ECONOMIC FEASIBILITY OF FLOATING SOLAR PV AND LAND BASED SOLAR PV IN NORTHERN CYPRUS

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Approval of the Board of Graduate Programs

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ABSTRACT

ECONOMIC FEASIBILITY OF FLOATING SOLAR PV AND LAND-BASED SOLAR PV IN NORTHERN CYPRUS

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While the world faces rising energy demands and seeks sustainable solutions, renewable energy sources have begun to play a crucial role in the production of energy. In terms of climatic conditions, Northern Cyprus is viewed as a suitable location for solar-powered electricity generation. The purpose of this thesis study is to conduct an economic feasibility analysis for the installation of a floating solar panel plant on the island, which has never been installed before, and the replacement of the panels in the island's current land-based solar panel plant. Both facilities have an installed capacity of 1 MW. Also, the same panel type and inverter were preferred. METU NCC was selected as the location for land-based solar panel testing, while Geçitköy Dam was selected for floating solar panel testing. In the economic feasibility study, multiple different parameters were used. Calculations of Net Present Value (NPV) and Leveled Cost of Energy (LCOE) were performed using the

System Advisor Model (SAM) developed by the National Renewable Energy Laboratory of the US Department of Energy. The temperature values required for the system for the T.R.N.C are provided by the Meteorology Department. According to the obtained results, the NPV for both power plants was positive, and the projects were considered feasible. Similarly, in the LCOE calculations derived from both installations, results were nearly half of the Cyprus Turkish Electricity Authority (KIB-TEK) tariffs. Although the results are comparable, the implementation of the floating solar panel plant, which is more expensive than the land-based solar panel plant, has a greater number of advantages and is therefore better suited for Northern Cyprus.

Keywords: Land-based and Floating Solar PV, Economic Feasibility, NPV, LCOE, SAM

ÖZ

KUZEY KIBRIS'TA YÜZER GÜNEŞ PANELLERİ VE KARA TABANLI GÜNEŞ PANELLERİNİN EKONOMİK FİZİBİLİTESİ

Ünlükuş, Utku Asena
Yüksek Lisans, Sürdürülebilir Çevre ve Enerji Sistemleri
Tez Yöneticisi: Prof. Dr. Murat Fahrioğlu

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Dünya artan enerji talepleri ile karşı karşıyayken ve sürdürülebilir çözümler ararken, yenilenebilir enerji kaynakları enerji üretimi için çok önemli bir rol oynamaya başladı. Kuzey Kıbrıs konumu gereği iklim şartları açısından güneş panelleri ile elde edilecek elektrik üretimi için uygun bir bölge olarak görülmektedir. Bu tez çalışmasının amacı, daha önce ada için yapılmamış bir çalışma olan yüzen güneş paneli santrali kurulumu ile halihazırda adada bulunan kara tabanlı güneş paneli santralindeki panellerin değişikliği için ekonomik fizibilite çalışması yapmaktır. Her iki santralin de kurulum gücü 1 MW olup, aynı panel tipi ve invertör tercih edilmiştir. Kara tabanlı güneş paneli analizi için konum olarak ODTÜ KKK seçilmiş olup, yüzen güneş paneli analizi için Geçitköy Barajı tercih edilmiştir. Ekonomik fizibilite çalışması için birden çok farklı parametre kullanılmıştır. Net Bugünkü Değer (NPV) ve Seviyelendirilmiş Enerji Maliyeti (LCOE) hesaplamaları, ABD Enerji Bakanlığı Ulusal Yenilenebilir Enerji Laboratuvarı tarafından geliştirilen Sistem Danışmanı

Modeli (SAM) ile elde edilmiştir. Sistem için gereken sıcaklık değerleri K.K.T.C. Meteoroloji Dairesi tarafından sağlanmıştır. Elde edilen sonuçlar doğrultusunda, her iki santral için de NPV pozitif çıkmıştır ve projeler mümkün görülmüştür. Aynı şekilde, her iki kurulumdan elde edilen LCOE hesaplamalarında Kıbrıs Türk Elektrik Kurumu (KIB-TEK) tarifelerine göre neredeyse yarı yarıya sonuçlara ulaşılmıştır. Her ne kadar çıkan sonuçlar birbirine yakın olsa da, kara tabanlı güneş panel santraline göre daha maliyetli olan yüzen güneş panel santralinin kurulumunun avantajları daha fazladır ve bu santralin kurulumunun Kuzey Kıbrıs için daha uygun olduğu görülmektedir.

Anahtar Kelimeler: Kara Tabanlı ve Yüzen Güneş Paneli, Ekonomik Fizibilite, NPV, LCOE, SAM

To Everyone Who Provided Me with Support

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ABBREVIATIONS	
CO_2	Carbon Dioxide
c-Si	Crystalline Silicon
EffG	Efficiency Gain
EG	Energy Gain
FSPV	Floating Solar PV
HDPE	High-density Polyethylene
IRR	Internal Rate of Return
LCOE	Levelized Cost of Energy
LSPV	Land-based Solar PV
MW	MegaWatt
NPV	Net Present Value
OT	Operating Temperature
PV	Photovoltaic
PVCT	PV Cell Type
PVT	Photovoltaic Tilt Angle
PWR	The Maximum Electric Power

SAM	System Advisor Model
TLCC	Total Life Cycle Cost
TRNC	Turkish Republic of Northern Cyprus

CHAPTER 1

INTRODUCTION

1.1 Background and motivation

The phenomenon of global warming emerged in the second half of the 20th century. Every person, regardless of size, contributes to global warming as it happens as a result of industrial activities and increased emissions of methane, nitrous oxide and chlorofluorocarbons, known as greenhouse gases, in the atmosphere [1]. As a result of the emergence and expansion of greenhouse gases, the severity of global warming worsens daily which causes the average temperature of the world to increase a little more every year, leading to climate change [2]. Due to the rapidly increasing impact of climate change in recent years and its evolution into a crisis, many national organizations have defined sustainable agendas and goals.

Sustainability is about what resources we can transfer to the future and how we can ensure continuity. These resources may be natural, man-made or limited or over-sustainable but must be entirely renewable [3]. Renewable energy sources exist by themselves in nature, and when utilized, they play an important role in reducing greenhouse gas emissions and provide sustainability to a great extent [4]. Renewable energy sources are solar, wind, geothermal, tidal, water and bio energy. Solar energy is used in the conversion of heat into energy types such as electricity by the sun's natural heat transfer to the earth [5].

Currently, the role of renewable energy sources in electricity generation in Northern Cyprus is very low. Available data shows that almost all of the electrical energy production is produced with petroleum. According to data in Northern Cyprus in 2022, there are several different plants that contribute to energy production. These are respectively: Kalecik Diesel (36.11%), Teknecik Diesel (29.48%), Teknecik Steam Turbine No.2 (13.34%), Teknecik Steam No.1 (13.05%), gas turbines (1.13%) and finally Serhatköy Solar (0.07%). T.R.N.C. the total electricity production graph for 2022 is shown in figure 1.1. In addition to these plants, there is also the total installed power of PV, which contributes 5.55 percent to energy production [6].

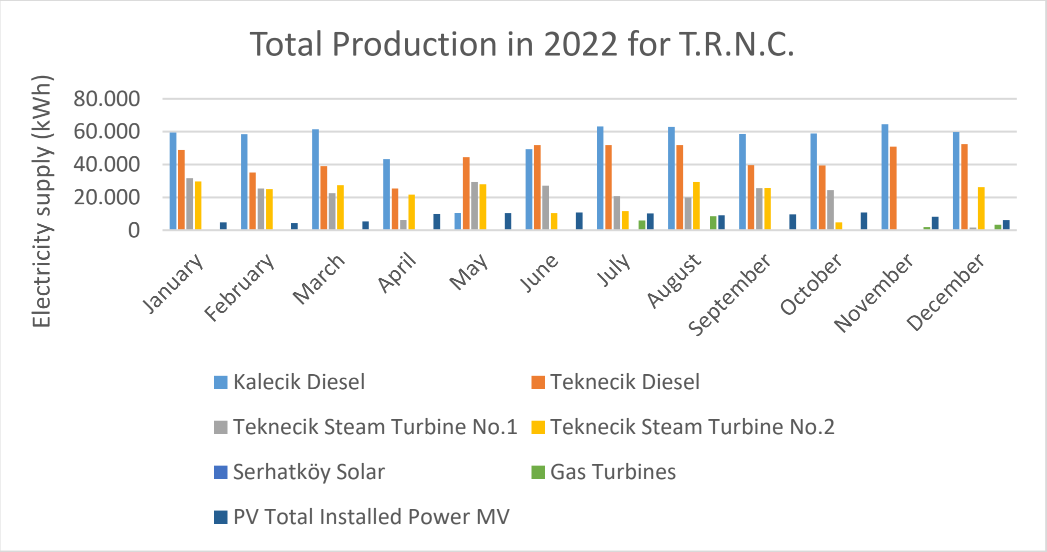

Figure 1.1: Histogram of Northern Cyprus's monthly electricity demand for the year 2022

When all of this data are evaluated, it is seen that the use of renewable energy in Northern Cyprus is very low in electricity generation. For this reason, the importance of making effective solar panels plays a big role in increasing the use of renewable energy. However, since Cyprus is an island, it has a sunny geographical structure throughout the year, even in the winter months. For this occasion only, the use of solar energy for electricity generation and consumption is much more efficient and effective in terms of both sustainability and economy.

Due to the fact that Cyprus is both an island and in the Mediterranean region, it has more than enough heat to benefit from solar energy. In Northern Cyprus, solar panels are used in certain land areas. In addition, there are examples in many countries of the use of solar PV not only on land but also over the ocean, such as Indonesia [7]. Building these solar PVs on fresh water like dams instead of waters with high salt content such as the ocean or the sea takes sustainability to a new level. Recently, some countries such as India have started to install solar panels on dams. [8]. An advantage of this situation is that solar PV installed on the dam reduces evaporation and balances water use. Since there is water scarcity in the island countries, reducing evaporation makes energy production more effective. However, dam-mounted solar panels have never been installed in Northern Cyprus before and that is the building block of my research.

My purpose and motivation for doing this study is to measure and evaluate the ability of solar panels to be installed on the Geçitköy dam in Northern Cyprus, since such an attempt has not been made before.

1.2 Sustainability Aspects of Solar PV

In energy production processes the concept of sustainability comes first [9]. In addition to promoting environmental sustainability, pure electricity production enables societies to adapt to a more sustainable way of life. In addition to the energy efficiency that can be achieved with solar energy, it is known that water scarcity, economic efficiency, and awareness also arise. Given that the concept of sustainability, which is crucial to society, is comprised of multiple factors, it must be examined from a very broad vantage point. In general, figure 1.2 depicts the sustainable development perspective for solar panel energy systems and renewable energy [10].

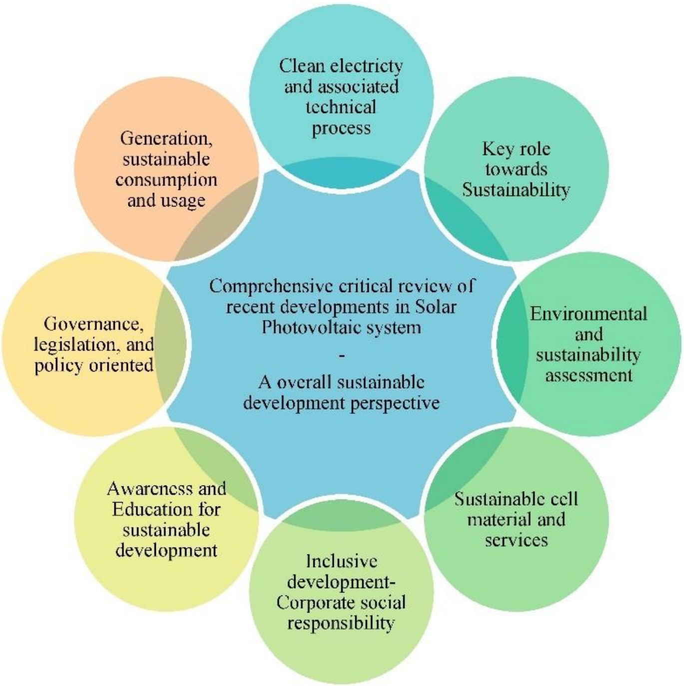

Figure 1.2: Perspectives on sustainability for comprehensive review [10].

As a result of climate change the world's water bodies are warming, and consequently, hazardous algae was discovered on water surfaces [11]. Land-based solar panel power facilities have sustainability benefits including long-term generation of renewable energy, economic growth, and increased employment opportunities. It has been demonstrated that floating solar panel facilities are more sustainable than land-based versions. For instance, the use of FSPV on water reservoirs conserves water by decreasing evaporation at summer temperatures. With the quantity of water to be conserved, irrigation or additional energy production can be accomplished. Additionally, water conservation, inexpensive electricity generation, sustainable city construction, and diverse land use are all significant sustainability factors [12].

With the signing of the Paris Climate Agreement in 2015, a number of countries have begun to work with significant efforts to reduce greenhouse gas emissions. The production of clean energy via solar panels plays an essential role in these studies. LSPV and FSPV decrease carbon emissions caused by fossil fuels and provide societies with sustainable energy production [12].

1.3 Objective

Comparing a floating photovoltaic system and a land-based photovoltaic system in order to determine their economic viability is the primary objective of the thesis. This study aims installing a floating solar panel system on the Geçitköy Dam in the Girne region of Northern Cyprus in order to produce energy in a more sustainable manner by utilizing existing water reservoirs rather than utilizing an unused land area. As mention previously, the Northern Cyprus Campus of Middle East Technical University was selected for the installation of land-based solar modules. The reason is that such a study has been conducted on campus within the past few years and was immensely successful. This thesis differs from others in such a way that it modifies the extant installation based on the energy capacities of today and compares the costs of the to-be-installed plants to those of today. The progression of the thesis is as follows:

a) A comparison of the technical aspects of solar energy generated on land with solar energy generated on floating platforms,
b) In the economic analysis section, calculations are performed using multiple variables; the most common of these calculations are NPV, LCOE, and SAM.

As a result of the study, it is expected that quantitative indices will be used to determine which of the selected locations will be the most efficient for Northern Cyprus. Thus, this study will serve not only as a prerequisite for a master’s thesis but also as a foundation for future research on energy production in Northern Cyprus.

1.4 Outline of Thesis

This thesis is divided into six parts. Chapter 2 contains a thorough review and overview of past research on solar photovoltaics and relationship between sustainability and solar photovoltaics. In chapter 3, the methodology and the data used in the thesis research will be explained. In chapter 4, case study areas; METU

NCC and Geçitköy dam are analyzed in detail. In chapter 5, the data used will be analyzed, compared and discussed. Finally, chapter 6 includes the conclusion of the thesis.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the general background information on land-based solar pv and floating solar PV, as well as previous countries' studies in the literature about their economic feasibility analysis methods will be explained.

2.1 Overview of Solar PV

Photovoltaic conversion is the direct conversion of sunlight into electricity without the use of a heat engine. Photovoltaic devices are designed to be durable, simple, and low-maintenance. The greatest benefit of these devices is that they are constructed as independent systems with outputs ranging from microwatts to megawatts. In megawatt-scale power plants, various application ranges of photovoltaics are implemented. The demand for photovoltaics increases annually [13].

Small to large isolated and grid-connected applications have grown throughout the world. PV system efficiencies are affected by a number of meteorological variables such as sun radiation, ambient temperature, dust cyclones, and wind speed have the greatest influence. In general, solar PV installations in sunny, arid regions are expected to generate significant amounts of PV energy [14].

Approximately 90% of solar cells are produced using crystalline silicon wafers (c-Si), according to estimates. Crystalline silicon wafers are known as monocrystalline, meaning single crystal, or polycrystalline, meaning multiple crystals [15]. It is known as the leading technology in producing silicon solar cells to obtain high efficiency (%12 and %17 [16]) from the sun's rays. Figure 2.1 provides an overview of the materials used in solar cell manufacturing. Researchers are trying to find new technologies to replace silicon due to its high cost. One solution found is thin-film technology [17]. The reason for the low cost of the thin film is that the material used is less, and it is much thinner than crystalline silicon solar cells. However, thin film technology cannot have the same energy efficiency as mono and polycrystalline technology [18]. For this reason, the most preferred are monocrystalline and polycrystalline. Table 2.1 shows the most popular panel type and the countries where the system has been installed.

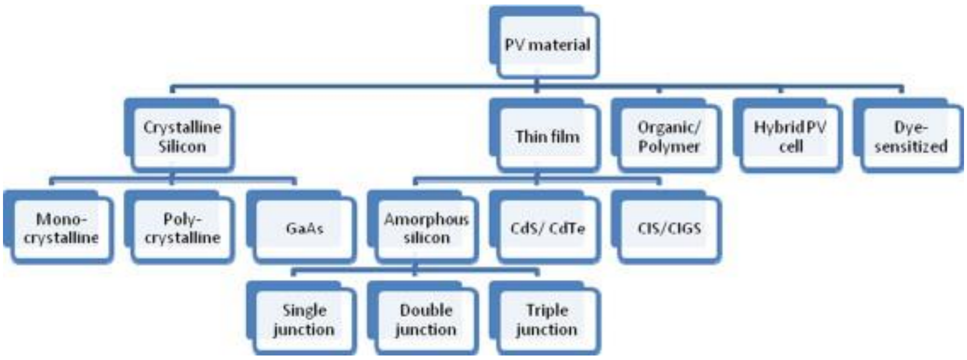

Figure 2.1: PV material chart [18]

Table 2.1: Some examples of panel types and countries [19]

No.	Panel Type	PV System	Country	Modules Efficiency	Functional Unit	Ref.
1	Poly. And amorphous	Roof-mounted	US	From 6.3 to %13	1 kWh	[20]
2	Poly.	Roof-mounted	Several locations (EU, Austria, US)	%16	0.65 m² panel	[21]
3	Poly.	Ground-mounted	Italy	%14.4	1 kWp	[22]
4	Poly.	Ground-mounted	Germany	%12.5	1 kWh	[23]
5	Poly. And mono.	Roof-mounted	South-European locations	From 11.5 to %14	1 kWp	[24]

Moreover, there are three types of solar PV and storage systems: grid-tied or direct-to-grid PV systems, off-grid PV systems, and grid/hybrid or grid-energy storage interaction systems [25].

- **Grid-tied or direct-to-grid PV system**: This system consists of a simple solar installation with an inverter and grid connection. This grid-connected solar power system lacks a battery cell for energy storage. Therefore, energy production and consumption are only possible during daylight hours. The advantages of the current system can be mentioned as cost-effectiveness, simplicity, and low maintenance [25].

Solar panels have the potential to generate more electrical energy than the loads need. Excess electricity can be given back to the grid without being stored in the battery. Excess electrical power produced by the solar panel is sold. Thus, additional income can be earned [25]. In economic terms, this results in an even lower LCOE (levelized cost of electricity) [26]. DC is used for collecting the energy generated by PV panels. Thus, an inverter is needed to convert power from DC to AC.

This system has the disadvantage that it can only be used during daylight hours. This disadvantage can be turned into an advantage by using a battery bank. However, when a battery bank is added to the system, the installation cost of the system will increase [25].

- **Off grid PV system**: This technique is beneficial for consumers who are unable to connect their energy load to the grid. Thanks to the storage of the electricity produced during the day, the battery-operated system provides off-grid solar energy, which can be used in any future emergency or overnight [26]. The system has the disadvantage of requiring a secondary generator when there is no constant sunlight and snow accumulates on the PV panels. Non-renewable raw materials such as gasoline, diesel and petroleum are used for the operation of the backup generator [25]. Furthermore, it is more costly and expensive. On the other hand, the advantage of the system is that the PV panels produce enough energy for a house away from the grid [26].
- **Grid/hybrid or grid-energy storage interaction system**: This system, on the other hand, consists of the combination of the two systems above. Customers who are already connected to the mains and desire a backup battery find this system ideal . This system has the benefits of both a grid-connected system and a stand-alone/off-grid system. In the event of a power disruption, the battery bank can provide energy to the system [25].

Moreover, by choosing types of solar PV and storage systems, solar PV can be installed more than one different area to produce energy. There are five different categorization types of solar PV installation is shown in Fig. 2.

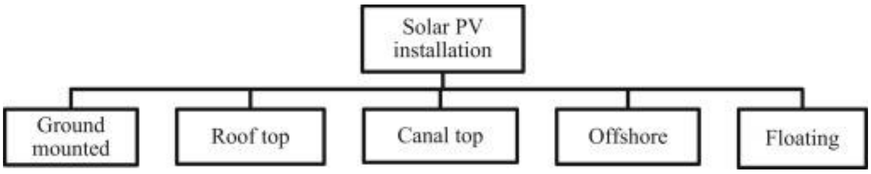

Figure 2.2: The categorization of different solar PV installations chart [27]

In this chapter, instead of explaining all solar pv installation systems, groun-mounted (land based) and floating solar pv systems will be examined. Before explaining the details about land-based and floating solar PV, advantages and disadvantages of solar PV will be examined in table 2.3.

Table 2.2: General information about advantages and disadvantages of Solar PV [28, 27]

Advantages	**Disadvantages**
Zero CO_2 emissions and no noise during electricity generation	Technical, ecological and land use limitations
System life approximately 25-30 years	PV systems are expensive
Wide range of applications for powering structures such as homes, offices, and large power facilities	Small quantity of land is needed to construct large-scale power plants
The silicon material used does not pose an environmental hazard and is an abundant material	PV modules produce less energy during power generation (energy losses)
Energy is free and continuous, only the sun is enough for energy	Expensive investment and construction process like PV modules
Recycling of energy consumption used for production and decrease in prices	It is the increased cost and time required to construct a structure that can withstand cyclones, high winds, and other potential natural disasters
Low maintenance demands	
PV panels are easier to clean and maintain.	

2.1.1 Land-Based (Ground-mounted) System

Solar panels grid connected systems are interconnected systems. The generated energy power is transmitted to the general electricity grid. Systems with high power generation are also known as systems that are connected to the grid and serve the customer or seen as a central power plant. These systems are defined as central type systems feeding the power transmission network [29]. According to the literature, more than 80% of the studies involve grid-connected systems [30].

A land-based PV system is known as a conventional PV system that is installed on the ground or installed on small and large scales such as solar farm systems [31]. In addition to the development of solar photovoltaics, many nations around the globe have installed numerous solar power facilities for the production of clean energy. The current capacities and locations of the largest land-based solar power facilities in 2023 are displayed in Table 2.4.

Table 2.3: The largest land-based solar PV installations around the world 2023 [32]

No.	Capacity	Location/place of installation
1	2.8 GW	Golmud Solar Park in China
2	2.7 GW	Bhadla Solar Park in India
3	2.05 GW	Pavagada Solar Park in India
4	1.63 GW	Mohammed Bin Rashid Al Maktoum Solar Park in UAE
5	1.61 GW	Benban Solar Park in Egypt

2.1.2 Floating PV System

Floating PV technology is an interesting and innovative way of using the energy-water connection to meet the energy and water demand. With the emergence of floating PV, these systems have gained universal popularity and acceptance. Recent research indicates that approximately 25 percent of the world's electricity demand will be met with floating pv sytems. It is estimated that only the 1% of FPV facilities installed on the existing water surface area will be able to satisfy this demand [33].

In Aichi, Japan, the National Institute of Advanced Industrial Science and Energy (AIST) constructed the first 20 kW solar floating facility [34]. In the first 20 kW FPV plant to be built in Japan, the water cooling effect and efficacy were analyzed. In this research to cool the FPV modules, an intermittent water system was installed. The intermittent irrigation system employed water from a reservoir. As a consequence of the study, a decrease in module temperature was obtained, and an increase in PV module efficiency was observed [35]. With the establishment of the first FPV system and subsequent research, the FPV system began to be favored and utilized in numerous countries, including the United States, South Korea, France, Spain, Italy, and China.

There are a number of nations in the globe that lack adequate land area for the establishment of PV institutions. In addition to other island nations, Japan, Singapore, Korea, and the Philippines, can be named. Existing nations already have a demand for floating PV systems. Aside from that, this demand is likely to grow and extend across the globe. The following are the installation areas for floating solar panel systems [27]:

- Oceans
- Lakes
- Lagoons
- Dam lakes
- Irrigation ponds
- Wastewater treatment plants
- Wineries
- Fish farms
- Dams
- Water channels

Normal solar PV panels for solar energy production convert between 4 and 18 percent of the sun's radiation into energy that can be used. Due to the remaining solar radiation, the temperature of the PV panel increases significantly [36, 37]. The efficiency of the PV module is an important point and depends on the temperature. Therefore, it is important to install solar PV systems on the water surface instead of land-based solar panels [38, 39, 40, 41]. Because of the cooling effect of water, a significantly lower PV module temperature is achieved. As a result, the average efficiency of floating solar panels is 11% greater than that of land-based solar panels [42]. In addition, floating PV systems provide several advantages as well as some disadvantages that make this technology useful for solar plant developers. These advantages and disadvantages are given in Table 2.5.

Table 2.4: Explanation of the advantageous and disadvantages aspects of floating solar PV [27].

Advantages	Disadvantages
Efficiency increase: The temperatures of floating PV panel modules remain cooler than land-based PV panel models and the efficiency is increased.	Power plants installed on the water surface are exposed to water events such as high tides, storms, sea waves and tsunamis.
Reduction in evaporation of water: Floating PV systems reduce evaporation as they cast shadows on the water surface.	It is the increase of corrosion in the metallic structure and components of the PV modules and the decrease in the life of the system.
Improving water quality: It is the reduction of photosynthesis in the water and better water quality with algae growth, since the water surface uses a certain area.	It is the decrease in the contact of the sun's rays with the water body, which affects the growth of aquatic organisms and seaweed.
Reduction in dust effect: It is known that areas with high solar energy potential are more dusty and drier. Compared to land-based PV panels, floating PV panels are found in less dusty environment.	It causes negative thermal shift as a result of the decrease in efficiency caused by decreasing humidity and temperatures on the panel.

Land saving: Land needs to be used and protected for activities such as agriculture, mining and tourism. Therefore, the conversion of non-income water surfaces into commercial solar power plants is another advantage	The accumulated clay layer on the river and lake sides needs to be cleaned regularly.
	Active water areas such as fishing and other transportation activities are affected by PV panels and cannot function properly.

2.1.2.1 Concept of Floating PV System

Installation of Solar photovoltaic system by using floating technology on bodies of water counts as a new attempt. As a result of the power generation that will be used a combination of PV technology plant and floating technology will be obtained. FPV technology has started to replace PV plants built on the land. A pontoon or separate floating mooring system, solar panels, and cables are included in the implementation of the FPV system. According to a study, it has been observed that there is a decrease in water evaporation in the available water capacity due to the PV panels in the pontoons and reservoirs of the FPV system [27]. According to an Australian study, up to forty percent of open reservoir water could be lost because of evaporation [43].

Table 2.5: Examples of floating solar PV installations around the world [27]

No.	Company name	Capacity	Location/place of installation
1	Kyocera TCL solar	13.4 MW	Yamakura dam, Japan
2	Infratech Industries	4 MW	Jamestown, South Australia
3	Kyocera TCL solar	1.2 MW	Higashira pond, Japan
4	Bryo	500 kW	Bubano, Italy
5	SCINTEC	30 kW	Lake colignola, Italy

2.1.2.2 Components of Floating PV System

-Floats/Pontoon: The floats consist of a multiple, plastic, hollow part that has effective buoyancy and the ratio of its own weight. By combining each float, a large area is obtained, and a pontoon is formed. Due to their HDPE (high-density polyethylene) composition, the floats' structure is durable and highly favored [27], known for their tensile strength, maintenance-free, and UV corrosion resistance. Pontoon is considered to be the main component that allows floating solar panels to float on water. It is known globally as the most common and useful material for FPVs [44]. The pontoon, which has enough buoyancy to float on its own, is known as a buoyancy device that is able to carry weight. The platform to be installed according to the space's need and suitability can be designed as a serial-parallel combination using the appropriate number of modules [45, 46]. Figure 2.3 illustrates the buoys and the structure of the pontoon.

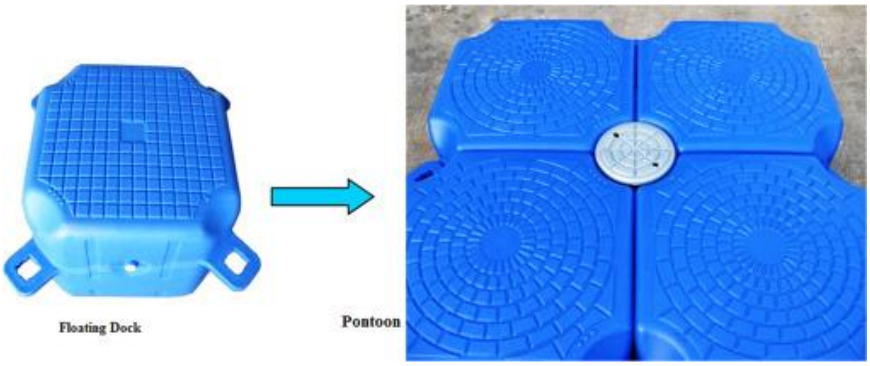

Figure 2.3: Structure of Pontoon of Floats [27]

-Mooring System: Typically, a mooring system is any permanent structure to which a container can be secured. Quays, wharves, jetties, piers, anchor buoys, and mooring buoys are examples. A floating solar system's mooring system prevents the panels from rotating and drifting [47]. The installation of a mooring system in deep water can be difficult and expensive. A mooring system consisting of nylon wire rope slings that are attached to bollards on the bank and fastened at each corner can be used to secure a floating platform. Figure 2.4 depicts the mooring system utilized by floating power facilities.

Figure 2.4: Mooring System in floating power plant [27]

-Solar PV Module: In most studies, crystal solar PV modules, which are the most common for floating solar energy systems installed so far, have been preferred and used [27].

-Cables and connectors: The solar array is used to generate and transport electricity to the land. Thus, the energy can either be supplied into the grid or stored in batteries. The initiatives that have been commissioned thus far have not submerged cables, but have kept wiring above water. Despite the fact that no electrical components are submerged, floating solar projects require cables with the correct amperage rating and junction boxes with an IP67 rating. Other electrical components, including inverters and batteries, remain 'clean and dry' on the land. To assure a long service life, cables must be resistant to high temperatures, water, and abrasion [27].

2.3 Floating Solar PV Sytems Vs Land-Based Solar PV Systems

2.3.1 Benefits

- Compared to land-based solar PV panels, floating solar PV panels are more convenient and advantageous in terms of energy efficiency. Since floating solar PV panels have water under them and the temperature under the panel is cooler than land-based solar PV panels, floating solar PV panels have higher energy generation efficiency [48].
- FSPV creates shadows on the surface of the water. Thanks to this shading, a decrease in algae formation and less contact with the sun's rays will cause the water temperature to be lower. Thus, FSPV will be positively affected in terms of performance [49].
- FSPV reduces the temperature of the water as it prevents the contact of the water with the sunlight and causes a decrease in the evaporation of the available water amount. According to the research, there was a reduction in water evaporation of 33% in natural lakes and ponds and 50% in man-made ones [50].
- Conversion of non-income and commercially viable water surfaces into solar power plants provides significant savings in energy production costs.
- Drinking-water freshwater bodies, hydroelectric structures, industrial ponds, quarry and mining lakes, irrigation reservoirs, and water treatment fields are transforming into solar-friendly real estate for FSPVs.

- For FSPVs, the same panels are used as the roof and land-based single-axis solar panels which are available in the market.
- Most countries have grants, incentives and federal subsidies for the installation of FSPVs.
- Water is available for cleaning the panels and increasing efficiency. FSPVs have gained widespread acceptance, thanks to the benefit obtained with FSPVs installed above the water surface [51].
- Different installation types are available on the water surface. With the flotation method, the general power plant is installed without heavy equipment. According to another study, there is a significant reduction in installation time and costs due to limited space [52].

2.3.2 Challenges

- The biggest challenge is to design an appropriate system so that the FSPV project can stay afloat and withstand the force of the water [53].
- System performance may be affected by high humidity as the FSPVs will be in an area surrounded by water [47].
- Corrosion and unfavorable environmental conditions may have a negative impact on the floating structure's design. In these circumstances, system damage may occur.

- It is thought that the power to be produced by FSPVs may create a safety problem due to cables and water during transportation from the water surface to the land area.
- The flotation system must be able to adapt to environmental factors such as water quality, water depth, changes in water temperature, evaporation rate, oxygen, algae growth, and living organisms.
- FSPV systems must be able to withstand natural disasters such as floods, hurricanes, waves and strong winds.
- High initial setup cost is seen as the second biggest obstacle to the expansion of the FSPV market.
- According to a study, in its early years the cost of generating electricity from solar panels is about 10 percent more expensive than fossil fuel-based non-renewable methods [47].
- FSPV will be affected due to tidal events in the seas and therefore its installation is not done on the sea [54]. At the same time, high wind speed at sea will adversely affect the power generation efficiency of the FSPV system.
- Direction-controlled mooring systems are required to keep the FSPVs in the same direction and position on the water. Otherwise, a reduction in power output will occur.
- Stress and vibration problems may occur in FSPV plants due to reasons such as wind, waves and external forces. This can cause microcracks in modules and problems in electricity generation.

2.4 Previous Studies on The Economic Feasibility of Floating and Land-Based Solar PV

In northern Iran, Semeskandeh et al. [55] compared the techno-economic and environmental impacts of a land-based solar power plant and a floating photovoltaic power plant. Net Present Value (NPV) and Levelized Cost of Energy (LCOE) have been calculated as part of the research's economic analysis. According to the findings of the study, the panels in the FSPV system remained cooler than the land-based solar panels, and the efficiency of the panels was 19.47% and 27.98% higher, respectively.

Makhija et al. [56] conducted a techno-environmental-economic analysis of floating solar PV, land-based solar PV and grid expansion systems in India. Certain results were obtained using the System Advisor Model (SAM) software for the three systems under consideration. NPV analysis was performed among the parameters selected for the economic analysis. As a result of the economic analysis, except for the floating PV system, the other two systems had a negative project life of 25 years, while the floating PV system had a positive NPV life in its 28th year. Considering the SAM and NPV results, it is stated that the FSPV system is the most suitable solution in all respect.

Goswami et al. [57] conducted a similar study for India. The study is on the techno-economic analysis of floating solar energy and land-based solar energy. The parameters used in the economic analysis studies are NPV, Total Life Cycle Cost

(TLCC), and levelized tariff. When the results are examined, it is stated that the total financial savings of a 10 MW FSPV system are higher than LSPV. Moreover, the FSPV plant was found to be 39% cheaper than the LSPV plant. Likewise, the FSPV has a lower leveled tariff than the land-based system.

Sukarso and Kim [7] examined a performance and economic analysis study of floating solar energy for West Java Province in Indonesia. In the study, it was stated by the researchers that FSPV had a higher efficiency of 0.11% compared to LSPV. As a result of the economic analysis, it was estimated that FSPV could save approximately $46,260 (647 million rupees). Moreover, at the end of the research as a result of the NPV analysis for FSPV and LSPV setup, LSPV has 91.2% and FSPV 99.6%. It is calculated that FSPV has a better probability in this case.

Miah et al. [58] carried out a techno-economic analysis of a floating solar power system integrated with a hydroelectric power plant in Bangladesh. For economic analysis, simple payback period and LCOE calculations are examined. As a result of the calculations, in contrast to the land-based solar energy system, the LCOE for FSPV was found to be 0.056/kWh USD less with a 7% discount rate. Moreover, the payback period of the system is only 9 years, which is more tempting. It has been reported that 21.12 million tons of CO_2 emissions will be reduced annually with the envisaged FSPV facility.

Ramzan and Jamil [59] performed a comparative analysis of floating solar photovoltaic plants and land photovoltaic plants. As a consequence of the examination, it was determined that FSPV produces 44.5 MWh/year (for a 500kW plant) more energy than LBPV under standard temperature conditions. In the economic analysis part, NPV and LCOE calculations were used for the power plants. Compared to LBPV, the LCOE was less for FSPV. NPV, on the other hand, is calculated more for FSPV as opposed to LCOE. However, due to the cooling effect of water on the panels, the energy efficiency of FSPV is increased and the payback period is shortened by the researchers.

Micheli [60] researched the energy and economic evaluation of floating photovoltaics in Spain. In this comparative study, economic comparisons were made between FSPV and LSPV. The LCOE and NPV were calculated by the researcher in the economic analysis part. According to the results, in order to reach the LCOE and NPV of FSPV systems in Spain, a capital expenditure between 1% and 10% lower than LSPV systems is required. According to other results, FSPV has more advantages due to the irradiance and ambient temperature values.

In addition, Micheli et al. [61] published a general study on the techno-economic potentials and perspectives of FSPVs in Europe. In this study, the LCOE was examined for economic analysis. As a result of the research, it was revealed that FSPV performed better than LSPV in the southernmost countries. On the other hand, FSPV was found to have worse performance in northern countries and mountainous regions of Europe. Moreover, the researchers expect that FSPV will require lower capital costs than LSPV due to reduced land use.

Singh et al. [12] conducted a study to evaluate the environmental and energy economics of hybrid FSPV systems to provide cost effective and low carbon clean energy generation. The research was based on 96 MW LSPV and FSPV power plants on dam in India. As a result of the research, the power produced by the FSPV plant has 2.4% more power production than the LSPV plant. At the same time, the life cycle of FSPV is 3347.11 GWh. In addition, the researchers concluded that 69.4 mcm (annually) of water was saved, which could be used for drinking water supply, irrigation and additional power generation according to the needs of the FSPV.

Yadav et al. [62] experimentally evaluated the energy performance of a 250W floating photovoltaic system at MANIT Bhopal. As a result of the study, a comparison was made between FSPV and land-based PV system. According to the results obtained, FSPV is superior by 0.79% in terms of production efficiency. In addition, it was found that the average temperature of FSPV was lower than that of LSPV. As a result, FSPV has better efficiency.

No.	**Author(s)**	**Year**	**Short Title**	**Purpose of articles**	**Types of studies**	**Discussion and Reflection**	**Ref.**
1	Ueda et al.	2008	Analyzing FSPV System Performance	This study aims to compare the operational characteristics of a 10 kW grid-connected floating photovoltaic (PV) system with a 10 kW land-based PV system.	Performance Evaluation	Comparing economic conditions	[64]
2	Choi et al.	2013	Research into efficiency	This analysis aims to present a comparative evaluation of a 100 kW Floating Photovoltaic (FPV) power plant and a 1 MW land-based Photovoltaic (PV) power plant, highlighting the superior efficiency of the FPV system by a minimum of 11%.	Analyses of Calculation and Comparison	Providing evidence of the disparity in system maintenance procedures	[65]
3	Mittal et al.	2017	FSPV vs. LBPV Comparison	When comparing the performance of floating solar photovoltaic (FSPV) systems to land-based PV systems, it is observed that FSPV generates an additional 2.48 percent of electricity on an annual basis. Furthermore, the temperature of the modules in the FSPV system is found to be 14.56 percent lower than that of land-based PV systems.	Comparative evaluation	Comparing the infrastructure requirements of systems	[66]

4	Yoon et al.	2018	Structural evaluation and planning	The author provides an analysis of the mechanical composition of FPV (Floating Photovoltaic) systems and proceeds to draw a comparison between a 100 MW floating PV plant and a 100 MW ground-mounted PV plant.	Structural evaluation	Justification for the higher efficiency of the floating type	[67]
5	Ranjbaran et al.	2019	A review of FSPV	This paper presents a comparative analysis and a current overview of several elements of FPV systems. Furthermore, a comparative analysis is conducted between ground-mounted and floating photovoltaic (PV) systems.	Structural and Comparative evaluation	Comparing both systems and different aspects	[63]

Table 2.6: A review of previously conducted research comparing FSPV and LSPV [63]

2.5 The Importance of The Relationship Between Sustainability and Solar Panels

The process of burning fossil fuels results in the emission of carbon dioxide and other greenhouse gases, which subsequently accumulate in the Earth's atmosphere. Consequently, fossil fuels are identified as the principal cause for climate change and the phenomenon of global warming [71, 72]. Each method of energy generation and transmission has an impact on the environment. It is evident that traditional energy sources have the potential to negatively impact various aspects of the environment, including air quality, climate patterns, water bodies, land ecosystems, and wildlife populations, while also potentially contributing to higher levels of hazardous radiation. Renewable technologies have a significantly higher level of safety compared to fossil and nuclear fuels, hence presenting viable resolutions to various environmental and social problems [73, 74].

With the advancement of technology, the emergence of environmental concerns, the need for more efficient power facilities, and the importance of renewable energy sources has increased. In this way, solar energy technologies (SETs) contribute to the sustainability of human activities [43]. The goal of the transition to renewable energy production rather than fossil fuel energy production is to reduce carbon dioxide (CO_2) emissions which leads to the reduction of global warming [75, 76, 77] because their main advantage relates to their low CO_2 emissions and lack of air emissions and waste products during operation [43].

Although solar panels are believed to be environmentally friendly and sustainable due to their ability to generate clean energy, it is necessary to consider other factors. Within the context of sustainability, three distinct titles are examined for these factors. These are known as environmental, social, and economic impacts. In order to explain the connection between sustainability and solar panels, these subjects are investigated in depth. Table 2.9 describes the sustainability and environmental, social, and economic impacts of solar panels.

Table 2.7: Relationship between sustainable development and solar energy [78]

Environmental Impact	**Social Impact**	**Economic Impact**
Limiting emissions of greenhouse gases and preventing climate change	Efforts to reduce rural poverty	Enhancement of economic expansion and development
The reduction of air and water pollution	Raise in quality of life	Reducing the cost of electricity bills
The reduction of hazardous waste	Improvement in air and water quality	New job opportunities
	Better lighting and a sense of security	

2.5.1 Social Impact

Providing solar energy in all regions, especially in the rural areas, is essential for dealing with the limitations on growth prospects and providing a satisfactory quality of life due to the lack of electricity [79].

People's living conditions improve as a result of the solar energy used to generate electricity. As shown in the table, this is a situation with social impact. With renewable energy, unlike traditional fuels, people do not experience interruptions in power. According to the findings of the study, people's pastimes such as viewing television and listening to the radio are crucial for information access. However, due to the power failure, they will be unable to access existing information. In this case, the social impact will have the opposite effect on the improvement of people's quality of life. Moreover, the proper operation of street light is essential for human life. Thus, the safety of individuals increases by improving nighttime visibility. This is an illustration of a positive social impact [80, 81].

Apart from these, it is expected that serious diseases affecting people's society will decrease with solar energy because unlike the traditional fuels used, the atmosphere is not polluted and the oxygen level is thought to be higher. Moreover, it improves the quality of human existence in terms of basic necessities such as education and health [82].

Although not included in the table above, solar energy affords men and women equal opportunities. Consequently, gender equality is advocated, particularly in rural regions [83].

2.5.2 Economical Impact

Insufficient energy hinders economic growth and development in countries. According to studies, in order to ensure economic growth and development, renewable energy sources play an essential role in energy production. Sustainable development also requires access to renewable energy sources [84, 85]. The use of solar energy as an alternative electricity source is important because it provides cost-effective and environmentally friendly energy solutions as well as meeting the desired electricity production and consumption demand [79]. Moreover, access to clean energy encourages economic activities such as job establishment. It also reduces electricity bills unlike other traditional energy fuels [86, 87, 88].

Thanks to solar energy, it is possible to have affordable and reliable electrical energy [89]. With the solar energy industry, employment rate increases in countries. This reduces the poverty rate [90]. The decrease in the poverty rate and the increase in the employment rate have positive effects, such as reducing hunger and creating a more equal environment by raising the standard of living [91]. It is important to invest in clean and affordable energy sources and infrastructures and innovation for these energy sources to manage the country's economy [92]. Investing in renewable energy sources such as solar panels will also eliminate the negative effects of forced labor, slavery, low wages and human trafficking, especially in developing countries [93].

The following is an analysis [78] of the economic effects of solar panels. Renewable energy sources exceed conventional measures of a nation's economic performance. Rather, it contributes to the global economic welfare. Solar panels support economically circular economy policies and regulations. The concept of circular economy is seen as a tool for the concept of sustainable development and environmental protection, which are actually new. This situation is exemplified for companies, governments and their employees as follows. In a circular economy system, it is essential to promote improved eco-designs (waste prevention, material recycling, etc.) while reducing waste and emissions. The reduction of energy leaks, industrial wastes and pollution after the incentive will add value to both businesses and the natural environment. Hence, the circular economy is an important step for a sustainable approach, but more research is needed in this area.

2.5.3 Environmental Impact

According to the researchers [94, 95], extensive land use, which can vary from approximately 2.2 to 12.2 acres/MW, is required for the construction of solar energy projects. When this land area is used in addition to the environmental changes to be made, various environmental effects in the soil, air, water, fauna and vegetation have also emerged [43, 96, 97, 98]. Major environmental impacts such as the destruction of a forest, loss of habitat and biodiversity have been identified with the field study. Solar panels that will be built on the soil cause many negative factors such as damage to vegetation and an increase in surface flow and soil erosion. Therefore, in order not to adversely affect the local geomorphology, it is necessary to ensure proper stormwater flow with heavy-duty machinery and to prevent sediment loading from the existing area. In short, sound pollution (noise) and deterioration of the soil structure are seen as important environmental factors throughout the duration of the project’s construction [99].

In recent studies [97, 100], bird deaths resulting from contact with solar energy flow in conventional solar panel (CSP) facilities established in areas such as deserts or as a result of direct impact on photovoltaic panels have been shown as examples of negative environmental effects. At the same time, according to another study [101, 102], insects can be attracted to PV systems. It has been stated that as insect accumulation occurs in PV systems, the probability of collision of birds with PV systems will increase. On the other hand, according to a study [103], the environmental effects of CSPs being built on the land surface will also cause the same result for solar panel systems on water. In the study, results were obtained that waterfowl would be attracted to the panels and die.

Due to adverse environmental impacts from CSPs such as deforestation, land allocation [104, 50], land cover degradation, erosion and so on, FPVs have emerged as a more sustainable alternative [99]. Researchers have stated that despite the fact that FPVs are viewed as an alternative solution, they have negative effects on the environment. In relation to the effects on geomorphology and geohydrology, it is stated that, despite the fact that FPV is a system constructed on the water's surface, there may be negative environmental effects at the lake's bottom due to technical requirements for the system, such as anchoring, cabling system, and trenching, that must be used on land (soil). At the same time, it has been stated that during the construction of the FPV, there may be effects that have the potential to alter water quality and increase water turbidity [99].

On the other hand, solar energy can be used to reduce the carbon footprint and greenhouse gas emissions [82]. Unlike fossil fuels, solar panels require less water for production and washing it off [9, 105]. Solar panels are preferable to other energy sources in this case.

Contrary to the deforestation and bird deaths in the above articles, another study claimed that solar panels reduce air pollution, as well as protect plants and animals. At the same time, solar panels reduce the degradation of forests [98]. It was mentioned that thanks to solar panels, the climate crisis will decrease in the cleanest way and natural beauty will increase by developing a more sustainable and clean environment [106].

It is important to acknowledge that both land-based and FSPV systems do have environmental implications, and it would be inaccurate to claim otherwise. The rationale behind this phenomenon is rooted in the fact that the development of energy systems necessitates the utilization of various equipment. Notably, a significant quantity of energy is expended during the manufacture process of photovoltaic (PV) modules, inverters, and other associated components. According to Aman et al. [95], the release of detrimental compounds into the environment occurs as a result of the expenditure of energy. However, existing research has established that FSPVs exhibit reduced environmental impacts. Due to this justification, FSPVs have exhibited a greater preference over LBPVs in recent times. The selection of FSPVs has several environmental implications, which can be outlined as follows [107]:

- Silence of the FSPV system during operation,
- Ensuring a decrease in algae growth in the presence of eutrophication,
- Generating clean electricity without any CO_2 emissions,
- The conservation of water resources through the prevention of evaporation,
- Less water usage/consumption for cleaning PV modules [108],
- Use of valuable lands for different purposes (eg. agriculture, mining, tourism and other) on account of PV modules installed on water bodies
- Fewer bird strikes with FSPVs compared to LBPVs [99]
- Improvement of water quality in reservoirs [109]

CHAPTER 3

METHODOLOGY

3.1 Reserch, Desing and Approach

The greatest benefit of solar power facilities is that the majority of existing system components do not require expensive maintenance. This is because there are no energy-consuming complex machines and system components in solar power facilities. Each part of the system components in the switchboards has a long-term warranty certificate. The costs of the parts that are broken, need to be changed or repaired are covered by warranty documents and are carried out at zero cost in terms of cost. Therefore, maintenance and repair costs are not reflected in the amount of cost, required for solar power plants [110].

The cost of the intended 1 MW solar power plant at METU NCC and Geçitköy Dam is detailed in table 10. Each parameter in the table describes the system components and installation procedure used to implement solar power plants. The prepared cost table varies according to the projects. More than one 1 MW solar panel power plant was examined to create the table showing the costs in the table.

This study's primary objective is to conduct an economic feasibility analysis for the construction of a 1 MW solar power facility in two distinct regions. The economic feasibility study that will be conducted in Northern Cyprus will provide crucial data for the economic evaluation of solar power facilities.

3.2 Data Collection

BAR-ER Energy, located in the Gaizmağusa region of Northern Cyprus, has obtained this thesis and all relevant technical information regarding the PV module and the inverter that is suitable, has sufficient efficacy, and can be used in Northern Cyprus. The panel designated is "Q.Peak Duo XL-G11.3", and the inverter is "SUN2000-100KTL-M1". When the power generated by a single panel that is 580 W, approximately 1725 solar panels will be required for a 1 MW solar panel installation. For a 1 MW power facility, ten inverters will be used, which is proportional to the number of solar panels that will be installed. The characteristics of the panel and inverter are detailed in tables 3.1 and 3.2.

Table 3.1: Solar module information

PV Array	
PV module rated power (1725 modules)	580 Wp (1 MW)
Maximum voltage	50.59 V_{dc}
Maximum current	10.91 A_{dc}
Open circuit voltage	53.64 V_{dc}
Short circuit current	12.92 A_{dc}
Efficiency	21.2%
Temperature coefficient of Voc	-0.27%/K
Temperature coefficient of Isc	+0.04%/K

Table 3.2: Inverter information

Inverter	
Rated active power	100,000 W
AC voltage	480 V/ 400 V/380 V
Efficiency	98.8%

Table 3.3 provides an approximate cost comparison based on the information and investigation gathered. In all cost calculations, the unit prices and desired quantity of units are multiplied. Since FSPV will utilize pantoons in its structural components, as opposed to LSPV, the price of structural components has increased. Similarly, an approximated additional cost has been added for the special protectors to be used in electrical components to avoid the potential risks posed by water contact. The rate to be paid to employees for the total system cost is calculated as 15% for LSPV employees and 18% for FSPV employees. FSPV is greater than LSPV because the hazards associated with working on the water surface are greater than those associated with working on land.

Table 3.3: A cost comparison of land-based and floating PV systems

	Land-Based PV	Floating PV
Location	METU NCC	Geçitköy dam
Size	1 MWp	1 MWp
Panels (Euro)	362,250	362,250
Inverter (Euro)	45,000	45,000
Structural components (Euro)	40,625	42,181
Electrical components (Euro)	19,260	25,745
Installation labor (Euro)	~82,435	~102,540
Others	~300,000	~420,000
Total	~849,570	~997,716

3.3 Economic Analysis

Financial feasibility study is the name given to the method of investigation that is utilized in the process of determining whether or not an investment will be profitable. Analyses are run on both the operational performance and the financial status of the investment that is going to be made. In addition to that, an investment's expected future financial situation is also evaluated and analyzed. The procedure known as "financial feasibility assessment" refers to the practice of analyzing both the projected profits from the investment and the risks associated with the investment.

According to the findings of the studies, an economic feasibility analysis should be performed on every topic before a decision on an investment is taken on that topic. The reason for this is that monetary and time loss problems can develop if the production or investment is not economically acceptable. When it comes to doing an economic study of capital investment, one can choose from a large number of different methodologies [111].

In this section, the formulas and explanations that will be used for the economic feasibility analysis of floating and onshore solar panels.

3.3.1 Net Present Value

The Net Present Value (NPV) is a method that can be utilized to determine whether or not an investment is profitable. The phrase "€/kW" has been underlined by a number of researchers as being the standard notation for NPV [112]. This is due to the fact that solar panel prices are expressed in this currency. The determination of the net present value (NPV) for a power plant project involves the calculation of the difference between the cash flow that is provided during the duration of the project and its present value, which is adjusted for the time value of money. In basic terms, the calculation of future cash flows, including both positive and negative values, related to revenues and panel maintenance costs, is dependent both input and output. This holds true for both positive and negative cash flows [113, 111]. If the NPV result is positive (NPV = 0 or NPV > 0) [114], it is assumed that the power plant is a profitable investment, and the project is approved. In this analysis, NPV is determined as follows:

$$NPV = \sum_{n=0}^{n} \frac{C_n}{(1+i)^n} \tag{3-1}$$

N= The lifespan of a project

C_n: Net cash flow

i: discount rate

3.3.2 Levelized Cost of Electricity

The levelized cost formula, which is a widely used method in the literature [110], is a typical cost formula that is used to examine the relationship between the total cost of a project's life cycle and the total amount of energy it will produce over the course of its lifetime [113]. To put this another way, the levelized cost of electricity (LCOE) is the computation of the average cost of producing one unit of energy in a specific facility. The following equation represents the method for determining the cost:

$$LCOE = \frac{sum\ of\ costs\ over\ life\ time}{sum\ of\ electrical\ energy\ produced\ over\ lifetime} \tag{3-2}$$

I_t : The initial investment costs which may start before the year 1.

OM : Operation and maintenance costs

F_t : The fuel costs

E_t : The electricity generation

3.3.3 Internal Rate of Return (IRR)

Internal rate of return (IRR) is used to determine the profitability of an undertaking by considering the time value of money. In other words, this method represents the discount that ensures the profitability of the undertaking [115]. The net present value (NPV) is used as a means of assessing the net cumulative discounted cash flow, while the internal rate of return (IRR) is utilized to analyze the predicted profitability of the project [114]. The Internal Rate of Return (IRR) is formally determined by the computation of the Net Present Value (NPV). The discount rate's whole determines the point at which the cumulative sum of all cash flows during the plant's lifespan reaches equilibrium. A higher internal rate of return (IRR) during the construction phase of the proposed power plant is acceptable, as it signifies more profitability for the project. According to the studies, the average IRR for solar PV installations is approximately 5% [115].

$$IRR = \sum_{t=1}^{T} \frac{C_t}{(1 + IRR)^t} - C_0 \tag{3-3}$$

Where

C_t: net cash inflow during period t

C_0: total initial investment cost

IRR: internal rate of return

t: number of time periods

3.3.4 System Advisor Model

Formerly known as the Solar Advisor Model, this modeling tool is now known as the System Advisor Model (SAM) [116]. Sandia National Laboratories and the National Renewable Energy Laboratory (NREL) list SAM as a method for modeling CSP systems [117]. SAM is a project that uses open sources software and techno-economic computer model [118].

The primary objective of SAM is to enhance the process of decision-making within the renewable energy industry [118]. The proposed project is subjected to performance and financial analysis in order to create a model. Based on the findings presented in technical report [119], it can be observed that a significant proportion of user profiles consist of individuals fulfilling various roles such as project administrators, engineers, incentive program designers, technology developers, and researchers. The SAM software application utilizes installation and operational expenses, along with system design characteristics, to create estimates of performance and energy costs for grid-connected energy programs.

According to the latest technical report, off-grid power systems and hybrid power systems that include several sources of electricity generation are not modeled by SAM [118]. On the other hand, it is able to give modeling for big concentrated solar power generation projects, such as residential rooftop photovoltaic installations and wind farms, regardless of their size. SAM performance models include:

- Photovoltaic (PV) systems with the possibility of battery storage
- Energy from concentrated solar radiation
- Heat from industrial processes
- Solar energy for heating water
- Wind energy
- Geothermal energy
- Biomass and
- Traditional power systems that either interact with the electrical load directly or transport electricity directly to the electrical grid.

In order to utilize SAM to model a project including renewable energy, it is necessary to choose a performance model and a financing model that appropriately depict the project. In this step, parameters like the location of the project, the type of machine that will be utilized in the system, the cost to install the system, and the cost to operate the system will be entered. Altering the values of the remaining input variables is an option, although it is also possible to use the values that are preset [119]. Several examples of variables that can be entered are provided below:

- Institutional costs, including labor, engineering, and equipment purchases
- Other project expenses: such as operation and maintenance
- Quantity of modules and inverters for PV systems, derating factors
- Collector and receiver type, solar multiple storage and power block capacity
- Analysis time for benefit finance modeling
- Real discount, inflation, tax and internal rate of return
- Electricity purchase price
- Building load and lifetime for commercial and residential finance models
- Tax credit and payment incentive amount rates

In addition, the receivers and collectors that are necessary for PV modules and inverters each have their own unique set of performance data and coefficients. It is sufficient to select one item from the list contained within the model for each of these several components. After all of the input variables have been entered precisely, fully, and in their entirety, the simulation can begin. The results have been collected and the process of analyzing them has begun by using the SAM.

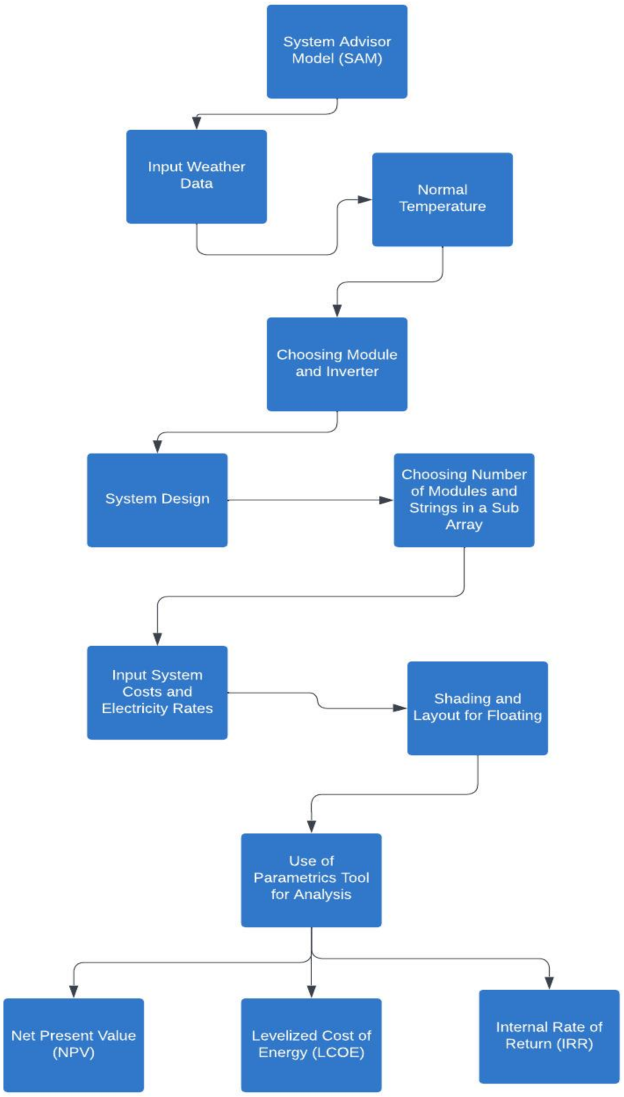

Figure 3.1: Flow Chart of the SAM program's procedures, Technical and Economic Comparisons for FSPV and LSPV

CHAPTER 4

CASE STUDY: NORTHERN CYPRUS

Cyprus is known as the third largest island in the world. Located on the Mediterranean Sea, the island is bordered by Turkey in the north, Syria in the east, and Lebanon and Israel in the southeast. As a result of diplomatic wars in the time, Cyprus is a single island but consists of two different states and societies. The northern side is known as the Turkish Republic of Northern Cyprus and the southern side is known as the Greek Cypriot Administration. The surface area of Northern Cyprus is 3,355 km². Since Northern Cyprus has a Mediterranean climate, summers are hot and dry, and winters are warm and less rainy.

The island enjoys ample sunshine throughout the year. The high temperatures, especially in summer, increase the use of solar panels, which are a renewable energy source. Solar energy has a significant potential to meet the energy needs of Northern Cyprus. Thanks to the island climate, the conversion of sunlight into electricity can be achieved with solar photovoltaic (PV) systems. In this way, dependence on traditional energy sources can be reduced. Unlike conventional and non-renewable energy sources, photovoltaic power systems that are clean and sustainable can be installed in open areas.

In Northern Cyprus, solar photovoltaic systems can be installed in multiple areas such as roofs, open spaces and above the water surface. The aim of this thesis is to study the economic feasibility of solar panels, one of which will be installed on an empty land in the Middle East Technical University Northern Cyprus Campus. Another area is Geçitköy dam. Floating solar panels, which have become popular recently, will be installed on this dam. Then, an economic feasibility study will be conducted.

4.1 Case Study: METU NCC

4.1.1 Background Information of the First Set Up of Solar PV in METU NCC

In this thesis study, the location designated for the land-based solar panel power facility is Kalkanlı village of Northern Cyprus. Figure 4.1 depicts the temperature chart constructed with Meteorology Department temperature values. Taking into account average temperature values, the increase in temperatures, particularly during the three-month summer period and in September, is sufficient for energy production. Similarly, the permitted module temperature range for continuous operation in the selected panel is between -40 °C and +80 °C. When the allowed module temperature and current annual temperatures are compared, it is expected that other months will produce energy efficiently..

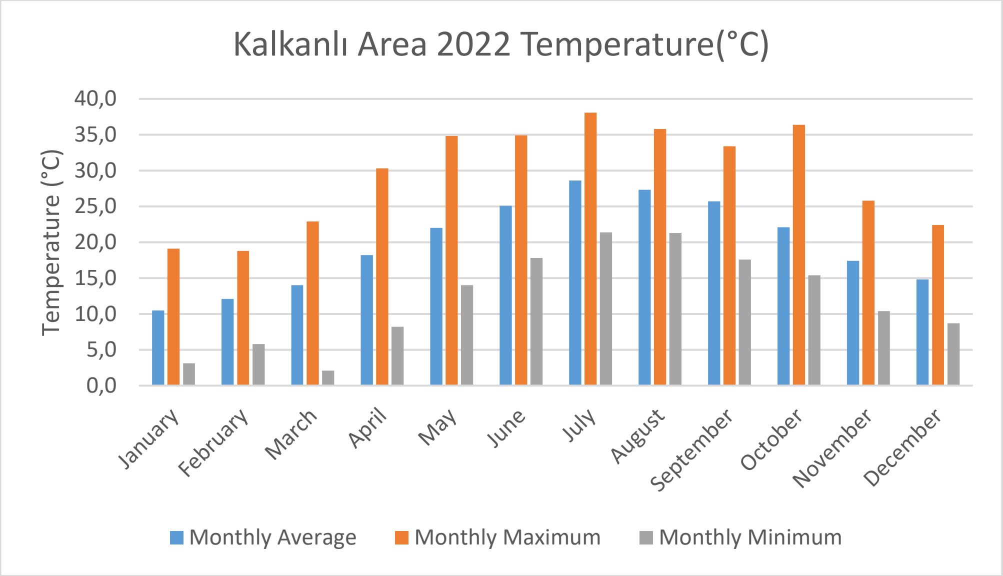

Figure 4.1: Data taken from the TRNC Meteorologıcal Department indicating the monthly temperatures for Kalkanlı region.

Middle East Technical University Northern Cyprus Campus was established in 2005 next to Kalkanlı village of Güzelyurt, Cyprus. In 2016, a 1 MW solar power plant was established as a result of the researches and studies carried out by the lecturers working at the university. The 1 MW solar panel power plant constructed on METU NCC land is shown in figure 4.2 from Google Maps. Likewise, table 4.1 provides general technical information about the installation.

As a result of the studies, it has been found that with the annual energy production to be produced from the solar pv central, the electricity needs of approximately 540 households with 4 people will be met. At the same time, it has been reported that this production will prevent the release of approximately 1 million kilograms of carbon dioxide into the atmosphere annually. It has been said that this value is approximately equal to fifty-two thousand seven hundred adult trees [120].

Figure 4.2: METU NCC Solar PV areas from google maps

Table 4.1: The technical data of the power plant installed on the campus[121]

Total installed power	1000 kW
Total installation area	16,500 m²
Annual estimated electricity generation	1,640,000 kWh
Annual estimated performance rate of the plant	%85
The annual energy need of the campus to be provided from the power plant	%20
The annual average daytime electricity consumption of the campus to be met from the power plant	%40
Number of panels	4000 (each 250 W, reference efficiency %15.37)
Number of inverters	40 (25 kW)
Degrees Angle of panels with ground	30
Weight of Galvanized steel constructions	70 tons
Estimated amortization period	6.5-7 years

The area occupied by the 1 MW solar power plant constructed in 2016 for the production of renewable energy is utilized because each panel is 250W. In current research, less space is required for a 1 MW power facility because the power of a single panel is nearly 2.5 times greater. Alternatively, it appears feasible to construct power facilities with higher MWs by occupying more space. Since there was not enough economic feasibility study for the island after this solar pv installation, which was established in 2016, a solar panel modeling study will be carried out to the current location according to today's efficiency of developing solar panels and prices.

4.2 Case Study: Geçitköy Dam

Northern Cyprus's Çamlıbel village has been selected as the site for the floating solar panel power facility. Figure 4.3 depicts the temperature chart constructed with Meteorology Department temperature values. When we compare the temperature values of the amlbel region to those of the Kalkanl region, we observe that the increase in temperature, particularly during the three-month summer season and in September, is sufficient for energy production. Since the same panel will be utilized, the temperature efficacy of the module is identical. In the coming months, it is anticipated that the amlbel region will produce energy as efficiently as the Kalkanl region.

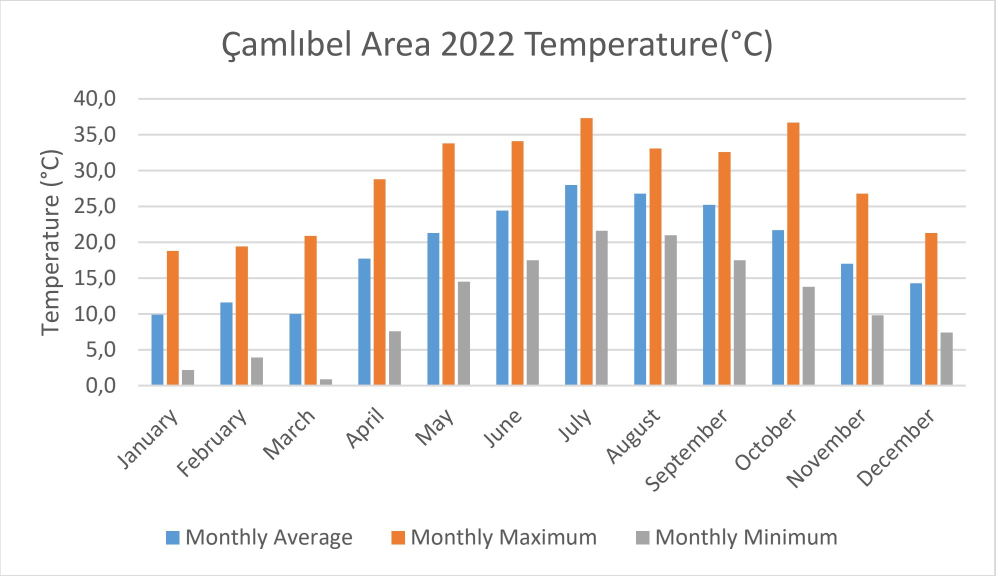

Figure 4.3: Data taken from the TRNC Meteorologıcal Department indicating the monthly temperatures for Çamlıbel region.

The Geçitköy dam, constructed in 2014, is located in Geçitköy, near the Girne district of the Turkish Republic of Northern Cyprus. The drinking water supply project in the TRNC, which was launched as a pioneering initiative, reached its completion in March 2014. The water transported from Turkey via subsea pipes satisfies the island's daily water requirements. The purpose of constructing the Geçitköy dam is to distribute the water in the existing dam to the people of the entire island, until the problem is resolved in the event of a potential lack of water in the Northern Cyprus region (due to a malfunction in the pipes). The elevation of the constructed dam indicated the active and inactive volume. By adhering to these elevation levels, the total area and volume of the dam are crucial for meeting water needs.

The project successfully fulfills the water demand of the TRNC, which amounts to around 70-75 million cubic meters annually. The allocation of water provided to the TRNC is divided into two categories: 50.3% for drinking and domestic usage, and 49.7% for agricultural purposes. Water transportation through pipelines has facilitated the provision of both drinking and potable water in the TRNC, with the projected capacity to supply the region's water demands for an estimated duration of 50 years. During this specific time frame, a total land area measuring 4824 hectares is subjected to irrigation practices, resulting in the generation of agricultural revenue [122]. The visual representation of the dam is presented in figure 4.4.

Figure 4.4: Geçitköy dam area from google maps

The Department of Dams and HEPP of the General Directorate of State Hydraulic Works has provided the elevation, area, and volume data of the dam, as presented in table 4.2. According to information provided by the government office, the Geçitköy dam's elevation volume begins at 40 meters. On the map, the water area and volume on the right side of the dam is labeled as inactive volume up to about 55 meters. In other words, the water level is almost at ground level, and if the waters recede, the FSPVs that can be mounted on the water surface with pontoons will not be able to fulfill their purpose by combining with the ground over time. The total volume is $26.52x10^6$ and the elevation is 100 meters. Again, when examining the map, the left side, where the dam begins, has the highest water level.

Table 4.2: Geçitköy Dam lake region elevation-area-volume data

Elevation (m)	**Area (km²)**	**Volume (hm³)**
40	0,000	0,000
42.5	0,008	0,010
45	0,011	0,034
50	0,028	0,132
55	0,087	0,419
60	0,210	1,160
65	0,288	2,405
70	0,383	4,084
75	0,486	6,258
80	0,612	9,003
85	0,745	12,396
90	0,856	16,399
95	1,017	21,081
100	1,160	26,523
105	1,341	32,776

Simultaneously, table 4.3 provides information on the overall volume of the dam, as well as the specific quantities of dead volume and active volume that constitute the total volume. Below 50m is considered the dead volume, while above 50m is the active volume. When the power of the examined FSPV and the panel power are calculated, 50m below is the total installation area (in km²). However, if a high-power solar energy panel is to be installed, a 0,612 km² area with an elevation of 80 meters is regarded as the optimal location.

Table 4.3: Geçitköy Dam volumetric information

Dead volume	$3.41x10^6$ m³
Active volume	$23.11x10^6$ m³
Total volume	$26.52x10^6$ m³

CHAPTER 5

RESULTS AND DISCUSSION

Three sections will be created for the results. The design section will include results such as the quantity of energy generated, the size of the power plant, the capacity factor, and other commonly used efficiency measurement parameters. Next, the economics section will be analyzed using the design results to determine if the FSPV is economically more feasible than its land-based counterpart in a variety of scenarios. Finally, a comparison between FSPV and LSPV will be made for Northern Cyprus.

5.1 Technical Results

Both power plants have the same general design parameters. This means that the models of the PV panels and inverters, the desired array, the DC-to-AC ratio, the orientation, the angle, and the losses caused by converting DC to AC are all the same. Table 5.1 summarizes the PV facility design specifications.

Table 5.1: FSPV and LSPV design parameters

Parameter	Value
Site Location	**METU NCC:** 35° 14' 15.83"N, 33° 1' 21.42"E **Geçitköy dam:** 35° 18' 54.73"N, 33° 4' 23.79"E
PV Module	Q.PEAK DUO XL-G11.3
Inverter	SUN2000-100KTL-M1
Number of inverters	10
Modules per string	18
Tilt	30°

The temperature of the cells in both power facilities is the first parameter to evaluate. Although the two solar power plants are located in distinct regions, they share the same climatic conditions because they are both located in Northern Cyprus. Therefore, the foundation of the established power facility is crucial. Since one will be located on land and the other on the water's surface, the cell temperature and energy output will vary. Due to the presence of water beneath the solar panels, FSPV operates at reduced temperatures. This will be advantageous for energy output.

A positive correlation is noted between energy production and temperature elevation during certain months. Upon examining each month individually in the provided tables, a clear trend emerges indicating a direct correlation between energy output and temperature growth. However, it is worth noting that there are several instances, namely in the months of July and August, where exceptions to this pattern are observed. Despite the fact that the temperature during the months of May and September tends to be lower compared to July and August, the weather conditions in September and May are often more beneficial due to the absence of dust and other related factors. Figure 5.1 illustrates the comprehensive monthly average temperature rate (represented by the orange line on right y-axis) and system energy production (depicted by the blue line on left y-axis) over the course of a year.

Figure 5.1: System power generated (kW) and weather file ambient temperature (C°)

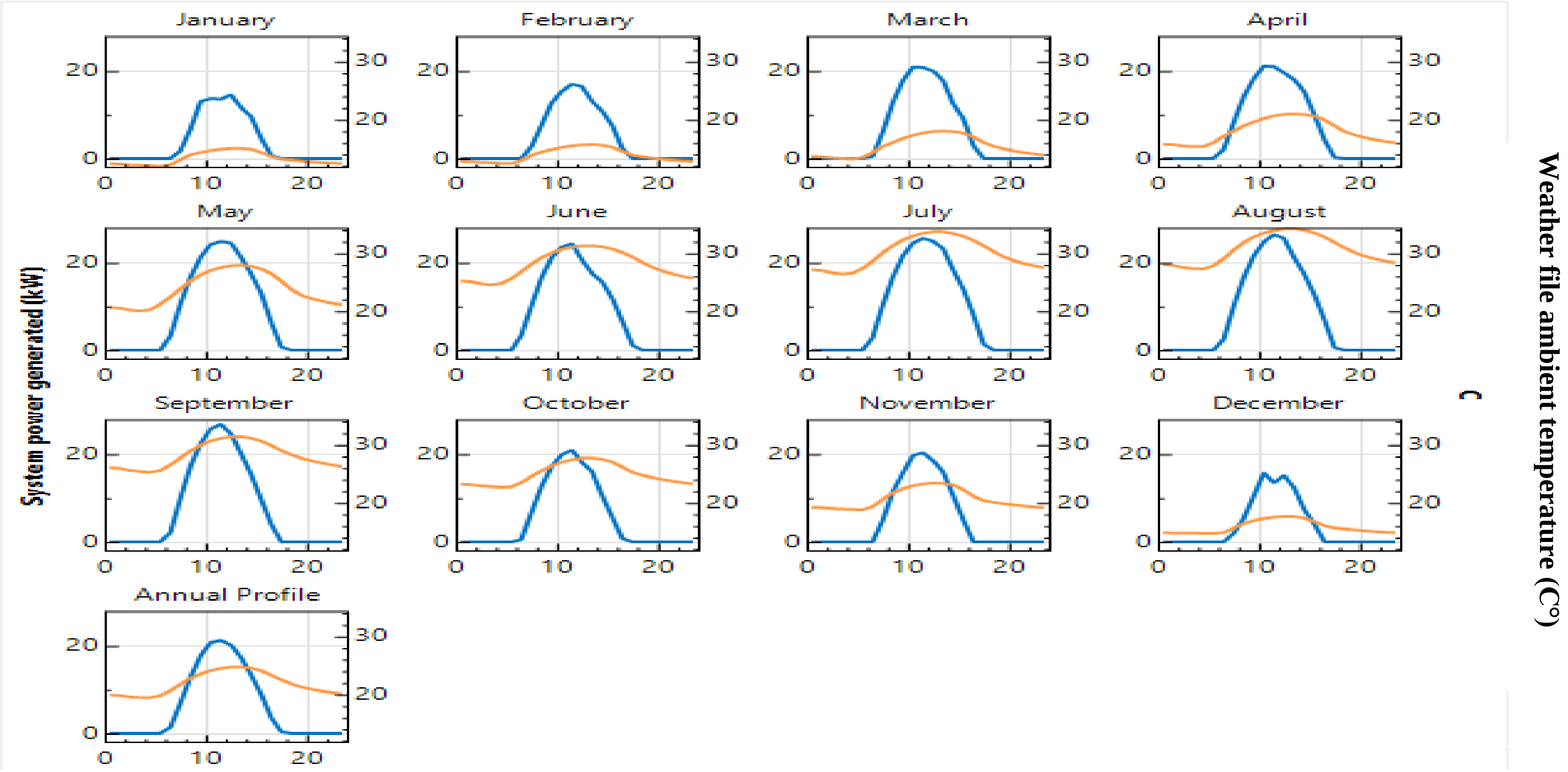

Table 5.2: Technical result of SAM for LSPV

Metric	**Value**
Annual AC energy in Year 1	1,048,190 kWh
DC capacity factor in Year 1	11.5%
Energy yield in Year 1	1,004 kWh/kW
Performance ratio in Year 1	0.79

Table 5.3: Technical result of SAM for FSPV

Metric	**Value for FSPV**
Annual AC energy in Year 1	1,033,063 kWh
DC capacity factor in Year 1	11.3%
Energy yield in Year 1	989 kWh/kW
Performance ratio in Year 1	0.78

The technical results obtained using the SAM program are shown in tables 5.2 and 5.3. Based on the input values entered, there is a difference in the results between land-based and floating solar panels. According to the general technical information obtained as a result of the researches, it is known that a solar power plant with 1 MW DC power produces approximately 1300-1400 times the more than current annual power. At the same time, for a solar power plant with 1 MW DC power, it is expected to produce approximately 1-1.1 GW of AC per year. When the table is examined in line with this information, the annual AC energy of LSPV in Year 1 was higher than that of FSPV. This is due to the fact that the DC capacitance factor in Year 1 is 0.02% higher for LSPV than FSPV. Considering the performance ratio in 1 year, it is seen that positive results were obtained for both solar power plants, since there was an almost equal ratio for both solar power plants.

5.2 Economical Results

Based on the input values entered, many different parameter results were observed. If we evaluate the land-based solar panel data in itself, it has been observed that the LCOE nominal value is higher than the LCOE real. The important reason for this is that the values of some of the entered parameters (such as the inital investment cost, operation and maintenance costs etc.) are different and higher than each other. Same situation is observed for FSPV as well.

Upon examination of the NPV parameter, it has been noted that positive outcomes are achieved in both categories of solar panels when the input values of project lifespan, cash flow, and discount rate are considered. A positive net present value (NPV) signifies that the project is financially viable. The outcomes derived from the SAM software employed for the economic evaluation of solar panels are presented in Tables 5.4 and 5.5. These tables provide the results separately for LSPV and FSPV.

Table 5.4: Economic result of SAM for LSPV

Metric	Value
LCOE Levelized cost of energy nominal	12.46 ¢/kWh
LCOE Levelized cost of energy real	5.32 ¢/kWh
NPV Net present value	$474,216
IRR Internal rate of return	12.00 %
Year IRR is achieved	20
IRR at end of project	12.78 %
Net capital cost	$1,035,822

Table 5.5:Economic result of SAM for FSPV

Metric	Value
LCOE Levelized cost of energy nominal	13.01 ¢/kWh
LCOE Levelized cost of energy real	5.55 ¢/kWh
NPV Net present value	$492,675
IRR Internal rate of return	12.00 %
Year IRR is achieved	20
IRR at end of project	12.78 %
Net capital cost	$1,075,768

5.3 Comparison Between Land-Based Solar PV and Floating Solar PV for Northern Cyprus

Considering the results of land-based and floating solar energy studies, it is a good result for a solar power plant project to have a low LCOE. A low LCOE indicates that the project is well designed from an economic point of view. LCOE values calculate the financial status of the project. Among these, there are many different factors such as how solar radiation is, equipment and maintenance prices. While preparing the feasibility report and proposal of a solar power plant project, it is very important to calculate the LCOE in order to be able to make a serious estimation of both the return and expense of the project and to give a price.

Low LCOE is normally known for a land-based solar power plant project. Among the biggest factors of this situation are the ease of access to panel maintenance, the preparation of the land for the power plant, and the easier construction works such as laying the foundation. Thanks to these, the LCOE is lower as the operating and maintenance cost of a land-based solar power plant is reduced, which shows that LSPV is more advantageous.

On the other hand, the biggest advantage of floating solar power plant projects is very little shading. FSPVs can generate more electricity due to less shading and the panels to stay cool all the time. At the same time, it is considered as a different positive approach that can be used in places where the land area is insufficient. However, it is expected that the LCOE real and nominal will be slightly higher, as FSPVs are more difficult to maintain and transport compared to LSPV.

Table 5.6: Comparison technical results between land-based and floating solar pv

Metric	Value for LSPV	Value for FSPV
Annual AC energy in Year 1	1,048,190 kWh	1,033,063 kWh
DC capacity factor in Year 1	11.5%	11.3%
Energy yield in Year 1	1,004 kWh/kW	989 kWh/kW
Performance ratio in Year 1	0.79	0.78

Table 5.7: Comparison economical results between land-based and floating solar pv

Metric	Value for LSPV	Value for FSPV
LCOE Levelized cost of energy nominal	12.46 ¢/kWh	13.01 ¢/kWh
LCOE Levelized cost of energy real	5.32 ¢/kWh	5.55 ¢/kWh
NPV Net present value	$474,216	$492,675
IRR Internal rate of return	12.00 %	12.00 %
Year IRR is achieved	20	20
IRR at end of project	12.78 %	12.78 %
Net capital cost	$1,035,822	$1,075,768

When looking at the economic comparison of land-based and floating solar panels from table 5.6 and 5.7, the results of the desired parameters differ from each other due to the different input values entered. First of all, if LCOE nominal and real values are evaluated as LSPV and FSPV, it is seen that the FSPV value is higher. One of the most important reasons affecting this is that the total cost value planned for FSPV is more costly than LSPV. The LCOE for LSPV is 0,0532 USD per kWh. This corresponds to approximately 1.42 TL with today's exchange rate. Likewise, the LCOE for FSPV is 0,0555 USD per kWh. This is equal to 1.48 TL in TL terms. When looking at the current KIB-TEK tariffs, the current electricity tariff is taken as a minimum of 3.98 TL. In this case, the income to be obtained from the production of both panels and the sale of the excess electricity will be high. Apart from this, it can be said that solar panels are valuable in both scenarios, instead of the cost to be spent by consuming fossil fuels.

It has been observed that the NPV value, which is one of the second and most important economic indicators, is higher for FSPV than for LSPV. One of the reason for this might be the effect of the entered shading and layouts parameters on the FSPV analysis. The positive NPV in both power plants means that these installations can be realized. A lifetime of 25 years is given for LSPV and FSPV plants. Without estimating the inflation rates in the coming years, the income to be obtained in the coming years has been calculated and it has been revealed that FSPV has more returns.

Table 5.8: A summary of experimental research into floating PV systems [68]

No.	Study Year	Types of installation information	Installation location on water body	Duration of test	Results for FSPV (Compared to LSPV)	Ref.
1	2014	**For FSPV:** PWR: 100 kW PVT: 33° **For LSPV:** PWR: 1 MW PVT: 30°	Hapcheon dam (South Korea)	Year	EffG: 11% OT: Less than LPV modules	[42]
2	2021	**For FSPV:** PVT: 15◦ Bifacial PV module **For LSPV:** PVT: 15◦ Monofacial PV module	A storm water pond (Weurt, Eastern Netherlands)	Year	EG: 17.3% (up to 29% in a clear-sky month) OT: Less than LPV modules	[69]
3	2021	PWR: 1 MW for both countries **1. Netherlands** **For FSPV:** PVT: 17◦	South-Holland lake (Netherlands)	Year	EG: 3% (in the Netherlands) and 6% (in Singapore) OT: Less than LPV modules	[70]

	PVCT: Poly-Si **For LSPV:** PVT: 22◦/35◦, PVCT: Poly-Si/Mono-Si	
	2. Singapore	
	For FSPV: PVT: 7◦/12◦ PVCT: Poly-Si **For LSPV:** PVT: 10◦ PVCT: Poly-Si	Tengeh Reservoir (West part of Singapore)

Although the total electricity produced from FSPV power plants was lower than LSPV in the study conducted for Northern Cyprus, as a result of studies conducted in different countries, FSPV was always found to be more efficient than LSPV. As an example, Figure 5.8 summarizes three different experimental studies for FSPV. Studies have obtained comparative results by performing LSPV analysis as well as FSPV analysis. Although the SAM program was not used in these results, the results show that FSPV has more energy and efficiency gains than LSPV. In another study, economic and technical results were obtained using the SAM program. This study is also included in the literature review [56]. According to the results of the SAM program, FSPV was found to be more convenient than LSPV. Moreover, the results showed that FSPV is a more efficient production method for India in terms of NPV and energy production.

CHAPTER 6

CONCLUSION

Today, renewable energy plays a crucial role in both energy production and the reduction of greenhouse gas emissions. Solar panels, one of the renewable energy types, are accepted as a convenient method for Northern Cyprus. The climate in Northern Cyprus is suitable for solar panel power facilities. Despite this, fossil fuels are used to produce and consume electricity. Therefore, the economic feasibility study of land-based solar photovoltaic (LSPV) and floating solar photovoltaic (FSPV) systems has provided valuable information regarding the potential for solar energy utilization in this region. The motivation behind this study was to evaluate the feasibility of installing solar panels on Geçitköy Dam, a pioneering study in this geographical region characterized by favorable climatic conditions for solar power generation. The results of this study show that both LSPV and FSPV systems offer promising power generation and financial prospects.

In the first year of operation, the LSPV system is expected to generate approximately 1,048,190 kWh, while the FSPV system is expected to generate approximately 1,033,563 kWh. These numbers demonstrate the substantial power generation capacities of both systems. Net Present Value (NPV) calculations, an important indicator of economic sustainability, reveal positive returns for both LSPV and FSPV. LSPV has an NPV of $474,216 while FSPV has an NPV of $492,675. These positive NPVs indicate that investment in solar systems is financially sound and can generate returns in excess of initial capital expenditure. Also, the Levelized Cost of Electricity (LCOE) for both LSPV and FSPV systems is very competitive with actual values of 0,0532 and 0,0555 USD per kWh, respectively. This demonstrates that both technologies can provide cost-effective electricity for the life of the project.

The overall cost of FSPV can be seen as a disadvantage. However, it still offers different advantages over LSPV. For example, in previous studies, positive factors such as the improvement in water in the FSPV installation area, the cooling of the panels due to water and the increase in efficiency, the establishment of high power plants by installing them in very large areas and saving on land area were discussed. In similar studies, it has been argued that these positive aspects are more valuable than the cost of installation.

In this thesis study, FSPV and LSPV power plants in Northern Cyprus were examined with all the methods included in the stated objectives. With the results obtained, it was found that both power plants were feasible for Cyprus. Moreover, this study concludes that both land-based and floating solar PV systems are economically viable and offer substantial advantages for electricity generation in Northern Cyprus. It had been expected that FSPV would generate more electricity than LSPV during the duration of the research. In consequence of the application of SAM, the opposite result was observed. In according to the findings and research, it has been determined that FSPV is more advantageous for island conditions over time. This is so that activities such as agriculture and animal husbandry, which are among the island's basic needs, can continue unrestricted. Another reason is that an island suffering from water shortage can prevent this problem by reducing water evaporation resulting from FSPVs. Moreover, it is a different matter that FSPV provides a more sustainable solution due to its advantages.

RECOMMENDATIONS FOR FUTURE WORK

Exploring the economic viability of floating and land-based solar energy in Northern Cyprus is a thrilling opportunity to develop sustainable energy. In contrast to other studies, it was stated in this thesis that a 1 MW power plant that can be built in Northern Cyprus is not only beneficial for LSPVs, but also suitable for FSPVs. In the future, more precise information on FSPVs may be obtained through a comprehensive review of the literature or experimental investigation. In addition, the success of this innovative project at Geçitköy Dam may inspire similar initiatives throughout the region, thereby guiding Northern Cyprus toward a more sustainable energy future.

To advance this research, it is suggested that a comprehensive site evaluation be conducted, taking into consideration geographical and technical factors, and that detailed financial models be developed, covering equipment costs, operation and maintenance costs, and local incentives. For the evaporation of water in the dam to be used for floating solar energy, a comprehensive study and calculations are required at the same time. Despite the fact that the floating solar energy efficiency analysis results of this study are lower than the land application, it is believed that this result will change with a more precise and accurate calculation compared to the System Advisor Model calculation. Ultimately, this research, along with future studies, will generate conclusive findings regarding the viability of FSPV and provide valuable data for future solar energy initiatives in the region and the renewable energy industry as a whole.

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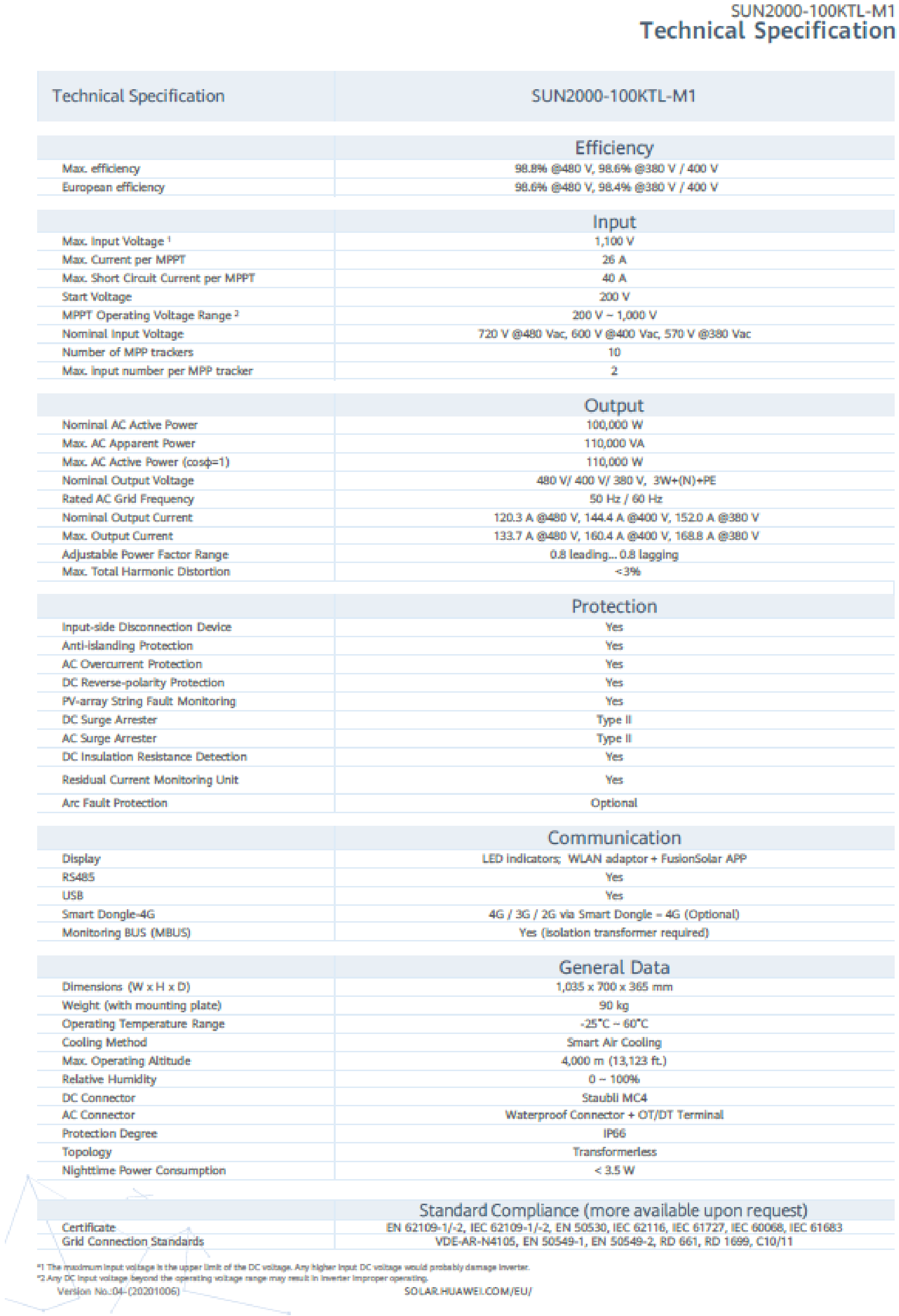
APPENDICES

A. Technical Information about Module and Inverter



SUN2000-100KTL-M1
Technical Specification

Technical Specification	SUN2000-100KTL-M1
	Efficiency
Max. efficiency	98.8% @480 V, 98.6% @380 V / 400 V
European efficiency	98.6% @480 V, 98.4% @380 V / 400 V
	Input
Max. Input Voltage [1]	1,100 V
Max. Current per MPPT	26 A
Max. Short Circuit Current per MPPT	40 A
Start Voltage	200 V
MPPT Operating Voltage Range [2]	200 V – 1,000 V
Nominal Input Voltage	720 V @480 Vac, 600 V @400 Vac, 570 V @380 Vac
Number of MPP trackers	10
Max. input number per MPP tracker	2
	Output
Nominal AC Active Power	100,000 W
Max. AC Apparent Power	110,000 VA
Max. AC Active Power (cosφ=1)	110,000 W
Nominal Output Voltage	480 V/ 400 V/ 380 V, 3W+(N)+PE
Rated AC Grid Frequency	50 Hz / 60 Hz
Nominal Output Current	120.3 A @480 V, 144.4 A @400 V, 152.0 A @380 V
Max. Output Current	133.7 A @480 V, 160.4 A @400 V, 168.8 A @380 V
Adjustable Power Factor Range	0.8 leading... 0.8 lagging
Max. Total Harmonic Distortion	<3%
	Protection
Input-side Disconnection Device	Yes
Anti-islanding Protection	Yes
AC Overcurrent Protection	Yes
DC Reverse-polarity Protection	Yes
PV-array String Fault Monitoring	Yes
DC Surge Arrester	Type II
AC Surge Arrester	Type II
DC Insulation Resistance Detection	Yes
Residual Current Monitoring Unit	Yes
Arc Fault Protection	Optional
	Communication
Display	LED Indicators; WLAN adaptor + FusionSolar APP
RS485	Yes
USB	Yes
Smart Dongle-4G	4G / 3G / 2G via Smart Dongle - 4G (Optional)
Monitoring BUS (MBUS)	Yes (isolation transformer required)
	General Data
Dimensions (W x H x D)	1,035 x 700 x 365 mm
Weight (with mounting plate)	90 kg
Operating Temperature Range	-25°C ~ 60°C
Cooling Method	Smart Air Cooling
Max. Operating Altitude	4,000 m (13,123 ft.)
Relative Humidity	0 ~ 100%
DC Connector	Staubli MC4
AC Connector	Waterproof Connector + OT/DT Terminal
Protection Degree	IP66
Topology	Transformerless
Nighttime Power Consumption	< 3.5 W
	Standard Compliance (more available upon request)
Certificate	EN 62109-1/-2, IEC 62109-1/-2, EN 50530, IEC 62116, IEC 61727, IEC 60068, IEC 61683
Grid Connection Standards	VDE-AR-N4105, EN 50549-1, EN 50549-2, RD 661, RD 1699, C10/11

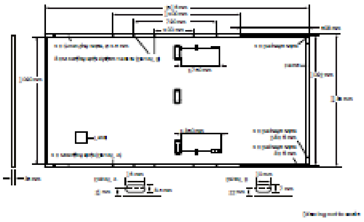
*1 The maximum input voltage is the upper limit of the DC voltage. Any higher input DC voltage would probably damage inverter.
*2 Any DC input voltage beyond the operating voltage range may result in inverter improper operating.

Version No.:04-(20201006)

SOLAR.HUAWEI.COM/EU/

MECHANICAL SPECIFICATION

Format	2416mm × 1134mm × 35mm (including frame)
Weight	30.7 kg
Front Cover	3.2 mm thermally pre-stressed glass with anti-reflection technology
Back Cover	Composite film
Frame	Anodised aluminium
Cell	6 × 26 monocrystalline Q.ANTUM solar half cells
Junction box	53-101 mm × 32-60 mm × 15-18 mm Protection class IP67, with bypass diodes
Cable	4 mm² Solar cable; (+) ≥750mm, (−) ≥ 350mm
Connector	Stäubli MC4-Evo2, Hanwha Q CELLS HQC4; IP68

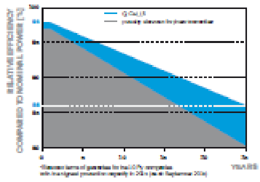


ELECTRICAL CHARACTERISTICS

POWER CLASS				570	575	580	585	590
MINIMUM PERFORMANCE AT STANDARD TEST CONDITIONS, STC[1] (POWER TOLERANCE +5 W / −0 W)								
Minimum	Power at MPP[1]	P_{MPP}	[W]	570	575	580	585	590
	Short Circuit Current[1]	I_{SC}	[A]	13.49	13.51	13.54	13.57	13.59
	Open Circuit Voltage[1]	V_{OC}	[V]	53.59	53.62	53.64	53.67	53.70
	Current at MPP	I_{MPP}	[A]	12.82	12.87	12.92	12.97	13.01
	Voltage at MPP	V_{MPP}	[V]	44.46	44.68	44.90	45.12	45.33
	Efficiency[1]	η	[%]	≥ 20.8	≥ 21.0	≥ 21.2	≥ 21.4	≥ 21.5
MINIMUM PERFORMANCE AT NORMAL OPERATING CONDITIONS, NMOT[2]								
Minimum	Power at MPP	P_{MPP}	[W]	427.6	431.4	435.1	438.9	442.6
	Short Circuit Current	I_{SC}	[A]	10.87	10.89	10.91	10.93	10.95
	Open Circuit Voltage	V_{OC}	[V]	50.54	50.56	50.59	50.62	50.64
	Current at MPP	I_{MPP}	[A]	10.09	10.13	10.17	10.22	10.26
	Voltage at MPP	V_{MPP}	[V]	42.39	42.58	42.77	42.96	43.14

[1] Measurement tolerances P_{MPP} ±3%; I_{SC}; V_{OC} ±5% at STC: 1000W/m², 25±2°C, AM 1.5 according to IEC 60904-3 • [2] 800W/m², NMOT, spectrum AM 1.5

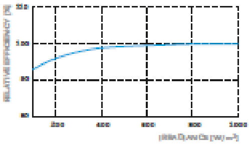
Q CELLS PERFORMANCE WARRANTY



At least 98% of nominal power during first year. Thereafter max. 0.5% degradation per year. At least 93.5% of nominal power up to 10 years. At least 86% of nominal power up to 25 years.

All data within measurement tolerances. Full warranties in accordance with the warranty terms of the Q CELLS sales organisation of your respective country.

PERFORMANCE AT LOW IRRADIANCE



Typical module performance under low irradiance conditions in comparison to STC conditions (25°C, 1000W/m²).

TEMPERATURE COEFFICIENTS

Temperature Coefficient of I_{SC}	α	[%/K]	+0.04	Temperature Coefficient of V_{OC}	β	[%/K]	−0.27
Temperature Coefficient of P_{MPP}	γ	[%/K]	−0.34	Nominal Module Operating Temperature	NMOT	[°C]	43±3

PROPERTIES FOR SYSTEM DESIGN

Maximum System Voltage	V_{SYS}	[V]	1500	PV module classification	Class II
Maximum Reverse Current	I_R	[A]	25	Fire Rating	C
Max. Design Load, Push / Pull		[Pa]	3600 / 1600	Permitted Module Temperature on Continuous Duty	−40°C - +85°C
Max. Test Load, Push / Pull		[Pa]	5400 / 2400		

QUALIFICATIONS AND CERTIFICATES

IEC 61215:2016, IEC 61730:2016.
This data sheet complies
with DIN EN 50380.

PACKAGING INFORMATION

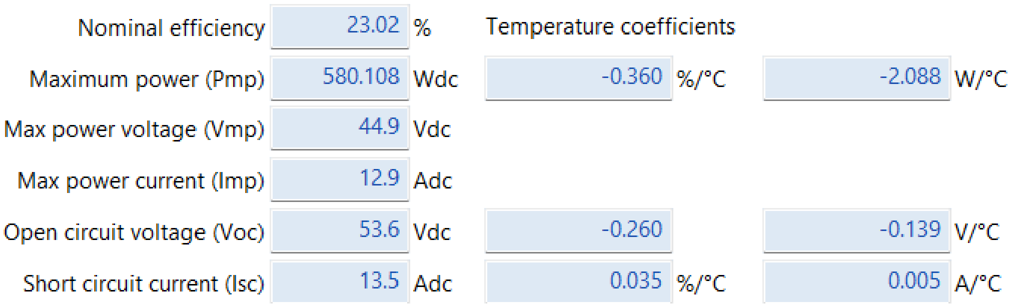
Vertical packaging	2458mm	1134mm	1270mm	1000kg	20 pallets	16 pallets	31 modules

Note: Installation instructions must be followed. See the installation and operating manual or contact our technical service department for further information on approved installation and use of this product.

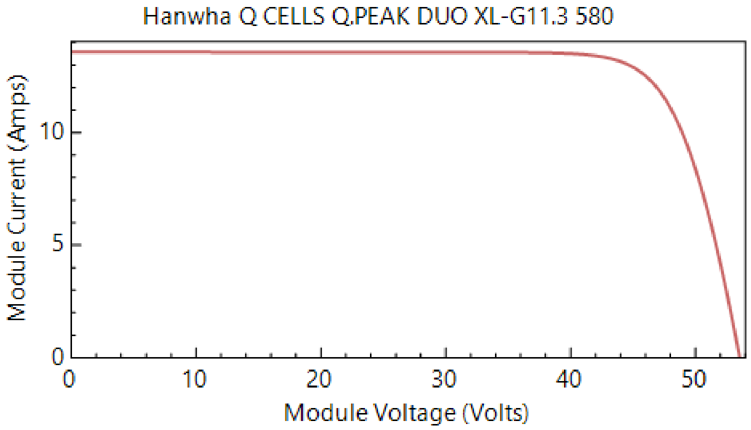
Hanwha Q CELLS GmbH
Sonnenallee 17-21, 06766 Bitterfeld-Wolfen, Germany | **TEL** +49 (0)34 94 66 99-23444 | **FAX** +49 (0)3494 66 99-23000 | **EMAIL** sales@q-cells.com | **WEB** www.q-cells.com

Specifications subject to technical changes © Q CELLS Q.PEAK DUO XL-G11.3_570-590_2021-08_Rev03_EN

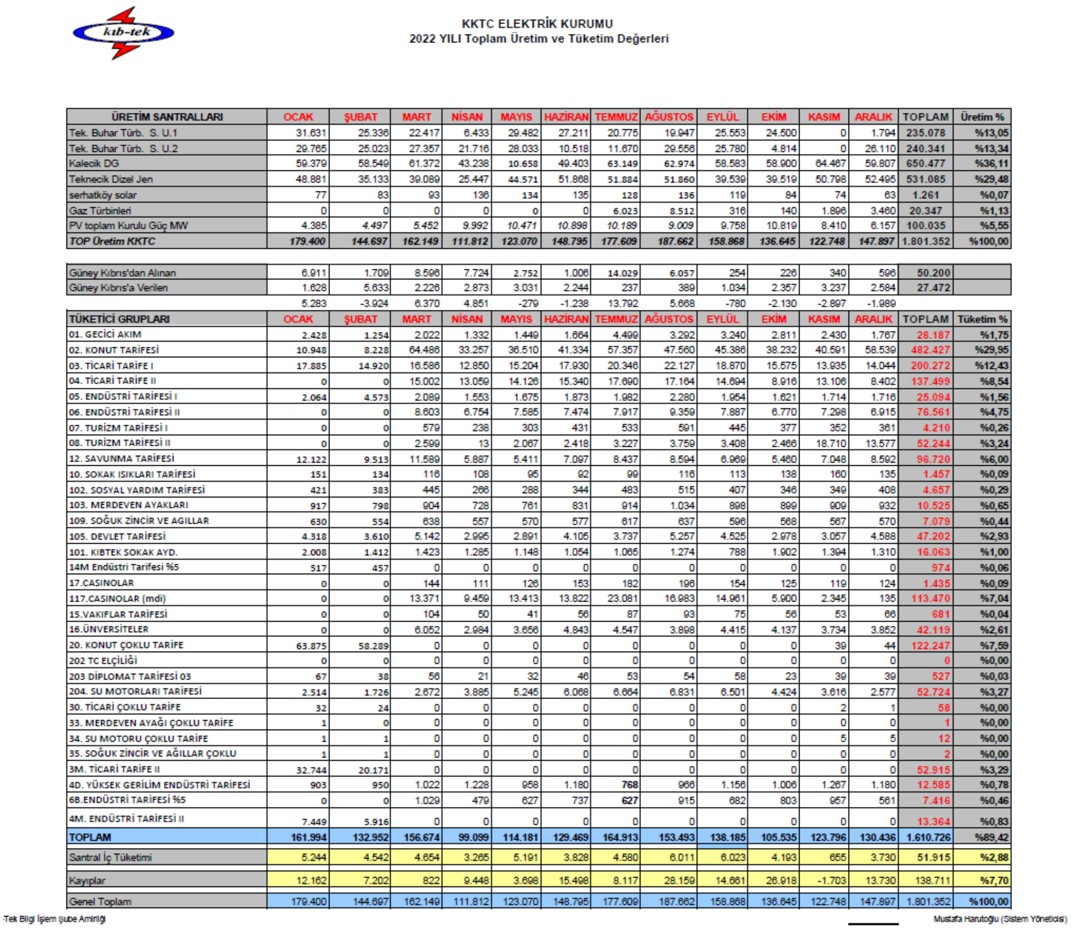
Engineered in Germany



Nominal efficiency	23.02	%	Temperature coefficients			
Maximum power (Pmp)	580.108	Wdc	-0.360	%/°C	-2.088	W/°C
Max power voltage (Vmp)	44.9	Vdc				
Max power current (Imp)	12.9	Adc				
Open circuit voltage (Voc)	53.6	Vdc	-0.260		-0.139	V/°C
Short circuit current (Isc)	13.5	Adc	0.035	%/°C	0.005	A/°C



B. KIB-TEK Total Production and Consumption, Tarrifs



KKTC ELEKTRİK KURUMU
2022 YILI Toplam Üretim ve Tüketim Değerleri

ÜRETİM SANTRALLARI	OCAK	ŞUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL	EKİM	KASIM	ARALIK	TOPLAM	Üretim %
Tek. Buhar Türb. S. U.1	31.631	25.336	22.417	6.433	29.482	27.211	20.775	19.947	25.553	24.500	0	1.794	235.078	%13,05
Tek. Buhar Türb. S. U.2	29.765	25.023	27.357	21.716	28.033	10.518	11.670	29.556	25.780	4.814	0	26.110	240.341	%13,34
Kalecik DG	59.379	58.549	61.372	43.238	10.658	49.403	63.149	62.974	58.583	58.900	64.467	59.807	650.477	%36,11
Teknecik Dizel Jen	48.881	35.133	39.089	25.447	44.571	51.868	51.884	51.860	39.539	39.519	50.798	52.495	531.085	%29,48
serhatköy solar	77	83	93	136	134	135	128	136	119	84	74	63	1.261	%0,07
Gaz Türbinleri	0	0	0	0	0	0	6.023	8.512	316	140	1.896	3.460	20.347	%1,13
PV toplam Kurulu Güç MW	4.385	*4.497*	*5.452*	*9.992*	*10.471*	*10.898*	*10.189*	*9.009*	9.758	10.819	8.410	6.157	100.035	%5,55
TOP Üretim KKTC	***179.400***	***144.697***	***162.149***	***111.812***	***123.070***	***148.795***	***177.609***	***187.662***	***158.868***	***136.645***	***122.748***	***147.897***	1.801.352	%100,00
Güney Kıbrıs'dan Alınan	6.911	1.709	8.596	7.724	2.752	1.006	14.029	6.057	254	226	340	596	50.200	
Güney Kıbrıs'a Verilen	1.628	5.633	2.226	2.873	3.031	2.244	237	389	1.034	2.357	3.237	2.584	27.472	
	5.283	-3.924	6.370	4.851	-279	-1.238	13.792	5.668	-780	-2.130	-2.897	-1.989		

TÜKETİCİ GRUPLARI	OCAK	ŞUBAT	MART	NİSAN	MAYIS	HAZİRAN	TEMMUZ	AĞUSTOS	EYLÜL	EKİM	KASIM	ARALIK	TOPLAM	Tüketim %
01. GECİCİ AKIM	2.428	1.254	2.022	1.332	1.449	1.664	4.499	3.292	3.240	2.811	2.430	1.767	28.187	%1,75
02. KONUT TARİFESİ	10.948	8.228	64.486	33.257	36.510	41.334	57.357	47.560	45.386	38.232	40.591	58.539	482.427	%29,95
03. TİCARİ TARİFE I	17.885	14.920	16.586	12.850	15.204	17.930	20.346	22.127	18.870	15.575	13.935	14.044	200.272	%12,43
04. TİCARİ TARİFE II	0	0	15.002	13.059	14.126	15.340	17.690	17.164	14.694	8.916	13.106	8.402	137.499	%8,54
05. ENDÜSTRİ TARİFESİ I	2.064	4.573	2.089	1.553	1.675	1.873	1.982	2.280	1.954	1.621	1.714	1.716	25.094	%1,56
06. ENDÜSTRİ TARİFESİ II	0	0	8.603	6.754	7.585	7.474	7.917	9.359	7.887	6.770	7.298	6.915	76.561	%4,75
07. TURİZM TARİFESİ I	0	0	579	238	303	431	533	591	445	377	352	361	4.210	%0,26
08. TURİZM TARİFESİ II	0	0	2.599	13	2.067	2.418	3.227	3.759	3.408	2.466	18.710	13.577	52.244	%3,24
12. SAVUNMA TARİFESİ	12.122	9.513	11.589	5.887	5.411	7.097	8.437	8.594	6.969	5.460	7.048	8.592	96.720	%6,00
10. SOKAK ISIKLARI TARİFESİ	151	134	116	108	95	92	99	116	113	138	160	135	1.457	%0,09
102. SOSYAL YARDIM TARİFESİ	421	383	445	266	288	344	483	515	407	346	349	408	4.657	%0,29
103. MERDEVEN AYAKLARI	917	798	904	728	761	831	914	1.034	898	899	909	932	10.525	%0,65
109. SOĞUK ZİNCİR VE AGILLAR	630	554	638	557	570	577	617	637	596	568	567	570	7.079	%0,44
105. DEVLET TARİFESİ	4.318	3.610	5.142	2.995	2.891	4.105	3.737	5.257	4.525	2.978	3.057	4.588	47.202	%2,93
101. KIBTEK SOKAK AYD.	2.008	1.412	1.423	1.285	1.148	1.054	1.065	1.274	788	1.902	1.394	1.310	16.063	%1,00
14M Endüstri Tarifesi %5	517	457	0	0	0	0	0	0	0	0	0	0	974	%0,06
17.CASINOLAR	0	0	144	111	126	153	182	196	154	125	119	124	1.435	%0,09
117.CASINOLAR (mdi)	0	0	13.371	9.459	13.413	13.822	23.081	16.983	14.961	5.900	2.345	135	113.470	%7,04
15.VAKIFLAR TARİFESİ	0	0	104	50	41	56	87	93	75	56	53	66	681	%0,04
16.ÜNVERSİTELER	0	0	6.052	2.984	3.656	4.843	4.547	3.898	4.415	4.137	3.734	3.852	42.119	%2,61
20. KONUT ÇOKLU TARİFE	63.875	58.289	0	0	0	0	0	0	0	0	39	44	122.247	%7,59
202 TC ELÇİLİĞİ	0	0	0	0	0	0	0	0	0	0	0	0	0	%0,00
203 DİPLOMAT TARİFESİ 03	67	38	56	21	32	46	53	54	58	23	39	39	527	%0,03
204. SU MOTORLARI TARİFESİ	2.514	1.726	2.672	3.885	5.245	6.068	6.664	6.831	6.501	4.424	3.616	2.577	52.724	%3,27
30. TİCARİ ÇOKLU TARİFE	32	24	0	0	0	0	0	0	0	0	2	1	58	%0,00
33. MERDEVEN AYAĞI ÇOKLU TARİFE	1	0	0	0	0	0	0	0	0	0	0	0	1	%0,00
34. SU MOTORU ÇOKLU TARİFE	1	1	0	0	0	0	0	0	0	0	5	5	12	%0,00
35. SOĞUK ZİNCİR VE AĞILLAR ÇOKLU	1	1	0	0	0	0	0	0	0	0	0	0	2	%0,00
3M. TİCARİ TARİFE II	32.744	20.171	0	0	0	0	0	0	0	0	0	0	52.915	%3,29
4D. YÜKSEK GERİLİM ENDÜSTRİ TARİFESİ	903	950	1.022	1.228	958	1.180	**768**	966	1.156	1.006	1.267	1.180	12.585	%0,78
6B.ENDÜSTRİ TARİFESİ %5	0	0	1.029	479	627	737	**627**	915	682	803	957	561	7.416	%0,46
4M. ENDÜSTRİ TARİFESİ II	7.449	5.916	0	0	0	0	0	0	0	0	0	0	13.364	%0,83
TOPLAM	**161.994**	**132.952**	**156.674**	**99.099**	**114.181**	**129.469**	**164.913**	**153.493**	**138.185**	**105.535**	**123.796**	**130.436**	**1.610.726**	**%89,42**
Santral İç Tüketimi	5.244	4.542	4.654	3.265	5.191	3.828	4.580	6.011	6.023	4.193	655	3.730	51.915	%2,88
Kayıplar	12.162	7.202	822	9.448	3.698	15.498	8.117	28.159	14.661	26.918	-1.703	13.730	138.711	%7,70
Genel Toplam	179.400	144.697	162.149	111.812	123.070	148.795	177.609	187.662	158.868	136.645	122.748	147.897	1.801.352	%100,00

·Tek Bilgi İşlem şube Amirliği

Mustafa Harutoğlu (Sistem Yöneticisi)

Tarife İsmi		Eski Maktu Ücretler	Yeni Maktu Ücretler	Eski Tarife Ücretleri	
01 Geçici Akım Tarifesi I				Her kWs için	**5,5484**
102 konut Tarifesi (ilk 500 Kws için) Yoksul muafiyetli		**25,00**	**35,50**	Her kWs için	**0,3442**
02 konut Tarifesi (0- 250 Kws)				Her kWs için	**1,9332**
02 konut Tarifesi (251-500 Kws)				Her kWs için	**3,9884**
02 konut Tarifesi (501-750 Kws)				Her kWs için	**4,2884**
02 konut Tarifesi (751-1000 Kws)				Her kWs için	**4,6484**
02 konut Tarifesi (1001 Kws üzeri)				Her kWs için	**5,5484**
03 Ticari Tarife	Tek faz	**35,00**	**46,90**	Her kWs için	**3,9884**
	Çok faz	**50,00**	**67,00**		
04 Ticari Tarife	Her KVA İçin	**8,00**	**10,72**	1.Dilim	**3,9884**
				2.Dilim	**3,9884**

05 Endüstri Tarife	Tek faz	**35,00**	**46,90**	Her kWs için	**3,9884**
	Çok faz	**50,00**	**67,00**		
06 Endüstri Tarife	Her KVA İçin	**8,00**	**10,72**	1.Dilim	**3,9884**
				2.Dilim	**3,9884**
07 Turizm Tarife	Tek faz	**35,00**	**46,90**	Her kWs için	**3,9884**
	Çok faz	**50,00**	**67,00**		
08 Turizm Tarife	Her KVA İçin	**8,00**	**10,72**	1.Dilim	**3,9884**
				2.Dilim	**3,9884**
09 Su Motorları	Tek faz	**35,00**	**46,90**	Her kWs için	**3,9884**
	Çok faz	**50,00**	**67,00**		
10 Sokak Işıkları				Her kWs için	**4,9484**
12 Savunma Tarifesi				Her kWs için	**3,9884**
13 Devlet Daireleri Tarifesi	Tek faz	**35,00**	**46,90**	Her kWs için	**4,9484**
	Çok faz	**50,00**	**67,00**		
15 Vakıflar	Tek faz	**35,00**	**46,90**	Her kWs için	**3,9884**
	Çok faz	**50,00**	**67,00**		**3,9884**
16 Üniversiteler	Tek faz	**8,00**	**10,72**	1.Dilim	**3,9884**
	Çok faz			2.Dilim	**3,9884**
17 Casinolar	Tek faz	**8,00**	**10,72**	1.Dilim	**4,9484**
	Çok faz			2.Dilim	**4,9484**