SOLROAD

Solar System Applications for Roadways

ESEN 492

Senior Design Project II

Instructor: Doç.Dr Elif Aslı Yetkin

Prepared by: Abdullah Güneş 118204023

Arda Erkan 117204007

Burak Akpınar 115204031

Istanbul Bilgi University

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ABSTRACT

The project's goal is to overcome the land issue, which is a major issue with solar energy systems. The places where solar energy system panels should be installed cover a large amount of territory. As solar energy becomes more widely used, the amount of land that may be exploited decreases. This Project proposal was examined, and the essential data and literature investigations were conducted in order to solve this problem. The necessary calculations for this project were made utilizing the data and reference studies that were acquired. Finally, the Project's viability was examined in depth.

1. INTRODUCTION

1.1. Definition of Solar Energy Applications

Solar energy is a radiation emitted by sun capable of producing heat, causing chemical reactions and generating electricity. The total amount of radiation reaching to the earth is vastly exceeding the world's current and anticipated energy needs. If it is suitably harnessed, this source has the potential to receive all future energy needs. For the future, solar energy is expected to become increasingly attractive as a renewable energy source due to it's unlimited supply and non-polluting characterization, in contrast to fossil fuels, natural gas and petroleum.

Figure 1. Common Uses of Solar

The sun is a potent powerful energy source, and sunlight is the largest energy source received by earth. However, its intensity at earth's surface is relatively low. This is because of the irregular radial spreading of radiation from the sun. Relatively minor losses are due to earth's atmosphere, clouds and mountains, which absorb or scatter almost %54 of the sunlight. The sunlight that reaches to the earth's surface is consist of %50 visible light, %45 infrared radiation and smaller amounts of electromagnetic radiation and ultraviolet. (Ashok, 2019)

The potential of solar energy is enormous since about 200,000 times the world's total daily electric-generating capacity is received by Earth every day in the form of solar radiation. Unfortunately, solar energy itself is free, the high cost of its collection, conversion and storage still limits its exploitation in many places. (Ashok, 2019)

1.2. Challenges In Solar Energy Field

The demand for energy in the world is increasing rapidly day by day. Countries continue to search for different sources to meet the increasing energy demand and continue their studies for more efficient use of existing resources. The most important renewable energy source is undoubtedly solar energy, as it is the origin of all energy sources. Solar power was used under the heading of thermal applications to obtain hot water in the past and today. However, the desired point has not yet been reached in using PV systems that convert solar energy directly into electrical energy (IRENA, 2019). Here are the problems and challenges that PV systems bring with them;

1.2.1. Environmental Factors

Thanks to political and technical success, electricity generation by the photovoltaic method has spread to more expansive areas. There are also millions of solar panels growing on the roofs of houses. Although the glass and aluminum materials of solar panels do not pose a big problem for the environment, panels made of solar cells contain various heavy metals, additives, and chemicals that may harm human health and nature. The main ones that can cause cancer and are highly toxic are: arsenite, lead, copper, gallium, cadmium telluride, cadmium sulfide, polyvinyl fluoride, selenium, silicon tetrachloride in crystalline silicon. The panel's cells are mostly crystalline silicon or very thin-film cadmium telluride or cadmium sulfide layers. Pure cadmium is harmful to kidneys and bones and can cause cancer. (IRENA, 2019)

Figure 2. Environmental Effects

For this reason, protective measures must be taken both in the construction of the panels and in their removal and removal after they have been used for 20 years in the future. While the panels are being made, protective clothing is used to protect them from harmful heavy metals. Some researchers claim that solar panels can be made without lead and cadmium. However, without these, the efficiency of the panels decreases. For this reason, it is necessary to develop scientific research and put non-toxic substances on the panels. (IRENA, 2019)

1.2.2. Storage

The energy produced from solar panels must be used immediately or stored somewhere (in batteries). The size of the batteries to be used in PV systems that are independent of the grid should be measured according to the system, and the battery required for a large solar panel system will be very costly. The problem is that the larger the battery, the less valuable it becomes. This level of storage can also increase the hazardous situation if the system stores it for extended periods. Despite having these conditions, batteries are still used to store large off-grid energy. (How solar power works - on-grid, off-grid and hybrid systems , 2014)

Figure 3. Storage

1.2.3. Efficiency

The fact that Pv Systems can be used when the sun out pulls it down efficiently. For this reason, since only 10-20% of the installed electrical power can be produced annually, the efficiency remains much lower than other power plants. Production costs come to higher prices per kWh than different types of electricity generation. In order to meet the continuous electricity needs of the factories at night, power plants using fossil fuels generally need to be activated. As it is known, the industry uses 75% of all electricity production. The share of renewable energies in this is negligibly tiny, only 3%. In addition, timely cleaning and control of solar panels affect their efficiency. Dust and malfunctions may occur due to structures, buildings, or weather events around the solar panel system. Solar panels remove a little bit of dust in every rain, but dust may accumulate at some points. In addition to the dust, bird droppings should be added to this pollution. (Rhodes, 2010)

1.2.4. Area

One crucial point is the area covered by the solar panels. Since the energy produced by the solar panels is directly proportional to the covered surface area, a large land area is required for solar energy farms. The world's largest solar panel systems are built in deserts and substantial open spaces. However, this will not be possible to use energy systems in small countries with limited landmass. (Rhodes, 2010)

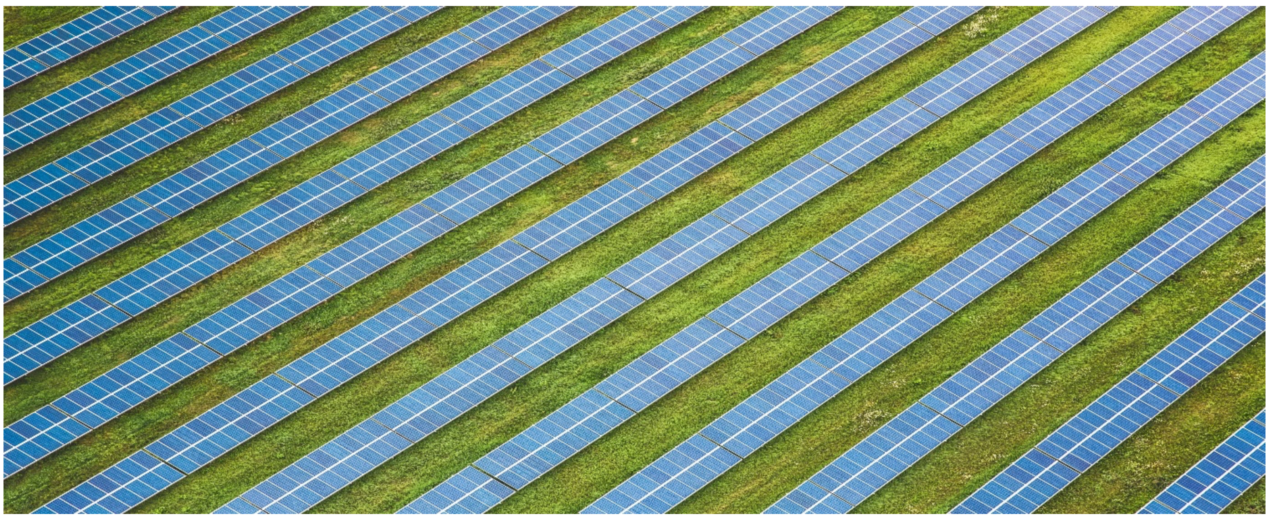

Figure 4. Area of Solar Power Plant

1.3. Aim of the Project

As a solution to this problem, highways used by many people every day will be used as a basis. There are three ways to do this. Lowering and positioning the road below ground level, placing it directly above the road, and installing a roof. Lowering the level of the road seems logical at first, but it is not very easy. It is necessary to remove the existing roads, dig trenches and build a new road into them. This is an arduous process in terms of cost and time. In addition, reinforcements and supports that should be made according to the hardness of the floor increase the cost even more. So this option was eliminated. Placing it on the ground, which is the other option, looks pretty reasonable in terms of cost. However, the structure of the panels must be developed to support the weight to be loaded on them. This is an extra cost. In addition, the road holding of the cars is affected, the ground cannot receive sunlight continuously due to the cars, and the particles coming out of the tires of the cars will cover the panels. So this option was also eliminated. The third option, installing a roof over the road, is currently the best option. The highway already exists. The panels will be able to receive light continuously. Moreover, cars will not be affected. As a result, the third option was chosen. With the roofs to be built on the highways, the space above the highways will be evaluated. Solar panels placed on the roofs will occupy less space and contribute to energy production.

2. DETAILS OF COMPONENTS

2.1. Why an off-grid Solar Panel system on this project is not used?

Before choosing, it would be more accurate first to explain what off-grid and on-grid are.

On-grid implies that the solar system is connected to the local utility's grid. Most residential buildings will utilize this if the solar system under or over-produces your variable energy demands. All of this means that the utility system serves as battery space. Suppose the system produces more energy than solar panels. The extra energy is transmitted to the grid's power provider, allowing earn credit that it may payout at the end of the year, known as net metering. (On Grid vs Off Grid Solar: Pros & Cons of Each System, 2020)

Being grid-connected is advantageous since it eliminates purchasing a costly battery backup system to store extra energy. Off-grid implies the system is not connected to the grid's electricity system or utility business. This is enticing since the energy use is entirely self-sustaining. However, there are drawbacks because off-grid systems necessitate the purchase of backup batteries, which may be costly, heavy, and not exceptionally environmentally friendly, defeating the objective of getting solar. (On Grid vs Off Grid Solar: Pros & Cons of Each System, 2020)

Since the system will not use the electricity generated, there is no need for batteries. If the solar energy systems used all over the world are looked at, it is seen that most of them use on-grid systems. After these deductions, it was reached to the server that the system would work more accurately with the on-grid system. (On Grid vs Off Grid Solar: Pros & Cons of Each System, 2020)

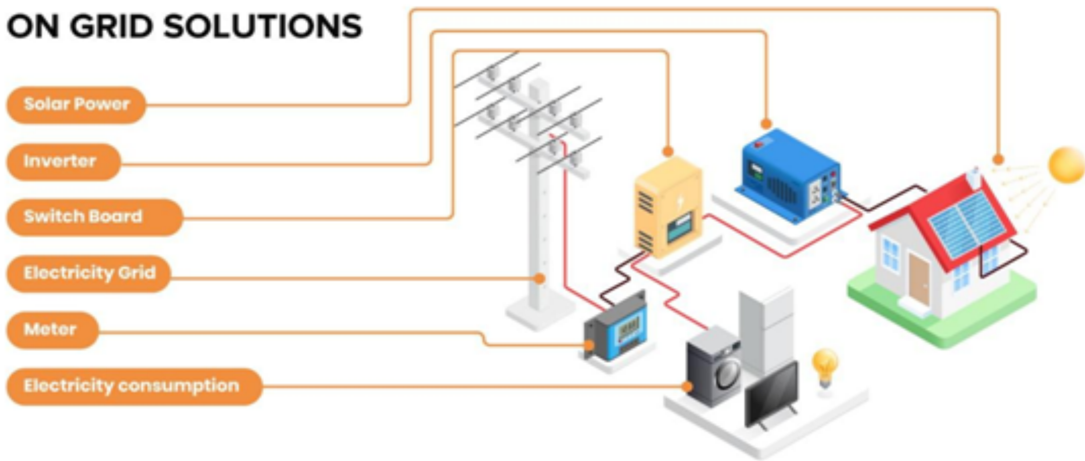

Figure 5. On-Grid Demonstration

2.2. The Process After Collecting the Energy

2.2.1. Inverter

The inverter is the heart of a solar energy system. It aids in converting the solar panel's DC (Direct current) output into an AC (Alternating current) supply.

Inverters not only aid in power conversion but also in synchronizing the produced electricity with appliances. This is accomplished with the assistance of a traditional transformer-based or transformer-less inverter. (Pendem, Desai, & Mikkili, 2020)

Grid inverter: The most popular inverter used in residential applications is linked to the power grid system. (Pendem, Desai, & Mikkili, 2020)

Grid inverters are further subdivided into:

String inverters are in great demand owing to their low cost and long-lasting technology. Multiple strings are linked together to form a single string inverter. It has the disadvantage that if a single string is damaged or falls into the shadow, the performance of a whole inverter may suffer. (Pendem, Desai, & Mikkili, 2020)

Micro-inverter: As the name suggests, this form of an inverter is most often employed in small solar projects where space is more important than cost (they are more expensive than string type inverters). These inverters are installed on each solar panel, individually converting DC to AC power. Even if one panel is darkened or damaged, the functioning of the other panels is unaffected. (Pendem, Desai, & Mikkili, 2020)

Central inverter: A central inverter is similar to a string inverter in that it has a high-capacity range and requires just one huge inverter for the whole plant/part of the plant. They are typically employed for large-scale utility applications. (Pendem, Desai, & Mikkili, 2020)

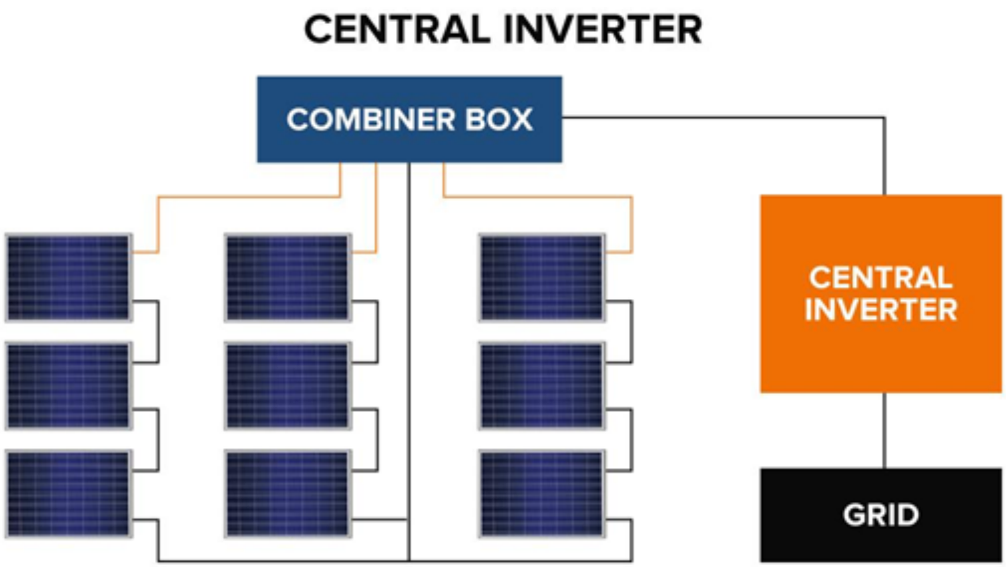

Figure 6. Central Inverter

The inverter selection was decided by looking at the on-grid solar systems around the world. It was decided that it would be more appropriate to use a Central inverter in the Solar Project.

2.2.2. Solar Racking and Mounting

Solar panels may be put on roofs, on the ground, or as a single pole-mounted array. Installing a solar panel in any following locations necessitates adequate mounting support. The mounting support aids in the attachment of the solar panel and in placing the panel at an angle that provides optimal exposure to solar radiation. (Rowley, 2021)

There are two kinds of mounting support:

Fixed mounts are less costly and more stationary. As it seen in figure 8, these mounts cannot adjust to the changing angle of the sun, they are less efficient. (Rowley, 2021)

Track mounts: These mounts are flexible and revolve around the sun's angle. As seen in figure 8, the sun's position fluctuates, and track mounts may follow solar radiation to get the best results. They are more expensive but more efficient than a permanent mount system. Track mounts take more upkeep and are best suited for bigger ground mount plants. (Rowley, 2021)

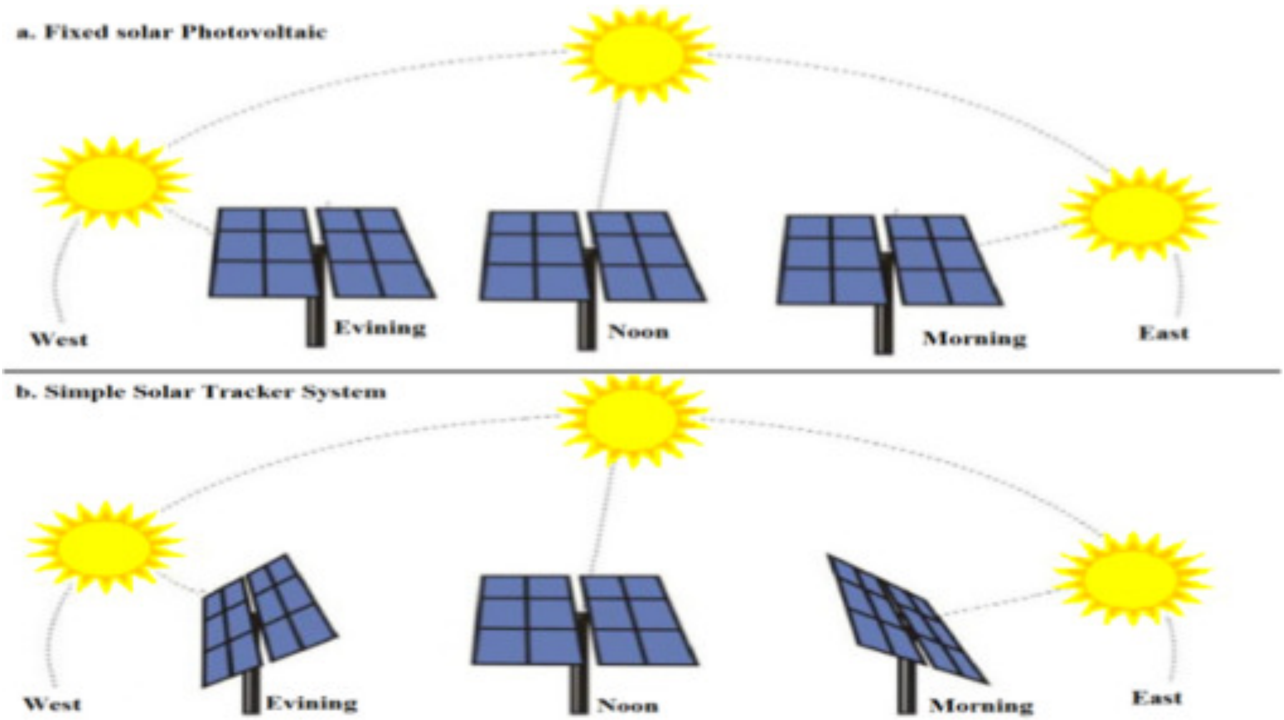

Figure 7. Fixed and Track Mounting

In rooftop systems, major businesses typically consider only permanent mounts; the angle at which the panel is positioned is optimized based on the location's latitude, allowing for as much electricity as feasible from a fixed system. (Rowley, 2021)

2.2.3 Cabling System

Solar cables are the solar installation blood vessels. They are responsible for the passage of electric current from the panels to the loads via the inverter. It is crucial to identify the suitable solar cable to guarantee the system does not overheat and has appropriate current-carrying capability while keeping costs reasonable. The size of the solar cable relies on the solar panel power output and the distance between the solar system and the loads.

Solar wires are categorized into two types:

AC cables connect solar power inverters to the grid via other protective components and provide AC power from the inverter to the grid/load.

DC cables link the panels to the inverter and transport the power produced by solar panels. These wires are utilized outside and, consequently, should be insulated correctly.

2.2.4. Distribution Box

The distribution box or distributional panel(board) is the component of the power delivery system. It is generally of two types:

DC Distribution Board (DCDB): DCDB is used for connecting the output power from the solar panel to the input of the inverter. Additionally, DC surge protection devices may be linked with the DC distribution box to protect against system malfunction. (Paridwal, 2021)

AC Distribution Board (ACDB): ACDB distributes the electrical power from a solar inverter to the AC load system using an energy meter. ACDB comprises extra safety equipment such as a circuit breaker, surge protector, or fuse to separate the solar system from the load side supply. (Paridwal, 2021)

Figure 8. Distribution Board

2.2.5. Protection Device

Due to direct and indirect lighting and other fault circumstances, components of the solar system may be damaged. Protective mechanisms such as surge arrestors, circuit breakers, grounding techniques, and other safety devices are added to safeguard the solar system.

As solar panels are put in open space, solar panels are sensitive to different environmental risks. Especially in the wet seasons, solar panels come in direct/indirect contact with lightning. To avoid the solar panels from these environmental risks following procedures must be taken:

Maintenance-free earthing trenches should be designed for the solar panels, inverter and lightning arrestor.

2.2.6. Net Metering

Net metering is a billing technique that rewards solar energy system owners for their power to the grid. For example, if a residential client has a PV system on their roof, it may create more power than the residence utilizes during daytime hours. If the house is net-metered, the electricity meter will run backwards to offer a credit against what power is spent at night or when the home's electricity demand exceeds the system's production. Customers are invoiced for their "net" energy consumption. On average, only 20-40 per cent of a solar energy system's production ever enters the grid, and this exported solar power feeds adjacent customers' loads. (What is net metering, method of billing and its advantages., 2022)

2.2.7. Lighting of Structure

Since the lighting of the system where the solar panel will be installed is almost similar to that of a tunnel system, it has been decided to install a tunnel lighting system in our system.

Tunnels are built for the brightest outdoor circumstances. This stage of maximum brightness, however, is essential just approximately 10 per cent of the time. For the remainder of the time, the entry lighting level has to be adjusted downward to various lighting levels so as not to overlight the tunnel, which may result in the use of too much power.

Based on the L20 portal luminance measurement, the tunnel’s control system will govern its multiple lighting phases. The number of phases has previously been specified as sunny, brilliant, cloudy, and dusk/dawn. However, nowadays, utilizing controllers and networked LED lighting, it is easy to add additional stages and modify the lighting to optimize the effectiveness of the installation depending on the circumstances that occur outside.

2.2.8. Battery

When we look at solar systems worldwide, it can be seen that the use of batteries in on-grid solar systems is not very common. However, it was decided to store the energy needed for the lighting equipment and other parts of the system in this project in a small battery. (Ashok, 2019)

A considerable percentage of the energy produced by a typical PV system will be exported to the grid. There is a rising need for solutions to better use this energy via energy storage.

Figure 9. Battery

A grid-connected solar system may be taken to a whole new level by adding deep cycle batteries. The cheapest approach would be to switch off the export feature and charge batteries instead. Such batteries may be significantly smaller than those used in stand-alone solar systems since the convenience of the energy grid remains at its disposal. The batteries have two purposes:

a - Increase self-consumption
b - Provide backup after grid breakdown

Self-Consumption

The inverter automatically charges the attached batteries. When solar panels create more electricity than the system needs, the inverter will charge the batteries. In the evening (or during foggy days), power is pulled from the batteries, optimizing self-consumption. The grid will only be utilized as a "top-up" or last option. (Ashok, 2019)

Backup Power

During a blackout, a grid feed system disconnects from the grid - not generating any power either for the grid or the supply of the property. The self-consumption update, as mentioned above (zero export system), will feed the system until a custom determined threshold is reached and then cut off. (Ashok, 2019)

3. DETERMINATION OF COMPONENTS

3.1. Roadway Selection

It is the selection of the first and most important criteria that make up our project. While choosing the road, many criteria such as the road to be chosen are suitable for the placement of solar panels, the presence of small roughnesses, and as little wind as possible was taken into consideration. While choosing our project, it was considered to lay solar panels on the Konya-Aksaray Road (D-300). However, by researching the internet, it was learned that the fogs formed on the Konya-Aksaray Road in winter prevented the sun's rays from coming. Less incoming sunlight causes meagre yields in winter.

Another problem is that the solid and heavy winds that occur in the autumn require the structure to be more robust. However, the more robust the structure, the higher the cost. After reaching these data, it was abandoned to choose the Konya-Aksaray Road. Interviewed with a logistics company from Gebze and asked where Turkey's smooth and bad roads are. The logistics company offered our group the Izmir-Aydin route. Searching for the İzmir-Aydın Road on the internet has been done. It was concluded that the İzmir-Aydın Road is a more suitable route for our project, since the İzmir-Aydın Road is longer in the daytime than the Konya-Aksaray Road in the day-night cycle, and it is quieter in winter than the Konya-Aksaray Road. Moreover, the wind is blowing lighter. The disadvantages of Izmir aydın road are that traffic accidents are more than other roads. The probability of these accidents damaging the solar panel system is relatively high. It was concluded that the system to be built should be designed according to accident risks.

Figure 10. İzmir-Aydın Road

3.2. Solar Panel Selection

This project uses Elin Energy's Sirius 182M model monocrystal 550 Wp panels. These panels have dimensions of 2279*1134 mm2 and weigh 27 kg for each. Besides, it can work up to 1500 V dc voltage and 25 A maximum current value. This brand and panel model had been chosen because when existing solar power plants were investigated, it was realized that this brand and model had been used in most of them. Besides, when the values of this panel were compared with other existing brands and models, it was realized that the solar panel that chosen had better values and was more resistant for long-term usage.

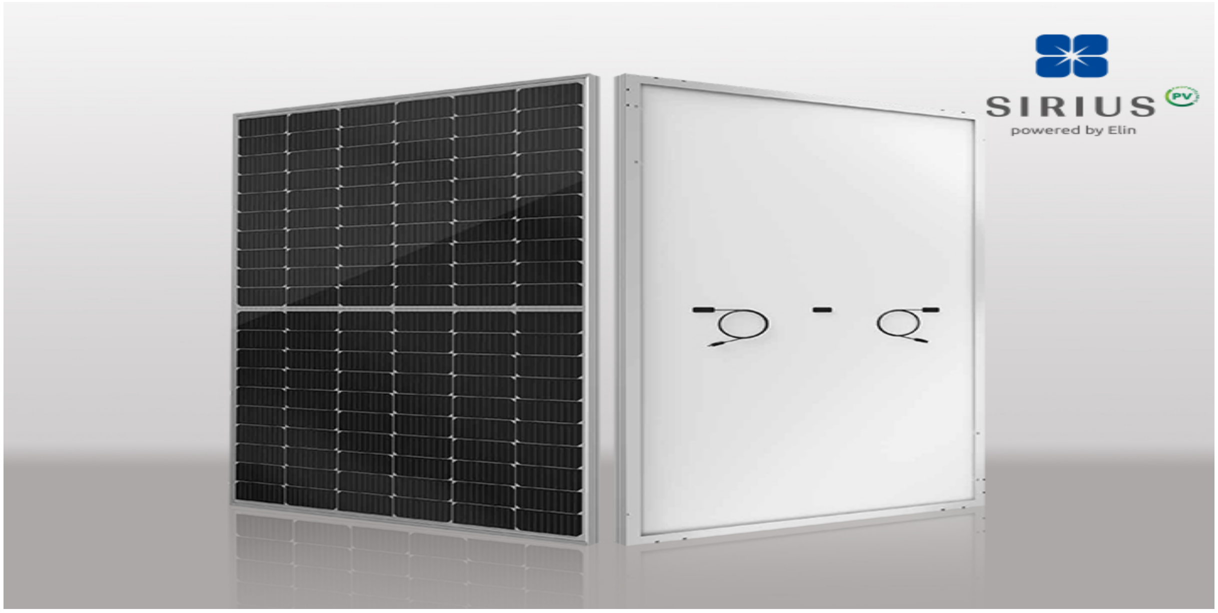

Figure 11. Sirius Monocrystal Pv Panel

3.3. Construction Material Selection

The choice of construction material is one of the most important steps. The skeleton on which the panels will stand must meet the necessary conditions. Details of construction material will be given in static calculation chapter with reasons and results.

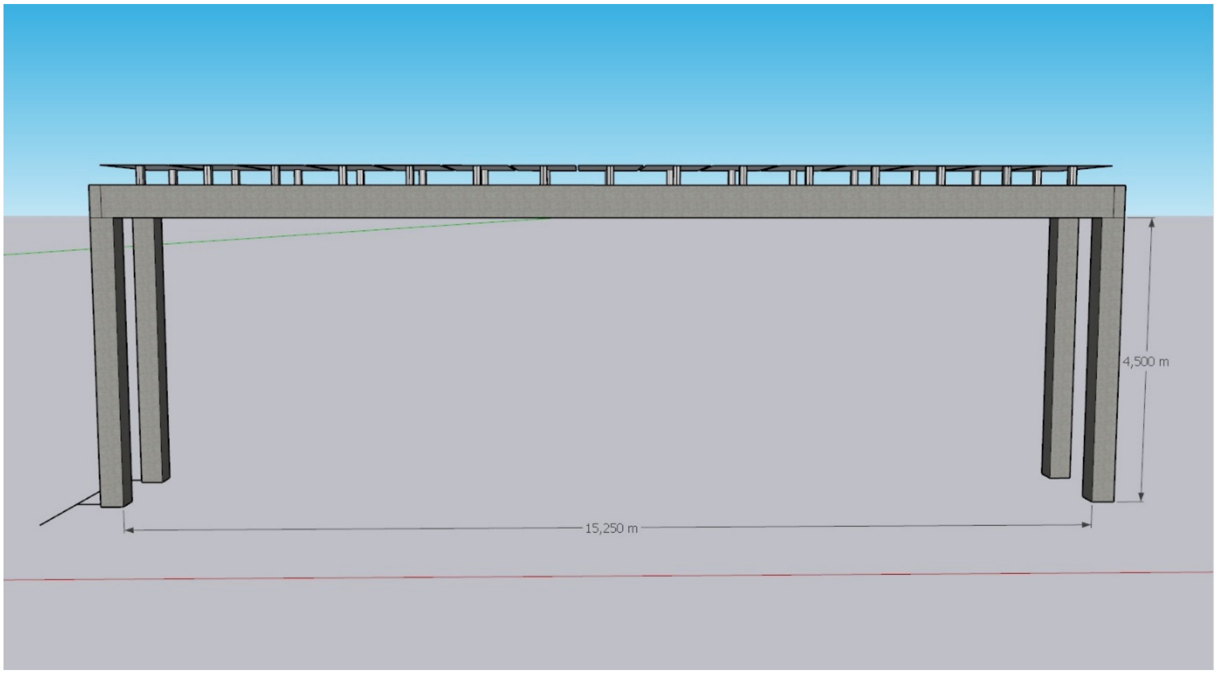

Figure 12. Drawn Skeleton and Dimensions

The selected Izmir-Aydin highway is 15.250 m wide. The height determined by the General Directorate of Highways is 4.5 m. The built skeleton should be made in these dimensions and it should be in a structure that can support the weight of the panel and other components for many years. In addition, an extra weight should be taken into account in case of any collapse or accident during maintenance. When these weights are calculated according to the selected components, it should carry a weight of about 240 kg. As a building material that meets all these conditions, the first thing that comes to mind was reinforced concrete. However, it should be investigated whether there is a cheaper material in terms of construction and material costs. It is necessary to apply to experts for the selection of construction material.

3.4. Cable and Other Connection Materials Selection

3.4.1. Inverter

In this project, SMA brand has been chosen as an inverter brand due to its recognition and one of the best inverter brand all around the world. Since the planning and drawing of the project have not been completed yet, model and capacity of inverter have not been decided. Further decisions will be taken according to the progress of the project.

Figure 13. SMA Brand Inverter

3.4.2. DC-AC Cables and Cable Tray

The Oznur cable brand was chosen for the DC-AC cable need for this project due to its worldwide popularity and widespread use among solar power plants. For cable trays, the EAE Electricity brand will be used. After associated calculations for power and energy needs are completed, the quantities of cables and trays will be determined.

Figure 14. Example of a Cable

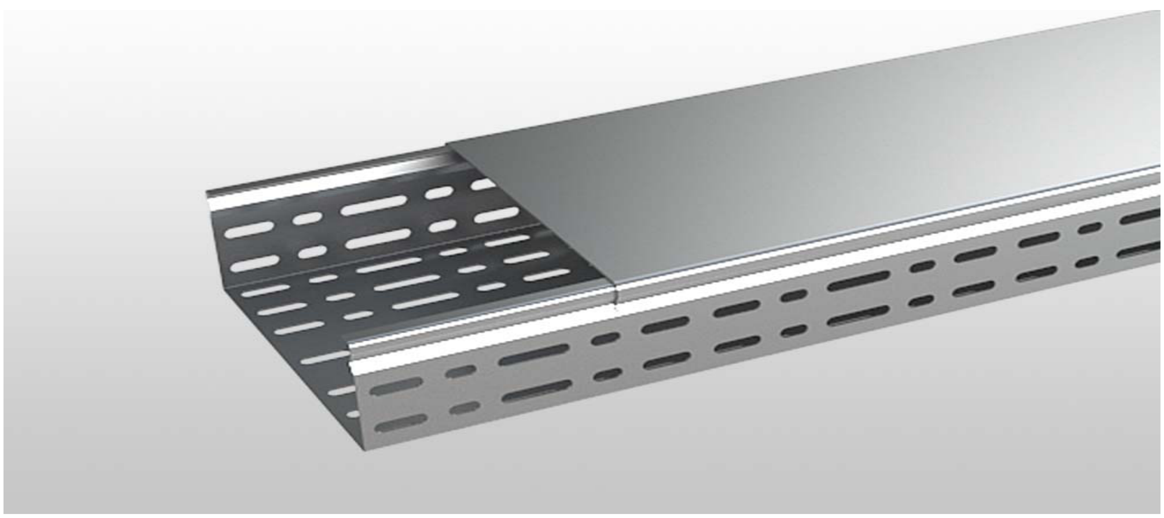

Figure 15. Cable Tray

3.4.3. Solar Panel Construction Materials

The ISOTEC brand ISOFLAT S13 models and it's mounting components were chosen to hold the panels on top of the skeleton. The rationale for selecting this brand and model is that, based on our study, it was discovered that this brand and model have been utilized in practically every solar power plant in a variety of conditions. Since resistance is so vital for the project, and solar panels are the most significant component, the most efficient approach is required.

Figure *16.* ISOTEC Material Example

4. DRAFT DRAWING OF THE PROJECT

After the component was determined, an idea was formed about the shape of the skeleton and the positioning of the panel.

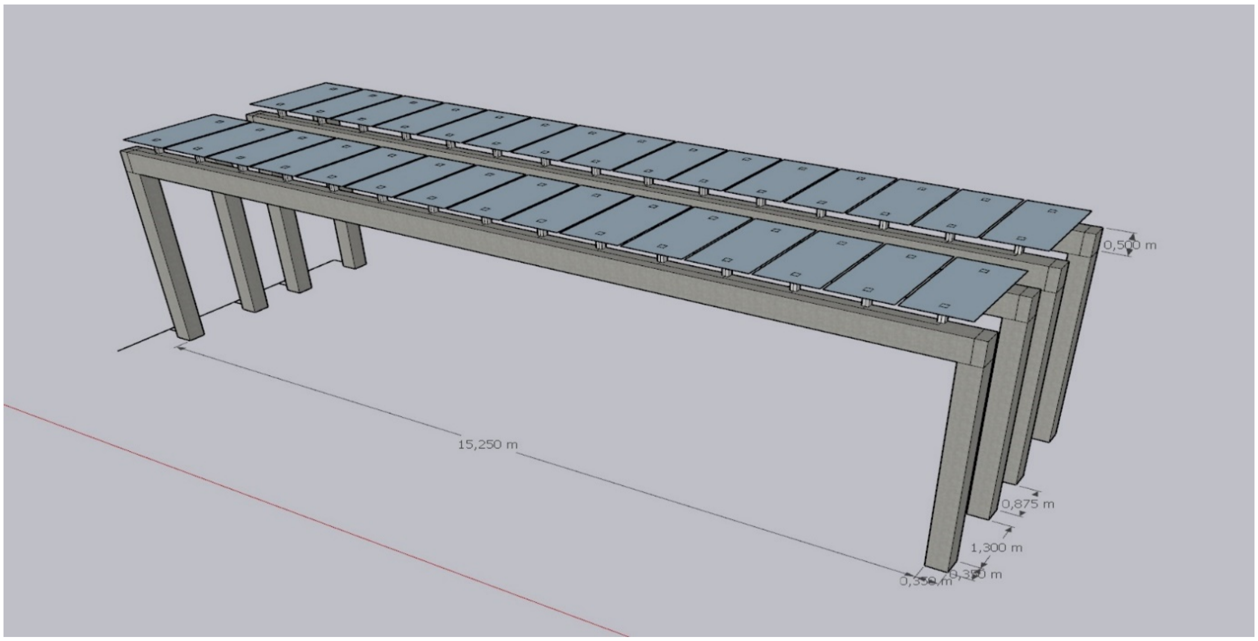

Figure 17. Draft Drawing Example 1

The legs of the skeleton were set as square with sides 0.35 m long. The upper part of the skeleton, that is, the floor where the panels will be placed, was adjusted 0.50 m thick. There was incomplete information in the selection of construction materials. Therefore, the building material was temporarily determined as reinforced concrete. It was envisaged that the panels would be attached with two supports along the long side. Since panels with a length of 2 meters and a width of 1 meter were chosen, the distance between the 2 skeletons was adjusted to 1.30 m. Finally, the skeletons were positioned at a distance of 0.875 m from each other. The reason for keeping this distance short is to provide convenience during maintenance. Depending on the width of the road, a total of 15 panels were placed on top of the 2 skeletons. In line with these temporary decisions, a temporary drawing consisting of 17 rows and 255 panels was made.

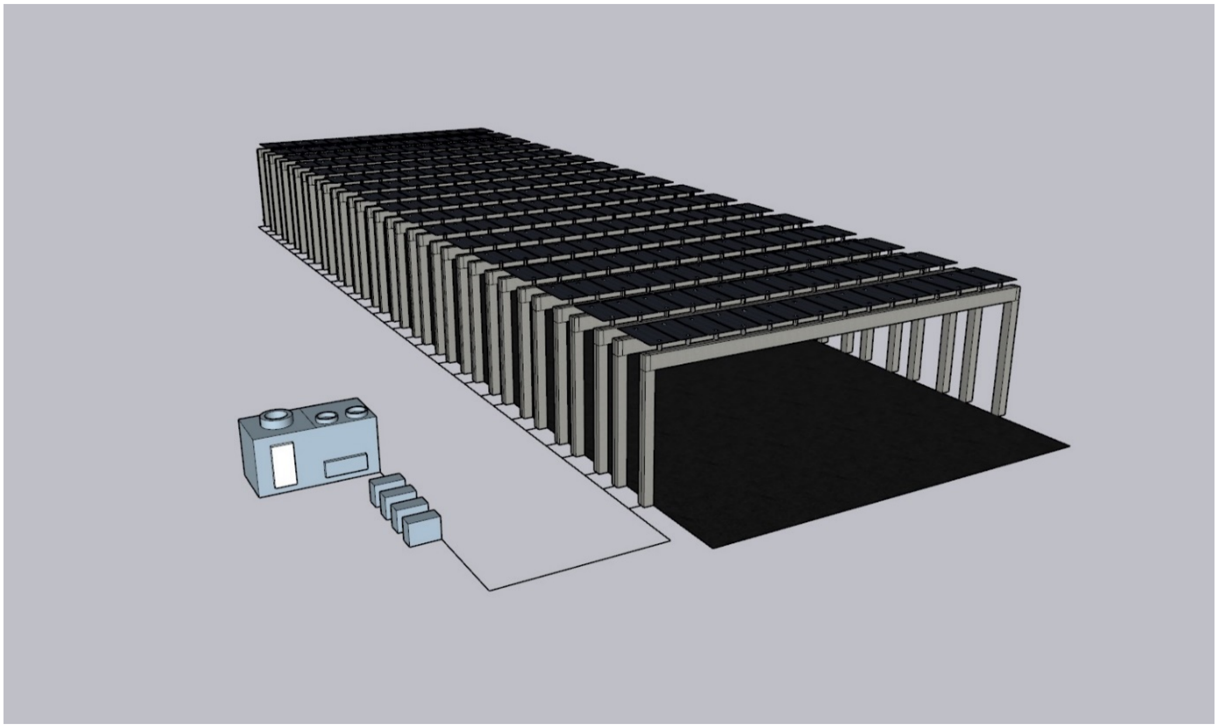

Figure 18. Draft Drawing Example 2

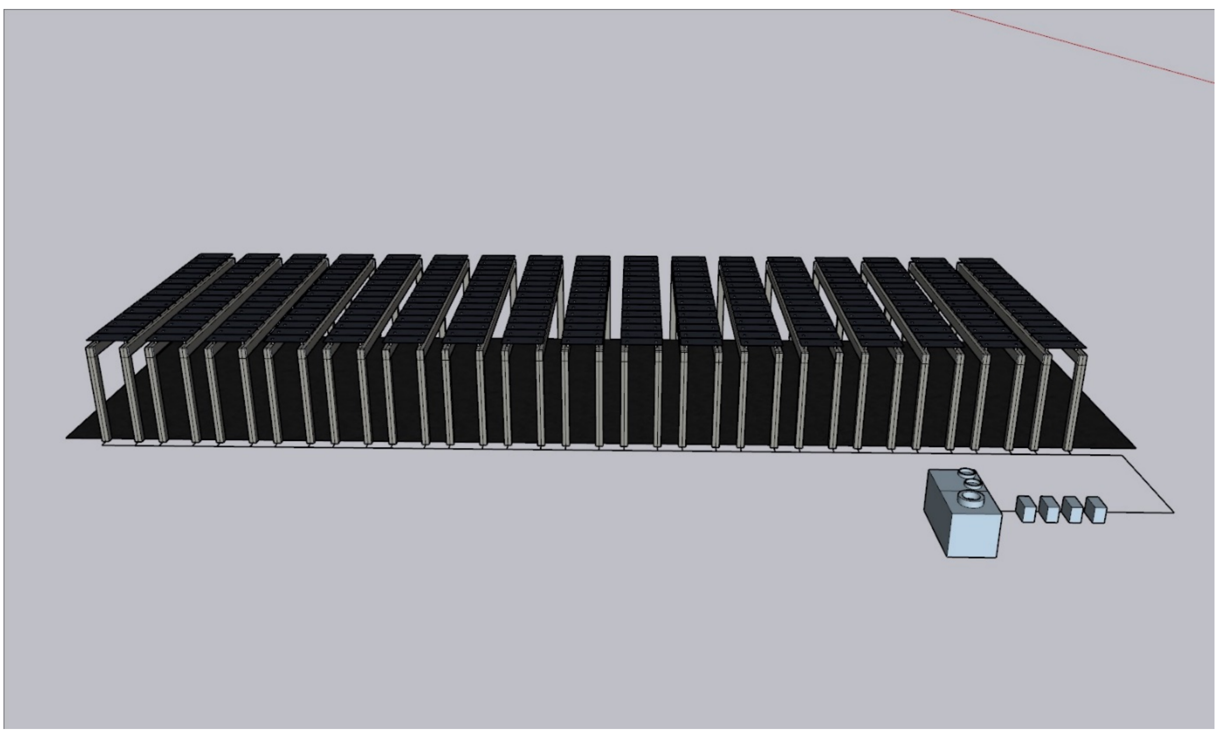

Figure 19. Draft Drawing Example 3

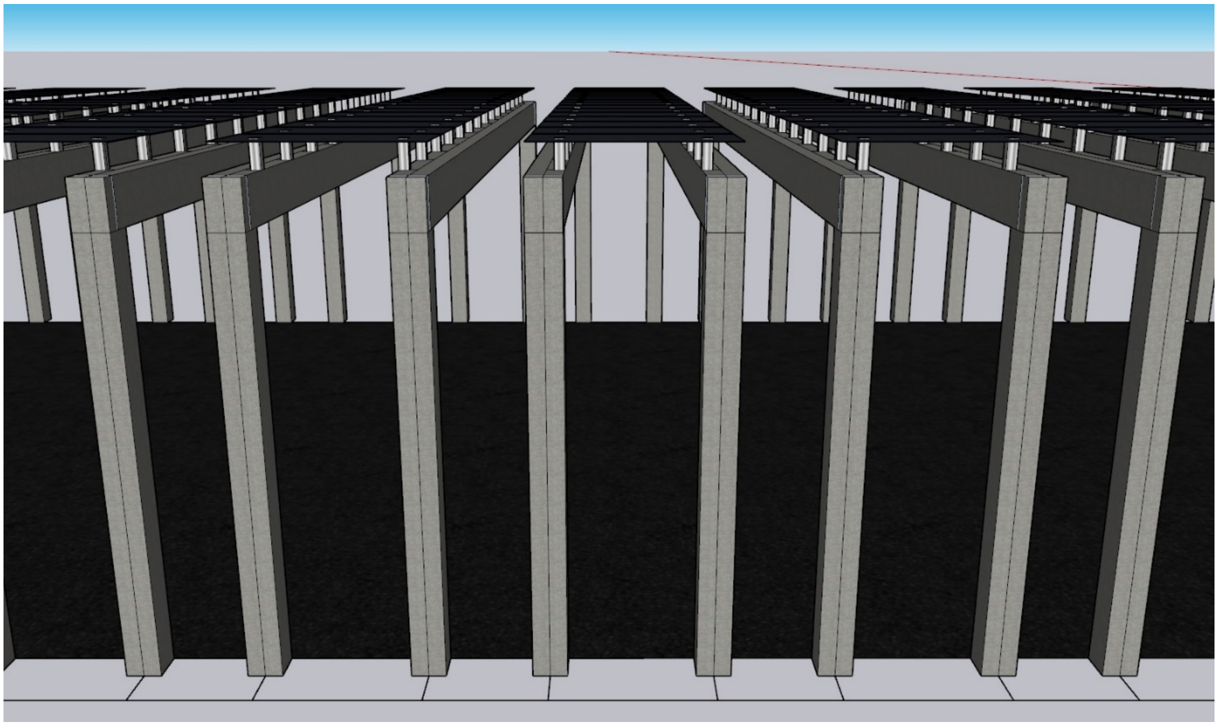

Figure 20. Draft Drawing Example 4

5. STATIC MEASUREMENT OF THE PROJECT

As it was mentioned in chapter 3. Details about choosing construction materials and static measurements will be given in details on this part.

As described in previous chapter. Draft drawing of the project has been made in accordance with the data and knowledges gathered by research. In order to come up with an exact and the most suitable design for the project, it was decided to consult a Civil Engineering and made significant changes in design. Changes are illustrated in figure 22 and 23.

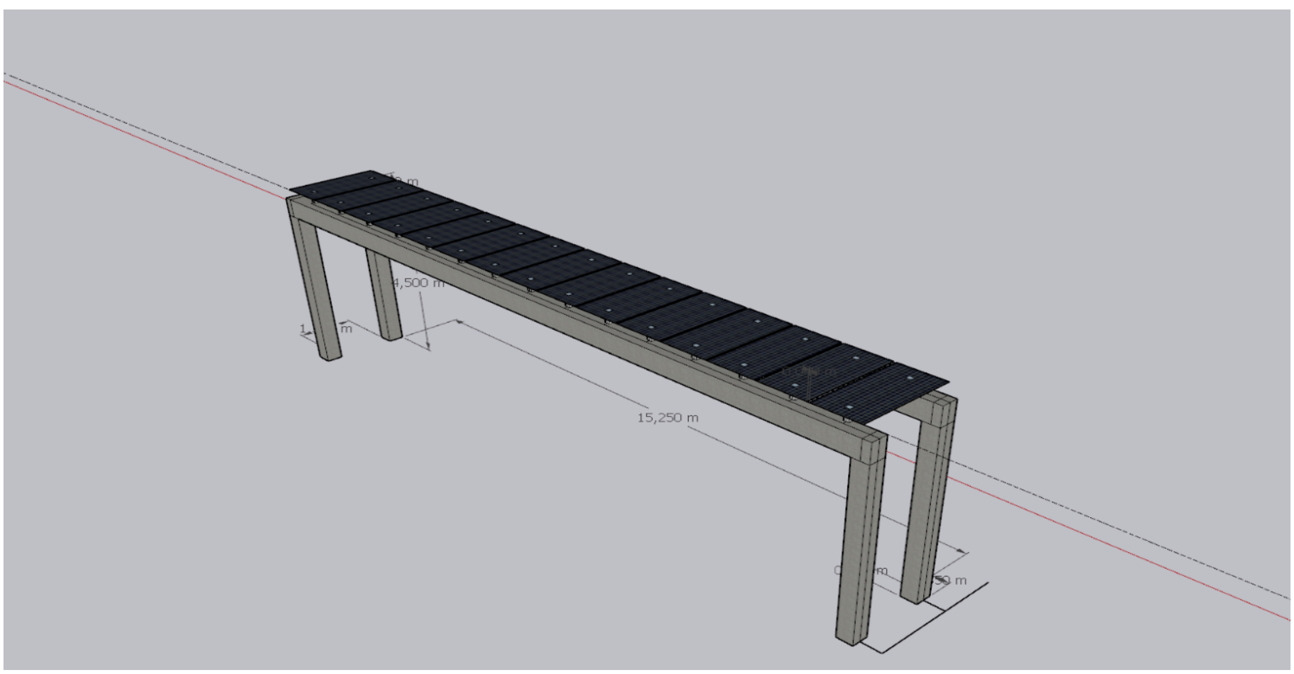

Figure 21. First Design of Skeleton

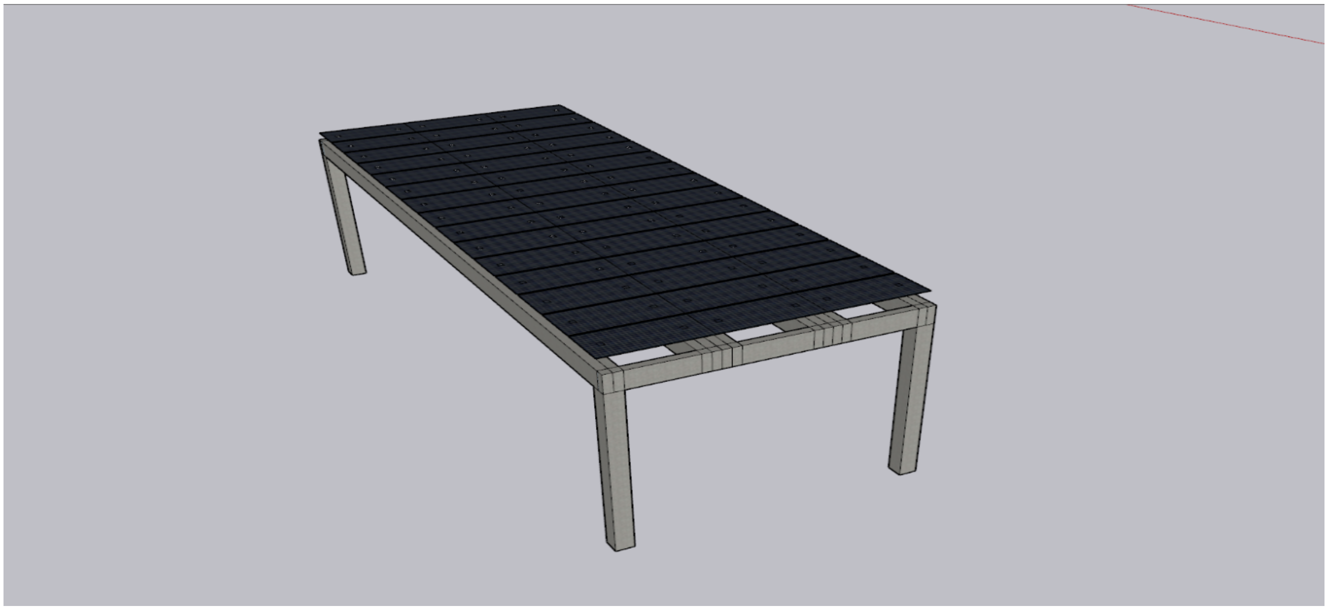

Figure 22. Updated Design of Skeleton

In new design, main changes were made at construction where panel strings are placed. As it can be seen in figure 22 and 23, settlement for each construction has been changed. While 15 panels (1 string) were planned to be mounted for each construction, it was ended up with a decision that it will be not cost-effective for the project. Instead, it was decided to modify draft construction into new construction model which has capacity to mount 45 panels (3 strings). Decision of new design has been made by calculating static endurance of the materials and most-effective fiat capabilities.

5.1. Material Selection

During the material selection and static calculations, SAP2000 "Static and Dynamic Finite Element Analysis of Structures" Version in analysis and design of structures 21.0. Structural analysis program was used. TBDY 2018 in sizing and detailing the building. The rules and controls given in Design, Calculation and Construction Principles of Steel Structures -2016, AISC-360-10 were made. Load and Strength Factors (YDKT) and Design Method were used in the design of steel elements. Columns, beams, purlins and braces in the building system were modeled as "rod -

frame" elements. The system has 6 degrees of freedom and the nodal points and directional assumptions of the rod elements are given below:

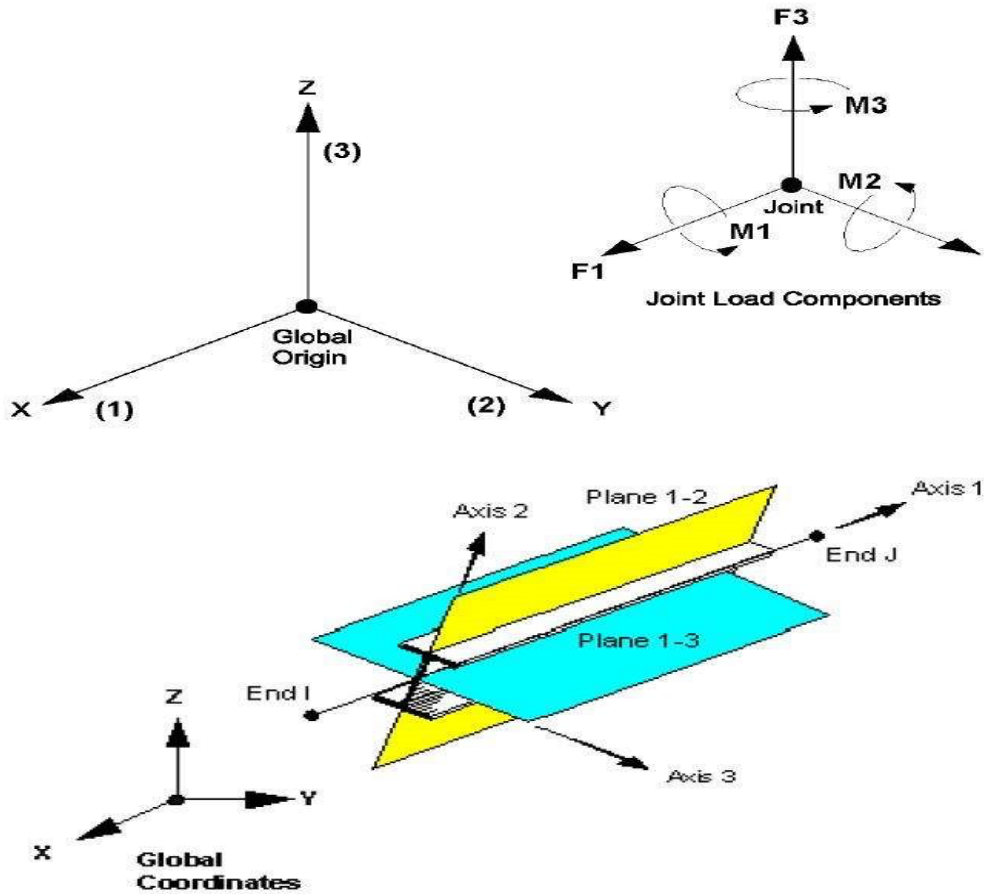

Figure 23. Rod Elements

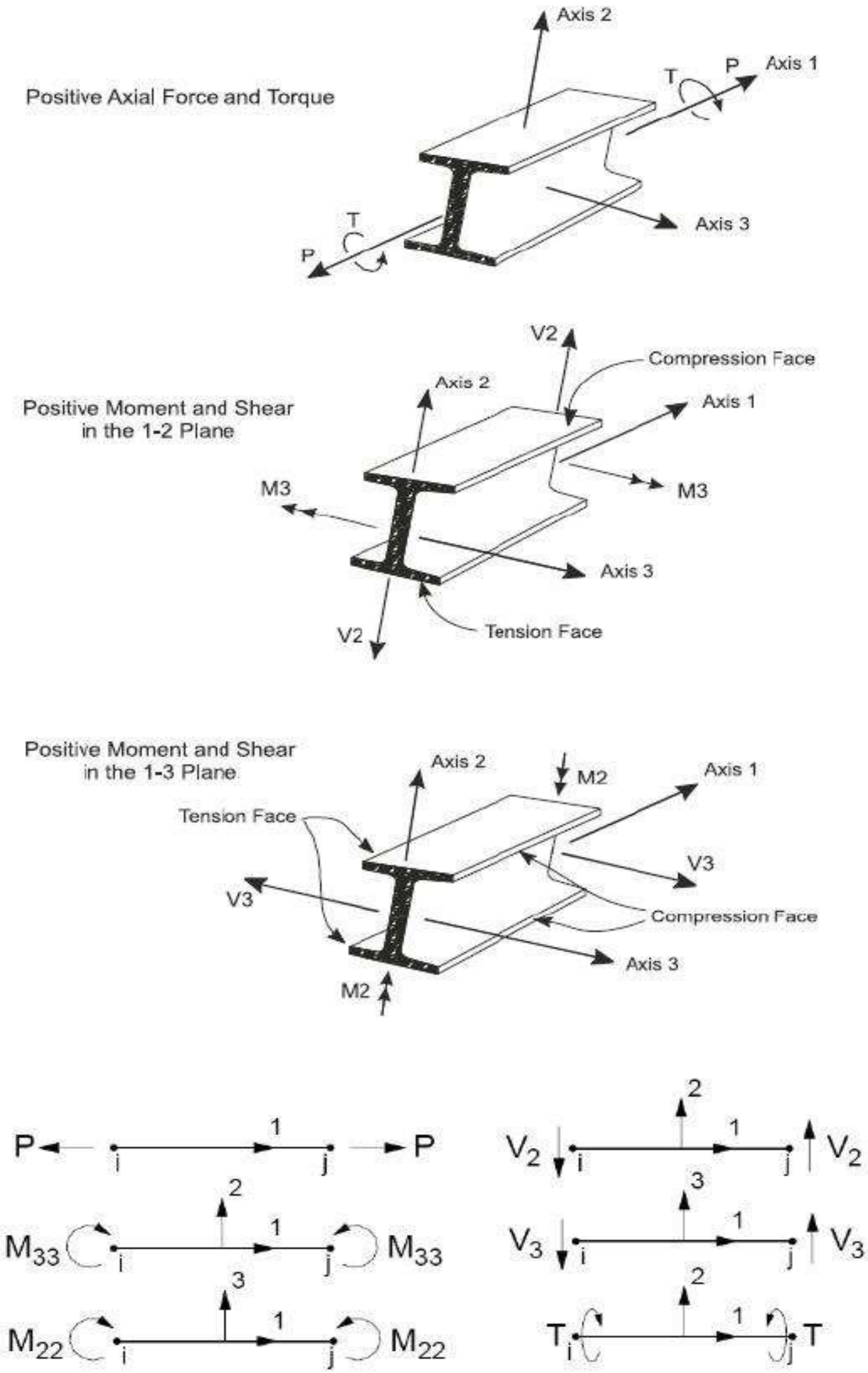

Figure 24. Rod Elements 2

As steel profile, S235JR (St37-2),S275JR (St44-2) type steel has been decided for usage. For Steel plates, C30/37 type concrete and S420a (BCII) type reinforcing steel will be used and material properites are given below;

S235JR (St37-2)		
Yield strength	235	N/mm^2
Tensile Strength	360	N/mm^2
Modulus of Elasticity	210000	N/mm^2
Poisson Ratio	0.3	
Coefficient of thermal elongation	0.000012	1/K

S275JR (St44-2)		
Yield strength	275	N/mm^2
Tensile Strength	440	N/mm^2
dulus of Elasticity	210000	N/mm^2
Poisson Ratio	0.3	
Coefficient of thermal elongation	0.000012	1/K

C30/37 Concrete Reinforcement Features:

C30 / 37 Concrete		
Density	2.5	t / m3
Characteristic Cylinder Pressure Strength (150mmx300mm)	30	N / mm^2
Equivalent Cube Pressure strength (150mmx150mm)	37	N / mm^2
Material Coefficient	1.5	
Design Compressive Strength	20.0	N / mm^2
Characteristic Axial Tensile Strength	1.92	N / mm^2
Axial Tensile Design Strength	1.278	N / mm^2
Modulus of Elasticity	31801	N / mm^2

S420a (BÇIII) Reinforcement Features:

Density	7.85	t / m3
Minimum Yield Limit	420	N / mm^2
Maximum Yield Limit	500	N / mm^2
Material Coefficient	1.15	
Design Tensile Strength	365.2	N / mm^2
Modulus of Elasticity	200000	N / mm^2

5.2. Static Measurement Displays

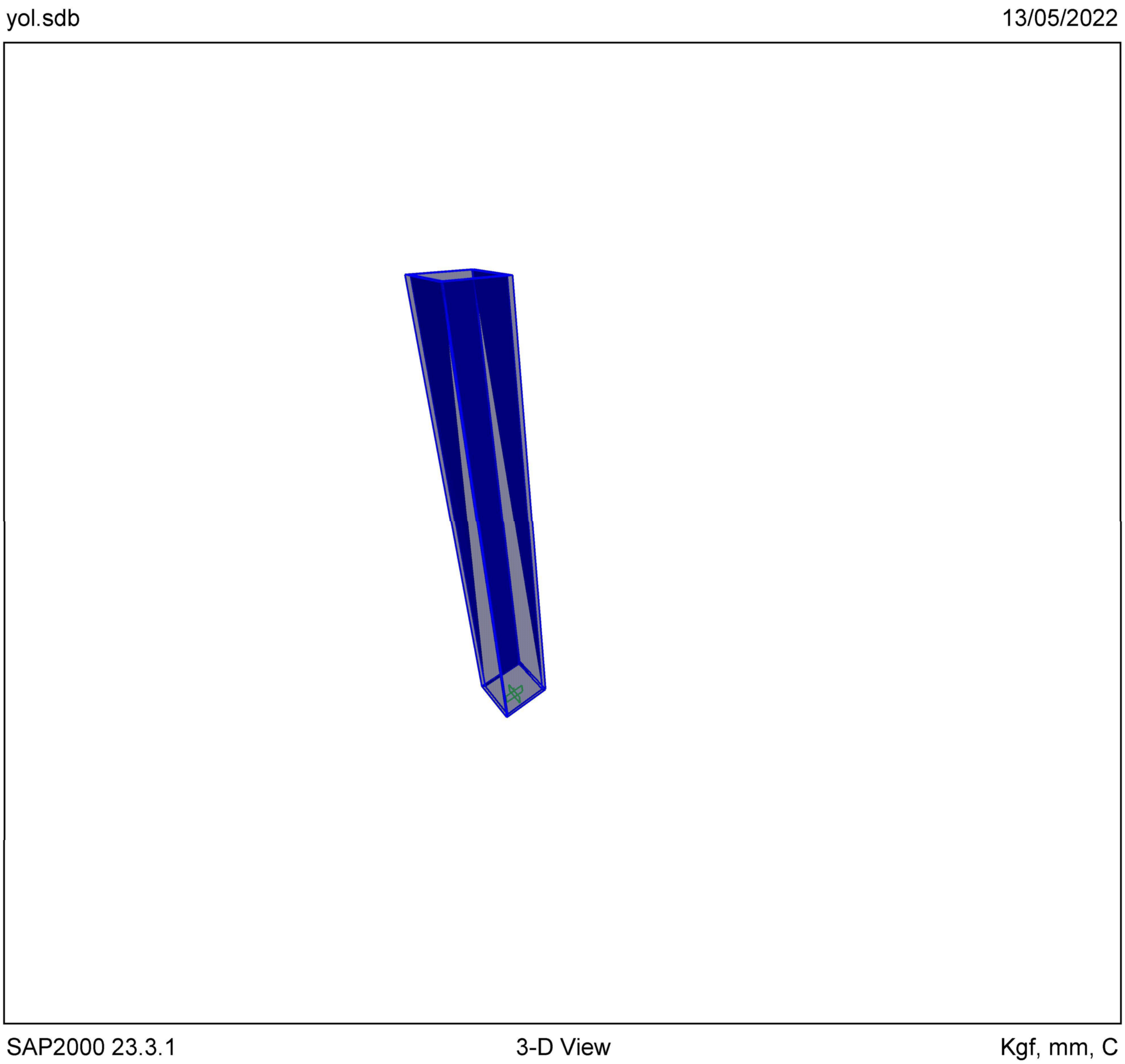

Figure 25. Display 1

6. FEASIBILITY STUDY OF THE PROJECT

6.1. Calculations Regarding Energy Generation

In order to be able to ensure fesaibility studies for this Project. Annual energy production of overall system and other significant values should be taken into account.

As we mentioned in chapter 5. In new design, each construction will carry 45 panels (3 strings) over 4 feet structure. Since we have 7.19m width for each construction, it was planned to compose a system which have 198 kWp installed power and consist of 360 solar panels (8 construction will be aligned sequently). In the end, Project will have 57,52 m total width.

Firstly, while determining the width of the Project, it was necessary to obtain annual porduction data of the system that makes the Project as feasible as possible. As it seen in figure 1,annual production data for the system have been gathered from PVGIS website. By taking into account all factors may influence feasibilty calculations, we have assumed some values for total installed power to be able to obtain annual energy production data.

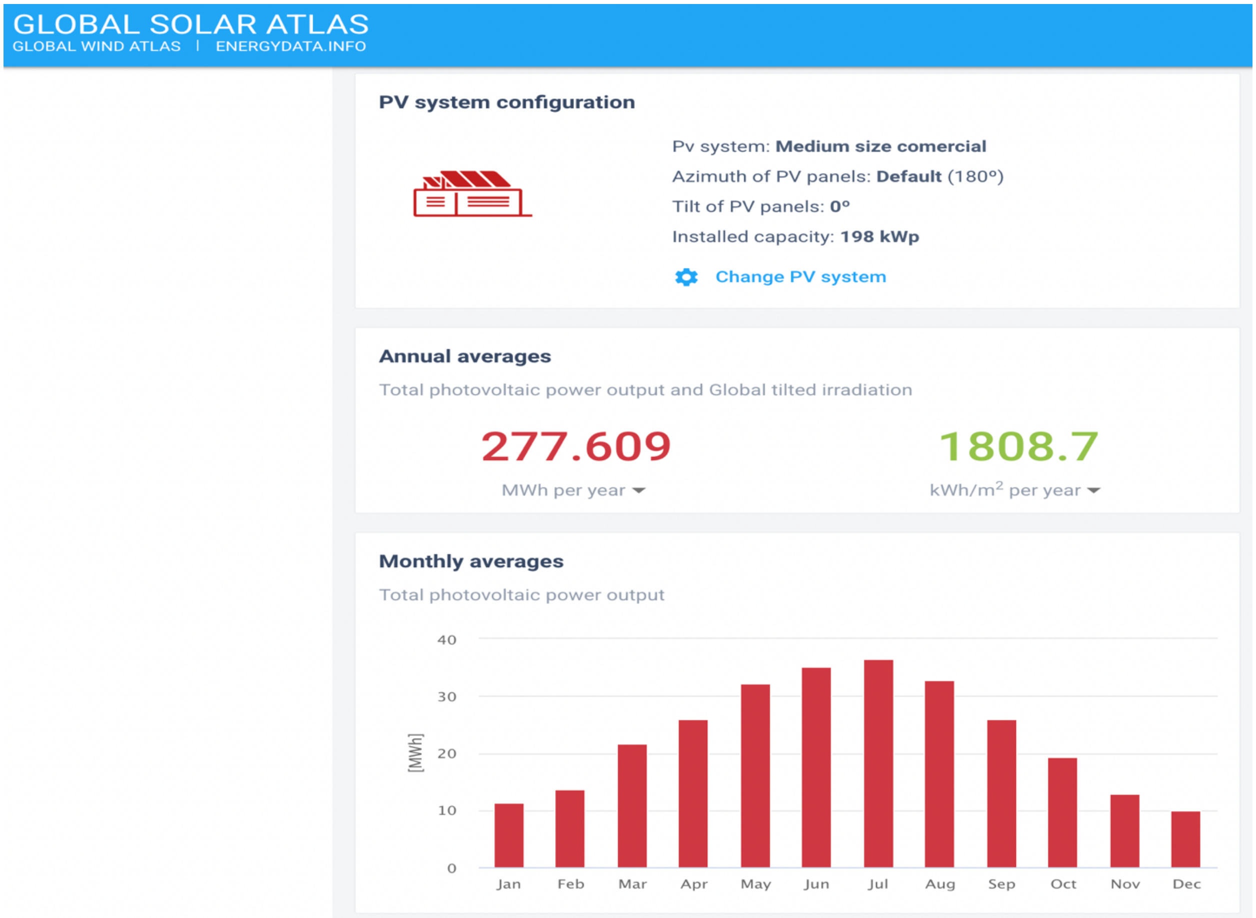

Figure 26. Data gathered by Global Solar Atlas Website

As a result, the system that has 198 kWp installed power can generate 277.609 MWh annual average energy per year. Steps of calculations are given below,

$$E = A \times r \times H \times PR$$

E stands for energy (kWh), **A** stands for total panel area (m^2), **H** stands for yearly average solar radiation on slanted panels, and **PR** stands for performance ratio, which is a constant for losses (ranges between 0.5 and 0.9, default value = 0.75). **r** is the solar panel yield, which is calculated by dividing the electrical output (in kWp) of one solar panel by the area of one panel.

6.2. Important Ratios for Calculating Annual Production

Incoming Radiation to the Horizontal Plane (kWh/m2): This is the value calculated using meteorological data observed and recorded in the simulation software from the past to the present. As new versions of the application are released, this value is updated. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Global Radiation to Solar Panel Surface (kWh/m2): It shows the gain or loss to be obtained according to the mounting angle of the panel. For example, for our country located in the Northern Hemisphere, this value is higher in panels placed at an appropriate angle to the south. While going up to the levels, this gain may decrease or even be a negative value depending on the low full slope or the change in the direction of the panels. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Radiation Loss Due to Shading: It shows the losses caused by shading that may occur in the facility according to the angle of the sun. In the report, this value is 2.5%. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Angle Reflection Factor: Every radiation coming to the panel surface cannot be absorbed by the cells. While most of the incoming radiation is absorbed inside the panel, some of it is reflected. For this reason, it shows the losses caused by the reflected beam according to the panel mounting angle over the incident spherical radiation. These losses also represent optical losses. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Panel Pollution Loss: It refers to a loss that may vary depending on the location of the plant. It symbolizes the energy that the panels cannot produce during the year due to the pollution on the panels on a percentage basis. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Radiation-Related PV Losses: It shows the losses caused by the radiation coming on the PV panels. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

PV Losses Due to Temperature: The voltage produced by the PV panels is inversely proportional to the temperature. That is, at the same amount of radiation, in colder weather, the arrays of identical PV panels generate more voltage than those in the cold environment. Since the starting voltage of the inverters differs from each other, the starting time of the system in the morning also differs accordingly. This value shows the percentage of electricity loss due to time differences. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Panel Efficiency Loss: It refers to the loss in efficiency of PV panels over time. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

LID (Light Induced Degradation) Loss: It shows the degradation rate that will occur in PV panels due to radiation. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Array Mismatch Loss: It is highly unlikely that all solar panels will have the same current and voltage value in the PV arrays created. The current value of the array is determined by the PV panel with the lowest current value connected in series on the array. In such a case, a potential loss of production will occur in panels with a current value greater than the current value in question. The corresponding value indicates this loss. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

DC Cable Loss: It shows the losses of the cables used on the DC side. This value differs according to the length, cross-section and conductor type of the cable. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Inverter Operating Losses: As with every machine, the inverter also has a certain efficiency.

has. These losses show the electrical energy that cannot be produced due to the inverter efficiency. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Inverter Overload Losses: When inverters are loaded with a DC power capacity above their AC output capacity, the energy that can be produced at certain time intervals may turn into a loss. This value shows the losses that will occur at such times. This value may vary depending on the system design. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Inverter Power Threshold Losses: It represents the loss that will occur if the power threshold value is exceeded or under the technical specifications of the inverter. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Inverter Over Rated Voltage Losses: String voltages that vary depending on the temperature may be below or above the nominal value at certain times. The energy loss that will occur at these times is indicated in this way. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Inverter Voltage Threshold Losses: It shows the inverter-induced losses, which are specified within the scope of the inverter technical specifications. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Obtainable Energy at Inverter Output: It shows the electrical energy expected to be produced at the inverter output. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

AC Wiring Losses: It refers to the amount of loss of electrical energy produced after the inverter due to AC cables. This value varies according to the cable cross-section, quantity and type of cable conductor used. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

External Transformer Losses: Losses caused by the transformer's own internal consumption symbolizes. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

Energy Transferred to the Grid: To be transferred to the grid after deducting the relevant losses shows electrical energy. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

6.3. Energy Consumption Calculation of the System

Since LED lightings will be used in this Project. Annual usage of LEDs (in kWh) will be extracted from Total annual production.

For LED lighting, *"TechBrite 48" 3 Lamp LED T8 Strip Fixture - 4000K - 7,500 Lumens*" brand has been choosen. The reason why this brand was chosen is that providing higher amount of lumens compared to consumption rate (W). So that System could have better illumination rates when the sun goes down.

Since the data that was gathered by LED lihgtings datasheet, it was obtained that each LED will have a consumption of 55.5 W of each. It was planned to place 80 LEDs in total (10 LEDs for each construction part will be aligned as group of 5). Total annual consumption of the system is calculated below;

$$\boldsymbol{4,400\,kW \times 6h \times 30\,days \times 12\,Month = 9,504.000\,kWh}$$

4,400 kW represents instant power capacity of total system, 6h represents Daily average working hours of LEDs.

After determination of annual energy production and consumption, Total income by energy should be quantified to have the explanation in terms of finance.

Since electricity price data per kWh and distribution fee are known by document published by EPDK shown in figure 2 and the system only have consumption due to LEDs. It is calculated by multipliyng annual average energy consumption of LEDs (kWh) with electricity price per kWh. The system is included into "business" tariff according to EPDK instructions. Electricity sale and distribution prices are taken by "business" tariff. (Şimşek & Bizkevelci, 2022)

EPDK Tarafından Onaylanan ve 1 Haziran 2022 Tarihinden İtibaren Uygulanacak Faaliyet Bazlı Tarifeler										
	1/6/2022	Faaliyet Bazlı Tüketici Tarifeleri (kr/kWh)					Güç Bedeli Hariç Toplam Tarifeler (kr/kWh)			
İletim Sistemi Kullanıcıları	Görevli Tedarik Şirketinden Enerji Alan İletim Sistemi Kullanıcıları	Perakende Tek Zamanlı Enerji Bedeli	Perakende Gündüz Enerji Bedeli	Perakende Puant Enerji Bedeli	Perakende Gece Enerji Bedeli	Dağıtım Bedeli	Tek Zamanlı	Gündüz	Puant	Gece
	Tüketici	245,3607	248,3693	392,2113	132,2746	0,0000	245,3607	248,3693	392,2113	132,2746
Dağıtım Sistemi Kullanıcıları	Dağıtım Sistemi Kullanıcıları	Perakende Tek Zamanlı Enerji Bedeli	Perakende Gündüz Enerji Bedeli	Perakende Puant Enerji Bedeli	Perakende Gece Enerji Bedeli	Dağıtım Bedeli	Tek Zamanlı	Gündüz	Puant	Gece
		Orta Gerilim					Orta Gerilim			
		Çift Terimli					Çift Terimli			
	Sanayi	248,3714	251,3801	395,2221	135,2853	14,7972	263,1686	266,1773	410,0193	150,0825
	Kamu ve Özel Hizmetler Sektörü ile Diğer	230,2455	232,5236	363,0085	128,7021	23,0611	253,3066	255,5847	386,0696	151,7632
	Mesken	152,9207	155,4131	246,1925	82,8186	22,8419	175,7626	178,2550	269,0344	105,6605
	Tarımsal Faaliyetler	157,6777	159,2914	251,4048	85,6839	18,9925	176,6702	178,2839	270,3973	104,6764
	Aydınlatma	212,2218				22,1336	234,3554			
		Tek Terimli					Tek Terimli			
	Sanayi	256,6870	259,8001	408,5735	139,7250	16,3448	273,0318	276,1449	424,9183	156,0698
	Kamu ve Özel Hizmetler Sektörü ile Diğer	235,0787	237,3568	367,8417	133,5347	28,7660	263,8447	266,1228	396,6077	162,3007
	Mesken	154,5685	157,0611	247,8392	84,4656	28,2039	182,7724	185,2650	276,0431	112,6695
	Tarımsal Faaliyetler	159,7360	161,3497	253,4633	87,7413	23,6477	183,3837	184,9974	277,1110	111,3890
	Aydınlatma	216,7131				27,6100	244,3231			
		Alçak Gerilim					Alçak Gerilim			
		Tek Terimli					Tek Terimli			
	Sanayi	262,2851	265,2400	406,5304	151,2050	25,2888	287,5739	290,5288	431,8192	176,4938
	Kamu ve Özel Hizmetler Sektörü ile Diğer (30 kWh/gün ve altı)	174,6438	246,0159	376,5007	142,1943	34,2716	208,9154	280,2875	410,7723	176,4659
	Kamu ve Özel Hizmetler Sektörü ile Diğer (30 kWh/gün üstü)	243,7383	246,0159	376,5007	142,1943	34,2716	278,0099	280,2875	410,7723	176,4659
	Mesken (8 kWh/gün ve altı)	95,5452	161,7720	252,5509	89,1764	33,5187	129,0639	195,2907	286,0696	122,6951
	Mesken (8 kWh/gün üstü)	159,2790	161,7720	252,5509	89,1764	33,5187	192,7977	195,2907	286,0696	122,6951
	Şehit Aileleri ve Muharip Malul Gaziler	38,7776				22,7335	61,5111			
	Tarımsal Faaliyetler	164,3828	168,6088	258,1106	92,3882	28,1603	192,5431	196,7691	286,2709	120,5485
	Aydınlatma	224,9134				32,8247	257,7381			
	Genel Aydınlatma	204,7600				32,8247	237,5847			

Figure 27. Electiricty Price Data by EPDK

Since the system have 9,504.000 kWh annual consumption due to LEDs. Total price of consumption that will be extracted from electricity generation income is calculated according to the formula below;

$$\boldsymbol{Annual\ Consumptions\ by\ LEDs\ (KWh) \times (tariff\ price\left(\frac{kurus}{kWh}\right) + \ distribution\ fee(\frac{kurus}{KWh}))}$$

$$\boldsymbol{9,504.000\ kWh\ \times \left(235.0787\ \left(\frac{kurus}{kWh}\right) + 28,766\ \left(\frac{kurus}{kWh}\right)\right)\ = 25,075.000\ TL}$$

6.4. Overall Income by Electricity Generation

After calculating the entire result of electricity use. It is required to calculate the entire revenue generated by the system.

According to EPDK's recently published electricity sales pricing database (shown above), the sale price for each kWh for unlicensed solar systems is 206,312 kurus/kWh (energy price-distribution charge) (Şimşek & Bizkevelci, 2022). The total income from the system's electricity generation is determined using the formula below:

$$\boldsymbol{Annual\ energy\ generation\ (KWh) \times Degredation\ and\ other\ loss\ factors\ \times 206.312\,\frac{kurus}{KWh}}$$

Because solar panels lose efficiency over time due to the variables described above, power output rates will fluctuate and deteriorate year after year. The calculations were done over a 25-year period because the typical life-cycle of solar panels is 25 years.

Finally, total energy production and income have been estimated and shown below, year by year.

Installed Capacity	198	kWp
Annual Average Production	277,609.000	MWh
Annual Module Losses	0,01	
Sale Cost of Electricity per kWh	206,312	Kurus

Years	2022	2023	2024	2025	2026	2027	2028	2029
Years	1	2	3	4	5	6	7	8
Electricity Generation (Thousand MWh)	309,719574	306,6530436	303,6168749	300,6107672	297,634423	294,6875475	291,769849	288,8810386
Price (TL)	₺ 638.988,65	₺ 632.662,03	₺ 626.398,05	₺ 620.196,09	₺ 614.055,53	₺ 607.975,77	₺ 601.956,21	₺ 595.996,25
Price (USD)	$ 38.915,26	$ 38.529,97	$ 38.148,48	$ 37.770,77	$ 37.396,80	$ 37.026,54	$ 36.659,94	$ 36.296,97

Years	2030	2031	2032	2033	2034	2035	2036
Years	9	10	11	12	13	14	15
Electricity Generation (Thousand MWh)	286,0208303	283,1889409	280,38509	277,609	274,83291	272,0845809	269,3637351
Price (TL)	₺ 590.095,30	₺ 584.252,77	₺ 578.468,09	₺ 572.740,68	₺ 567.013,27	₺ 561.343,14	₺ 555.729,71
Price (USD)	$ 35.937,59	$ 35.581,78	$ 35.229,48	$ 34.880,67	$ 34.531,87	$ 34.186,55	$ 33.844,68

Total Price (TL)	₺ 14.208.505,97
Total Price (USD)	$ 865.317,05

Figure 28. Total Energy and Income Calculation

6.5. Calculations Regarding Materials

After calculating annual energy production and net income, material costs must be calculated. Because all brands and models for each material have been chosen. The following is a cost analysis for each material.

6.5.1. Solar Panels

According to market data, the average price of a solar panel varies between 0.35 and 0.55 cents per watt. The cost of each panel was found to be 305 USD because the solar panel that would be utilized in the system is 550 Wp.

360 solar panels will be utilized in the system, and the cost will be calculated as follows:

$$305\frac{USD}{Panel} \times 360\,Panel \;= 109{,}800.000\,USD$$

6.5.2. Inverters

According to market research, the average price of a 200 kW central inverter ranges from $15,000 to $20,000. To receive the most precise data for financing, the highest price will be paid.

Because the system will only use one central inverter, the inverter cost will be expected to be 20,000 USD.

6.5.3. Panel Construction Materials

According to market research, average prices of panel construction materials changes between 95 -100 USD per KWp. Since the system have 198 kWp installed capacity, system will require 19,800 USD worth construction material. Cost calculation is given below;

$$100\,\frac{USD}{kWp} \times\ 198\ kWp = 19{,}800.000\ USD$$

6.5.4. Cables

Solar cables were chosen because their voltage losses would not exceed 1% of the system's total energy output, allowing the system to use substantially more energy production. (Anıl AKAR Yüksek Lisans Tezi Elektrik -Elektronik Mühendisliği Anabilim Dal)

The table below shows the essential information for computations;

Panel Nominal Voltage	Upanel
Number of Panels in String	nSeries
String Voltage	UString
Power Losses (W)	PLoss
Conductivity (Cu=56,Al=35)	K
Voltage Loss Rate	%e
Solar Cable Carrying Capacity	ITK

String Voltage Calculation;

$U_{String} = U_{panel} \times n_{Series}$

$U_{String} = 46{,}7 \times 15$

$U_{String} = 700{,}5$ V

In the table below, pieces of information were given to construct a system that consist of 15 panels (each 550 kW) for each string that will be connected to the inverter 50 m away from the construction site.

String Power	P_{string}	8250W
String Voltage	U_{string}	700,5 V
String Current	I_{string}	11,17 A
String Cable Length	L_{string}	50 m
String Shortcut Current	I_{SC}	14 A
String Cable Cross Section	S_{DC}	6 mm2

Because the panels are linked in series, the string current and string short-circuit current are the same as the panel's string current and short-circuit current. A 8250W array may be created by connecting 15 panels in series side by side. The string voltage is calculated by multiplying the nominal voltage of each panel in the string by the number of panels in the string. Copper solar wires with a 6 mm2 cross section have been chosen.

$PLoss = 2 \times Lstring \times Istring2 / SDC \times K$

$PLoss = 2 \times 50 \times 11{,}17 / 6 \times 56$

$PLoss = 37{,}13$ W

According to this finding, a 15-array with a distance of 50 m from the inverter will have a DC cable loss of 37.13 W. The voltage drop in this wire is computed using the calculation below:

$\%e = Lstring \times Istring / S_{DC} \times U_{String} \times K$

$\%e = 2 \times 100 \times 50 \times 11{,}17 / 6 \times 700{,}5 \times 56$

$\%e = 0{,}47$

Since 0.47 < 1, it is appropriate to use a 50 m long 6 mm2 solar cable. Current carrying capacities of solar cable sections are specified below;

Boyut ve Ağırlıklar				Elektriksel Bilgiler				
					Akım Taşıma Kapasitesi			
Nominal Kesit	Dış Çap Yaklaşık	Net Ağırlık Yaklaşık	1000 m Kablo İçin Sevk Makara Ölçüleri	20° C' de İletken DC Direnci (Maks.)	Toprakta (A)		Havada (A)	
mm²	mm	kg/km	cm	ohm/km	●●●	∴	●●●	∴
1x4 re	6,5	70	70	4,61	66	55	56	40
1x6 re	7,0	90	70	3,08	82	68	71	53
1x10 rm	8,5	130	70	1,83	109	90	100	74
1x16 rm	9,5	195	80	1,15	139	115	135	100
1x25 rm	11,0	290	90	0,727	179	149	180	133

Figure 29. Cable Properties

In line with the solar cable catalog information, the current carrying capacity for the 6 mm2 cable to be used in the project is 82A.

Since the system will consist of 24 strings, necessary amount of cable calculation is given below;

$$50\ \mathrm{m}\,\frac{\mathrm{cable}}{\mathrm{string}}\ \mathrm{x}\ 24\ \mathrm{string} = 1200\ \mathrm{m}$$

Due to unanticipated hazards, a 1,5 km long cable will be ordered as a precaution.

According to market data, each meter of cable costs 24,40 TL. The total cost of cable is calculated as follows:

$$24{,}40\,\frac{\mathrm{TL}}{\mathrm{meter}} \times\ 1500\ \mathrm{meter} = 36{,}600.000\ \mathrm{TL}$$

6.5.5. Workforce Expenses

Workers will be involved in the mounting procedure. This is due to the fact that worker compensation should be factored into feasibility assessments.

Expenses for the workforce range from 8,000 to 10,000 dollars.

6.5.6. Other Expenses

Solar systems should be insured against unforeseeable events as a precaution. This is because the cost of insurance should be factored into the feasibility analysis.

Annual O&M and cleaning expenditures will be determined by material costs. This cost will be added to the feasibility study due to unanticipated malfunctions and repair requirements. Solar panels need also be cleaned at certain times of the year. This is because the cost of cleaning should be factored into feasibility assessments.

6.6. Calculations Regarding Raw Materials

In addition to materials, the construction raw material costs of the skeleton where the system is installed must be calculated. The following is a cost analysis for each material.

6.6.1. Steel Profile

S235JR (St37-2),S275JR (St44-2) Type Steel

The typical price of these types of steel profiles, according to market data, is between 500 and 550 USD per metric ton. The following cost estimation is based on the fact that the system skeleton will require roughly 50-100 metric tons of steel profile.

$$525 \frac{\text{USD}}{\text{Metric Ton}} \times 75 \text{ Metric Ton } = 39{,}375.000 \text{ USD}$$

6.6.2. Steel Plate

C30/37 Type Concrete and S420a (BCII) Type Reinforcing Steel

According to the market research, average price of both model steel plates are given respectively.

C30/37 Type Concrete	S420a (BCII) Type Reinforcing Steel
14,850 TL / 900 USD per Ton	**915 TL / 55,5 USD per Ton**

The appropriate calculations were conducted based on the reference sites in order to acquire the required amount of concrete and steel. The computations are detailed below.

If overall footprint of the system is determined;

$$\text{Overall Footprint (m2)} \times\ 0{,}38 = \text{Amount of Concrete Needed (m3)}$$

Since the system's overall footprint has been determined, the amount of concrete required and the system's cost may be calculated using the method above.

$$110\text{ m2 per construction } \times\ 8\ \times\ 0{,}38\ \times\ 0{,}3 =\ 100{,}2\text{ m3 Concrete}$$

Since 1 m^3 concrete is equal to 2,5 ton, cost calculation is given below;

$$100{,}2\text{ m3 Concrete } \times\ 2{,}5\frac{\text{Ton}}{\text{m3}} \times\ 900\frac{\text{USD}}{\text{Ton}} = 225{,}450.000\text{ USD}$$

6.7. Overall Calculation of the System

Because all required data was acquired in the previous section in order to determine total financial requirements and capital required, the table below provides a complete illustration of entire data acquisition.

Installed Capacity	198	kWp
Annual Average Production	277,609.000	MWh
Annual Module Losses	0,01	%
Sale Cost of Electricity per kWh	206,312	Kurus

Years	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Years	1	2	3	4	5	6	7	8	9	10	11	12
Electricity Generation (Thousand MWh)	309,719574	306,6530436	303,6168749	300,6107672	297,634423	294,687547	291,769849	288,881039	286,0208303	283,1889409	280,38509	277,609
Price (TL)	₺ 638.988,65	₺ 632.662,03	₺ 626.398,05	₺ 620.196,09	₺ 614.055,53	₺ 607.975,77	₺ 601.956,21	₺ 595.996,25	₺ 590.095,30	₺ 584.252,77	₺ 578.468,09	₺ 572.740,68
Price (USD)	$ 38.915,26	$ 38.529,97	$ 38.148,48	$ 37.770,77	$ 37.396,80	$ 37.026,54	$ 36.659,94	$ 36.296,97	$ 35.937,59	$ 35.581,78	$ 35.229,48	$ 34.880,67
Initial Expenditure Cost of the System	$ 395.729,74	$ 357.199,77	$ 319.051,29	$ 281.280,52	$ 243.883,71	$ 206.857,17	$ 170.197,23	$ 133.900,26	$ 97.962,67	$ 62.380,89	$ 27.151,41	$ (7.729,26)

Total Price (TL)	₺ 14.208.505,97
Total Price (USD)	$ 865.317,05

Materials	Unit	Type	Cost($)	Total($)
Solar Panels	360	piece	$ 305,00	$ 109.800,00
Inverter	1	piece	$ 20.000,00	$ 20.000,00
Panel Construction Material			$ 19.800,00	$ 19.800,00
DC-AC Cables	1500	m	$ 1,48	$ 2.220,00
Raw Materials				
Steel Profiles				
S235JR (St37-2)	40	mt	$ 525,00	$ 21.000,00
S275JR (St44-2)	35	mt	$ 525,00	$ 18.375,00
Steel Plate				
C30/37 type concrete	100,2	m^3	$ 900,00	$ 225.450,00
S420a (BCII) type reinforcing steel			$ 55,50	
Labor			$ 8.000,00	$ 8.000,00
Assurance and Other Expenses			$ 10.000,00	$ 10.000,00
Total				$ 434.645,00

Figure 30. Overall Data Demonstration of the System

After determining energy side data (production and consumption) year by year, it was determined that the system's owner will be able to earn 865.317,05 USD at the conclusion of the system's life-cycle (14.208.505,97 TL). Because challenges may arise at any point during one's life, earnings may fluctuate.

Finding the duration of the payback period is one of the most significant things to achieve in this project, as it is the fundamental criteria for decision making. As seen in the chart above, if the system is built this year, the payback period will be 11 years.

Payback period may vary according to the parameters below;

1. **Installation date**

The payback period varies depending on when the system was installed. With the introduction of new technologies and shifts in the supply-demand ratio, the cost of installation and generation may shift.

2. **Currency Rate of the date**

Because the majority of the equipment is imported from other countries, the system will be deployed in Turkey. Due to strong inflation and currency fluctuations, the cost of installation and other fees may fluctuate.

3. **Technological developments**

For any industry, new technologies and innovations are always emerging. Electricity generated per m2 may be enhanced with new technologies, resulting in more efficient and powerful systems.

4. **Changes in consumption side tariffs**

Due to the currency fluctuations, electricity price tariffs may vary accordingly**.**

5. **Payment Method**

Since the manner of payment has been chosen to be equity capital. It was believed that the corporation installing the system would contribute funding from its own treasury. To get the greatest payback time, you should think about the payment option carefully before making a selection.

7. CONCLUSION

Solar energy uses on highways have been studied in this project. The Project's general literature studies and comparable studies have been investigated, and the relevant data has been gathered. Calculations and assumptions were made based on the information gathered and the sources used. As a consequence, it was determined that this project is not as viable as solar installations on the ground. If the project is launched for installation this year, as stated in earlier chapters, it will have a payback time of 11 years. When we compared the payback duration of solar systems built on a landscape with the payback period of this project, we found that landscape systems have payback periods of 5-6 years. It was also mentioned which occurrences can have an impact on the Project's payback term. According to the research and studies that have been conducted so far on this project, it is clear that this type of application is still at its infancy. Payback times will shorten as technology advances and public awareness of non-landscape solar systems grows, making them more practicable as landscape applications.

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