dağıtım Şirketi kriterleri sağlanacaktır.
Konstrüksiyon ve Altyapı Aksamı		
Mekanik Altyapı Aksamı	Schletter veya IBT Fast Tack	Aluminyum Altyapı Aksamı
Mekanik Altyapı Aksamı Montajı	IBT SOLAR	IBT Solar standartlarında kurulum gerçektestirilecektir.
AC Kablolama & AC Koruma ve Şalt Malzemeler		
Prysmian Ömür 0,6/1kV 1500V dayanımlı BAKIR kablolar planlanmıştır.		
Prysmian Ömür STS 0,6/1kV 1500V dayanımlı BAKIR kablolar planlanmıştır.		
veya Muadili IBT STS marka kablo tavaları planlanmıştır.		
SOLAR TEDAŞ şartnamelerine uygun özelliklerde etiketleme sistemi planlanmıştır.		
TURKUAZ veya muadili TEDAŞ şartnamelerine uygun özelliklerde planlanmıştır.		
ABB - Siemens - Schneider Şalterler ABB, Bara Sarkuysan, Akım Tr. Entes, Pano Karkası olarak planlanmıştır.		
Potansiyel Topraklama ve Gerilimden Koruma Altyapısı		
Potansiyel Topraklama Sistemi	AMPER - Radsan veya muadili	TEDAŞ tarafında onaylanacak olan revize Topraklama Şemasına ve Topraklama Yönetmeliklerine uygun planlanmıştır.
Ana Dağıtım Panosu		
Elektronik Çift Yönlü Sayaç	Köhler, Landis veya muadili	Dağıtım Şirketi tarafından talep edilen kriterlere uygun tahsis edilecektir.
Ölçüm ve Testler / Saha Operasyon / İş Teslimi	IBT SOLAR	IBT Solar Teknik Ekibi tarafından yapılacaktır.
Koruma Röleleri	Tythronic veya ABB	TEDAŞ MYD şartnamelerine ve revize edilecek onaylı projeye uygun tahsis edilecektir.
Güvenlik Ekipmanları		
Yangın Tüpleri 6 kg / 12 Kg	Hassa	Bölge Belediye İtfaiye Daire Başkanlığı Kriterlerine uygun olarak tahsis edilecektir.
Mühendislik- Kurulum ve Dokümantasyon		
Detaylı Saha Uygulama Projesi	IBT SOLAR	IBT Solar standartlarında TEDAŞ kriterlerine uygun uygulanacaktır.
Elektriksel Montaj	IBT SOLAR	IBT Solar standartlarında TEDAŞ kriterlerine uygun uygulanacaktır.
Mekanik Montaj	IBT SOLAR	IBT Solar standartlarında TEDAŞ kriterlerine uygun uygulanacaktır.

Figure 4.7. Material List for Sample Project Offer (Source: IBT Solar 2021)

Below is a sample feasibility report (Figure 4.8 and Table 4.12) that should be submitted to the financial institution, and a sample loan repayment plan proposed by the financial institution (usually banks are used) for this example (IBT Solar 2021).

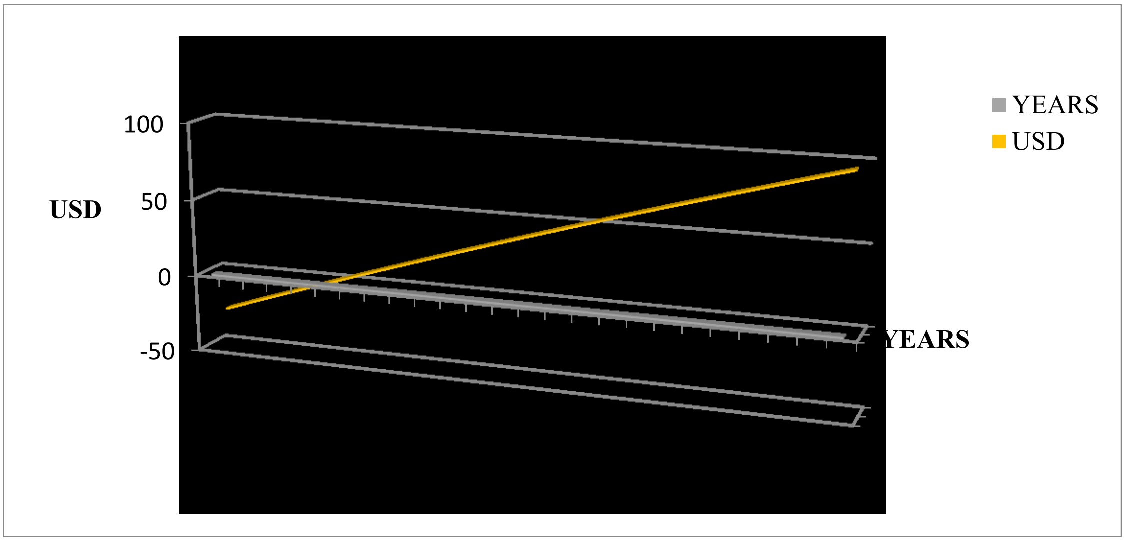

Figure 4.8. Feasibility Projection Used in Market (Source: IBT Solar 2021)

Table 4.13. Feasibility Projection Used in Market (Source: IBT Solar 2021)

Period	Year	Production (kWh)	Saving (USD)	Operating Expenses (USD)	Net Income (USD)	ROI
1	2020	54,309	5,974	200 $	5,774	-27,526
2	2021	53,829	5,921	200 $	5,721	-21,805
3	2022	53,351	5,869	200 $	5,669	-16,136
4	2023	52,406	5,765	200 $	5,565	-10,571
5	2024	51,939	5,713	200 $	5,513	-5,058
6	2025	51,474	5,662	200 $	5,462	404
7	2026	51,013	5,611	200 $	5,411	5,815
8	2027	50,556	5,561	200 $	5,361	11,176
9	2028	50,103	5,511	200 $	5,311	16,488
10	2029	49,653	5,462	200 $	5,262	21,750
11	2030	49,207	5,413	200 $	5,213	26,962
12	2031	48,765	5,364	200 $	5,164	32,127
13	2032	48,326	5,316	200 $	5,116	37,242
14	2033	47,893	5,268	200 $	5,068	42,311
15	2034	47,462	5,221	200 $	5,021	47,331
16	2035	47,035	5,174	200 $	4,974	52,305
17	2036	46,611	5,127	200 $	4,927	57,232
18	2037	46,192	5,081	200 $	4,881	62,114
19	2038	45,775	5,035	200 $	4,835	66,949
20	2039	45,108	4,962	200 $	4,762	71,711
21	2040	44,640	4,910	200 $	4,710	76,421
22	2041	44,173	4,859	200 $	4,659	81,080
23	2042	43,704	4,807	200 $	4,607	85,688
24	2043	43,237	4,756	200 $	4,556	90,244
25	2044	42,769	4,705	200 $	4,505	94,748
Total		1,209,530	133,048	5,000	128,048	

Although solar energy loans vary according to the structure of the project, they provide both low interest rates compared to market averages and financing opportunities up to 100% of the project. Financial institutions consider a simple feasibility study to be done in addition to a certain credit score adequate to provide such supports.

Below a sample loan repayment plan to be proposed by the financial institution could be seen (IBT Solar 2021).

Table 4.14. Credit Payment Plan (Source: Türkiye Finans 2020)

Credit Amount (USD)		**34,462**		
Monthly Interest (%)		1.13%		
Total Interest Payment (USD)		14,886		
Tax (USD)		744		
Tot Payment (USD)		50,091		
Commission (USD)		362		
No	Loan Instalment	Principal	Interest	Remaining Principal
1	747	327	0	5,251
2	747	344	59	33,790
3	747	348	380	33,442
4	747	352	376	33,089
10	747	378	352	30,884
11	747	383	381	30,501
12	747	387	343	30,114
20	747	425	307	26,846
21	747	430	302	26,416
22	747	436	297	25,980
33	747	496	240	20,835
34	747	501	234	20,333
46	747	577	162	13,833
49	747	598	142	12,059
58	747	665	79	6,348
61	747	689	56	4,306
64	747	713	33	2,191
65	747	722	25	1,469
66	747	730	17	739
67	747	739	8	-

CHAPTER 5

CONCLUSION

Grid-connected PV system for a fuel station is a completely unique project in terms of sector specific problems, notable benefit for potential users and also to all human-society. There is a clear dilemma between the current position of and consumer expectations from fuel sector. This makes such studies significant both for the sector needs and for the academic contribution to solving of specific engineering problems. Besides, photovoltaic solutions promise measurable targets like project base 20% gross profitability for the end user in balance and potential application at 5000 separate stations.

Excluding exceptional cases such as zoning problems, operation and ownership confusions and network problems, almost all of the 13,000 stations those are operating under license in Turkey need PV solutions. Investment to PV solutions seems highly recommendable for the businesses. Within this number, 5000 stations have the potential to act first when a package solution regarding photo voltaic applications for the industry is presented.

Grid-connected PV system for fuel stations a paradigm planned with a win-win philosophy for all its stakeholders. In this context, it has positive goals for every aspect and every participant, despite all the technical and conceptual turmoil in the processes of the area for fuel sector. The implementation method and final numerical goals are quite understandable for both the academy and the sector. These consist of related components in the context of sectoral needs and feasibility calculations.

Solar supported stations, beyond all commercial motives, is a clear step to be taken in terms of its concrete contributions to a sustainable environment, social sensitivity and the construction of the world of the future. From this perspective, it has virtuousness beyond staying within ethical lines. In addition, the positive contribution of this project to the current account deficit of Turkey makes the project a moral necessity.

Those and similar academic studies will create a driving force in an area which is out of focus by sector players and also potential users Near by a stimulating effect on all stakeholders of the sector could be expected. Current bureaucratic and legal conjuncture does not prevent the implementation of these practices, just the opposite includes incentives.

In parallel with the realization of renewable energy applications in the fuel sector, a significant reduction in carbon emissions and fossil fuel consumption is foreseen. Sustainable environmental sensitivity is a positive value for the study.

If benefits of applying photovoltaic solutions to fuel stations in a way that can meet the self-consumption of electricity, are listed:

- The stations to be installed within the scope of the project will be able to meet their own electricity consumption
- Environmental benefits due to renewable energy production
- The project system in which all the stakeholders of the project win thanks to the win-win situation
- Alternative contribution to our country's electricity needs
- Unification of all phases of the project under a single roof within the scope of the package Project
- Existing experience be under an obligation to strong partnerships
- Current and prospective profitability increase for station owners
- Additional revenues can occur with the integration of developing photovoltaic systems into facilities in daily use
- Profitability for the investor as a result of meeting the own electricity consumption by producing it
- Integration of emerging renewable energies into our country
- Development of the fuel distribution sector's vision for electric vehicles

More academic studies focusing on the following elements are needed:

- Entry into a market area with no previous experience within the country
- Competition factor that may occur with large fuel distribution companies
- The risk of economic recession in the current conjuncture
- The negative impact of the global pandemic on the markets

Besides factorial analysis, the results obtained from the studies on financials within the project have also showed that:

- As a result of the application, which is the subject of this project, a fuel station obtains an NPV of more than 3,000,000 USD with an investment of 30,000 USD in 25 years.
- The internal rate of return of the application in 15 years is 11% in US dollars. Which is a very good investment for the conditions of our country.
- Even when the calculation is made according to a MARR value as high as 10%, there is rate of up to 800%.
- Levelized cost of electricity (LCOE) for an average station is 0.25 USD cents according to calculations.
- When analyzed in terms of price sensitivity, photovoltaic applications at fuel stations seem rational if electricity retail sales prices remain above 0.88 USD cent level according to NPV and 0.66 USD cents according to IRR value.

For the last words, beyond all calculations and projections, the need for more academic studies and field applications is clear. In order for the photovoltaic applications to become widely available, technical bottlenecks should be overcome, rules and regulations related to commercial and residential photovoltaic applications needs to well-defined, bureaucracy and application procedures must be streamlined, and new financial tools and incentives must be developed.

The simple technical and financial analysis given in this thesis for a solar powered fuel station briefly describes technical and non-technical issues we are facing today and represent an excellent case-study for all fuel-stations and similar commercial application; however, it also shows the potential of the solar energy to become the dominant energy source in the future.

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