CRITICAL SUCCESS FACTORS FOR FLOATING PHOTOVOLTAIC SYSTEMS IN TURKİYE

by

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ABSTRACT

CRITICAL SUCCESS FACTORS FOR FLOATING PHOTOVOLTAIC SYSTEMS IN TURKİYE

Energy consumption is rising globally and in Türkiye, increasing reliance on nonrenewable resources with harmful environmental effects. Renewable energy (RE) sources, particularly solar energy, are gaining attention for their cleaner nature and adaptability. In Türkiye, the potential for floating photovoltaic (FPV) systems is significant due to the large number of suitable dams. However, research on FPV systems remains limited, focusing mainly on site selection. This study addresses this gap by examining critical factors for FPV system success using the Critical Success Factor (CSF) method along with qualitative and quantitative methods. A literature review identified 17 essential CSFs, followed by a survey targeting academia and the private sector. Using a Likert Scale, participants rated the importance of each CSF, and statistical analysis compared responses across groups. Out of 412 people contacted, 90 valid responses were received, providing a solid dataset for analysis. Factor analysis grouped CSFs into three main categories: Energy Optimization, Community Engagement, and Economic Sustainability. Key CSF groupings demonstrated the interconnectivity of environmental sustainability, economic feasibility, and stakeholder collaboration, providing a holistic perspective for FPV implementation in Türkiye. This study contributes to the literature by offering a roadmap for all stakeholders for evaluating FPV systems beyond site selection. Findings guide policymakers and investors in prioritizing resources to enhance FPV adoption, emphasizing the importance of addressing country-specific challenges and resource availability. Additionally, the insights underscore the value of aligning RE strategies with global sustainability goals while considering local economic conditions.

ÖZET

TÜRKİYE'DEKİ YÜZER GÜNEŞ ENERJİ SİSTEMLERİ (GES) İÇİN KRİTİK BAŞARI FAKTÖRLERİ

Artan enerji tüketimi, çevreye zararlı etkileri olan yenilenemez kaynaklara olan bağımlılığı artırmaktadır. Daha temiz bir enerji kaynağı olarak güneş enerjisi, diğer yenilenebilir kaynaklarla uyumluluğu sayesinde giderek daha fazla dikkat çekmektedir. Türkiye, barajlarıyla yüzer güneş enerjisi sistemleri (Yüzer GES) için büyük bir potansiyele sahip olsa da araştırmalar genellikle saha seçimine odaklanmaktadır. Bu çalışma, Yüzer GES sistemlerinin başarısı için kritik faktörleri inceleyerek bu boşluğu doldurmayı amaçlamaktadır. Yapılan kapsamlı bir literatür taraması ile 17 kritik başarı faktörü (KBF) belirlenmiş ve bir anket gerçekleştirilmiştir. Katılımcılar, her bir faktörün önemini değerlendirmiş ve gruplar arasındaki farklılıkları belirlemek için istatistiksel analizler yapılmıştır. Toplamda 412 kişiyle iletişime geçilmiş ve 90 geçerli yanıt alınarak analizler için sağlam bir veri seti oluşturulmuştur. Faktör analizi, KBF'leri Enerji Optimizasyonu, Toplum Katılımı ve Ekonomik Sürdürülebilirlik olarak kategorilere ayırmış; bu süreç, paydaş önceliklerindeki önemli farklılıkları ortaya koyarak projelerde özelleştirilmiş stratejilerin gerekliliğini vurgulamıştır. Kritik başarı faktörleri, çevresel sürdürülebilirlik, ekonomik fizibilite ve paydaş iş birliği bağlantılarını ortaya koyarak Yüzer GES uygulamaları için bütüncül bir perspektif sunmuştur. Bu çalışma, saha seçiminin ötesinde yüzer GES sistemlerini değerlendirmek için kapsamlı bir çerçeve sunmanın yanı sıra, tüm paydaşların takip edebileceği bir yol haritası da sunmaktadır. Bulgular, Yüzer GES uygulamalarını artırmak için kaynak önceliklendirmesinde politika yapıcılar ve yatırımcılara rehberlik sağlamakta; ülkeye özgü zorluklar ve kaynakların etkin kullanımına dikkat çekmektedir.

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LIST OF SYMBOLS

^oC	Degree celcius
α	Reliability level

LIST OF ACRONYMS/ABBREVIATIONS

ANOVA	Analysis of Variance
BESS	Battery Energy Storage Systems
BIM	Building Information Modeling
CAES	Compressed Air Energy Storage
CFD	Computational Fluid Dynamics
CMR	Construction Management Research
CO_2	Carbon Dioxide
CSF	Critical Success Factors
DO	Dissolved Oxygen
DSI	General Directorate of State Hydraulic Works
ERP	Enterprise Resource Planning
ETFE	Ethylene Tetrafluoroethylene
FAHP	Fuzzy Analytical Hierarchy Process
FPV	Floating Photovoltaic
GDP	Gross Domestic Product
GHI	Global Horizontal Irradiance
GIS	Geographic Information System
GWh	Gigawatt-Hours
GWP	Global Warming Potential
HDPE	High-Density Polyethylene
HPP	Hydropower Plant
IRENA	The International RE Agency
Km^2	Kilometer-square
KOSGEB	Small and Medium Enterprises Development Organization
Kwh	Kilowatt-hours
LCA	Life Cycle Assessment
LCOE	Levelized Cost of Energy
LPV	Land Photovoltaic

MCDM	Multi-criteria Decision-making
Mm	Milimeters
MW	Megawatt
NPV	Net Present Value
NRE	Nonrenewable Energy
O&M	Operations and Maintenance
OSC	Organic Solar Cell
PAF	Principal Axis Factoring
PCA	Principal Component Analysis
PH	Potential of Hydrogen
POI	Point of Interconnection
R&D	Research and Development
RE	Renewable Energy
RS	Remote Sensing
SME	Small and Medium-sized Enterprises
The UN	United Nations
The US	United States of America
TL	Turkish Lira
TÜBİTAK	The Scientific and Technological Research Council of Türkiye
TWh	Terawatt-hours
TYT	Clean Creative Technologies
USBR	The United States Bureau of Reclamation
YEKA	Renewable Energy Resource Areas
YEKDEM	RE Support Mechanism

1. INTRODUCTION

1.1. Background and Motivation

Energy and how to harvest it is a major topic in today's world, as total energy consumption worldwide has exceeded over 580 million terajoules (BP, 2019) (Global Energy Consumption, n.d.). This consumption is the main driver of the economy. Lee (2006) states the energy consumption's importance as being an important input for different economic activities such as industry and underlines its importance by looking into the G-11 countries' energy consumption.

Unfortunately, we are still relying upon nonrenewable energy (NRE) as a primary use of energy resources. To give an example, Ghose *et al.* (2024) give insight from the United States of America (USA), as the paper mentions NRE resources like petroleum, natural gas, nuclear energy, and coal still constitute 90% of the energy consumption in 2023, whereas only 10% of the energy consumption is coming from their renewable counterparts. The consumption of NRE resources continues to rise, albeit at a slower pace. The main two reasons for this slower pace are the limited amount of NRE resources and their harmful effects on the environment, especially the carbon dioxide (CO_2) emissions that the NRE resources cause. The research made by Jackson and Garthwaite (2023) concluded that for 2023, 37 billion tons of CO_2 emissions are due to the creation of energy derived from NRE resources, which is a 1.1% increase compared to 2022. It is stated that this will cause a 1.5^oC increase in temperature by 2030. However, the rate of increase in CO_2 emissions has declined. Liu *et al.* (2024) explain this decline in 3 items:

(i) Energy resources are being more efficiently utilized,

(ii) The energy mix is undergoing significant transformation,

(iii) Not relying on NRE completely.

The reason for not relying entirely on NRE is that renewable energy (RE) sources are gaining traction. Among these, Floating Photovoltaic (FPV) systems are attracting significant attention due to their innovative approach to energy generation. These systems are particularly relevant in Türkiye, where abundant water resources provide significant potential for solar energy production According to the Figure 1.1, which shows Global Horizontal Irradiance (GHI) levels for Türkiye, Türkiye benefits from favorable solar irradiance levels across much of its territory, highlighting its significant potential for solar energy deployment, including FPV systems.

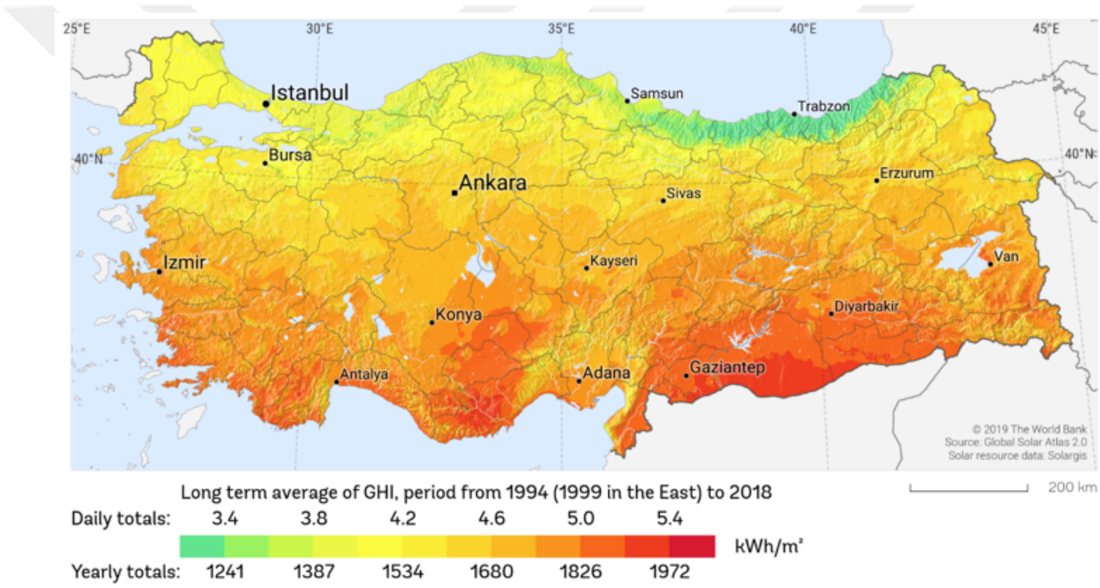

Figure 1.1. GHI for Türkiye (World Bank Group, 2023).

FPV systems can be deployed in two main applications: on inland water bodies such as reservoirs and lakes, or in offshore environments. This study primarily focuses on FPV implementation in inland water bodies, while also addressing critical information regarding offshore environments. Moreover, as a scalable and innovative technology, FPV systems represent a promising solution to address global energy demands while utilizing existing water infrastructure efficiently. By integrating FPV systems, countries can diversify their energy portfolios, enhance sustainability, and contribute to global renewable energy goals. Figure 1.2 illustrates a schematic representation of a typical large-scale FPV system and its components, including PV modules, floats or pontoons, anchoring systems, and underwater cables.

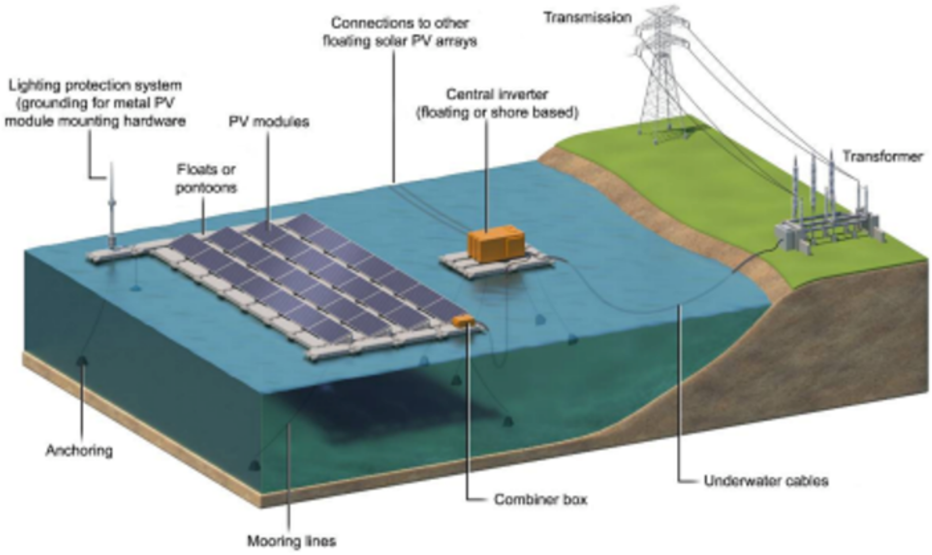

Figure 1.2. Typical FPV System (Gadzanku *et al.*, 2021).

FPV systems offer unique advantages over other renewable energy sources in terms of adaptability, scalability, and economic potential. Wind turbines are highly dependent on specific site conditions, such as open areas and stable high wind speeds, limiting their geographic applicability. Compared to Hydroelectric Power Plants (HPP), FPV systems avoid the environmental impact associated with dam construction. Hydropower projects can disrupt ecosystems and displace communities, whereas FPV systems utilize existing water bodies without introducing significant environmental disruptions. FPV systems are easier to integrate with existing water infrastructure, providing scalable and adaptable solutions for renewable energy generation.

When compared to other floating renewable energy sources, such as floating wind and floating tidal systems, FPV systems stand out for their economic feasibility. Floating wind systems face higher levelized cost of energy (LCOE) values, averaging \$120–150/megawatt-hours (MWh), while floating tidal systems have an LCOE between \$150–280/MWh, both significantly higher than FPV's \$60–80/MWh (IRENA, 2022). FPV systems are not constrained by specific geographic conditions and involve simpler installation and maintenance processes, making them a more viable option for large-scale deployment. FPV systems can also be integrated with hydropower facilities, enabling hybrid systems that enhance energy output and consistency.

When comparing FPV systems to Land Photovoltaic (LPV) systems, FPV systems address key challenges such as land scarcity and conflicts with agricultural or urban development. While LPV systems generally have a lower LCOE, FPV systems offer economic benefits by generating more job opportunities during installation and operation. They can also contribute to local economies by creating new revenue streams for communities reliant on reservoirs and dams, further strengthening their appeal as part of a renewable energy strategy.

With RE sources becoming increasingly important, the focus now shifts to the effective implementation of innovative systems like FPV, which require careful planning and execution to realize their full potential. In the implementation of complex projects like FPV systems, identifying and addressing Critical Success Factors (CSFs) is essential. CSFs refer to the key elements that determine the success or failure of a project by highlighting the areas requiring prioritization and careful management. These factors provide a structured framework to guide stakeholders in aligning resources, addressing challenges, and optimizing outcomes. For FPV systems, CSFs play a pivotal role in ensuring not only technical feasibility but also environmental sustainability and economic viability. By focusing on these critical factors, stakeholders can navigate the complexities of FPV projects and enhance the likelihood of their successful implementation.

Both the adoption of innovative technologies like FPV systems and the identification of CSFs underscore the importance of aligning renewable energy efforts with global climate goals. Thus, reducing carbon emissions has become a primary focus globally, with a significant driver being the net zero carbon emission goal set by the United Nations (the UN) for 2050. The urgency of addressing carbon emissions is driven by several factors. The first of these factors is that carbon emissions ultimately lead to climate change, causing global warming worldwide, with severe consequences such as extreme weather conditions, harm to ecosystems, and rising sea levels (Liu *et al.*, 2024). Furthermore, the harmful gases released during the process of burning NRE resources result in critical health conditions that can be fatal. Lastly, the acidification of water bodies due to CO_2 emissions disrupts both offshore and on-land ecosystems, significantly reducing biodiversity, as water is a vital source of life (Friedlingstein *et al.*, 2023).

In order to reduce this high emission of carbon, in 2015, a pact was signed at the Paris Agreement, and it was agreed that to achieve net zero carbon emissions, carbon emissions must be balanced with the amount of carbon discharged from the atmosphere (Zhao C. , 2022), meaning that there should be no net increase in atmospheric carbon. To achieve that, reducing emissions from fossil fuels and other sources while making investments in the infrastructure for RE sources, particularly systems such as FPV systems, is required.

Due to NRE seeming like an unfavorable option day by day, the need for different energy resources that do not harm the environment as much is increasing. Luckily, especially over the last decade, the use of RE in energy consumption is increasing significantly. Another example from the USA, which is given by Ellerbeck (2023), shows that around 40% of the generated energy is from RE resources, which should not cause confusion, as it was previously stated that energy consumption in the USA at the same time was around 10% for NRE resources; the discrepancy is caused by energy resources imported. In Türkiye, on the other hand, this contribution of RE into the energy production was even higher, around 42% in 2023, while hydropower alone constitutes almost half of RE share (Albayrak, 2024). This is mostly caused by the availability of water resources. The main contributors to this 42% are hydro, wind, and solar energy.

1.2. Problem Statement

FPV systems are complex and unique structures regardless of their size. Different stakeholders, such as project owners or clients, investors, contractors, subcontractors, architects, engineers, and suppliers, need to cooperate and coexist. Moreover, government and regulatory bodies, banks and financial institutions, insurance companies, end users, as well as community and environmental groups, can all play significant roles. All the stakeholders contribute to the project's financing, handling, compliance with regulations, and outcome in their own way. The probable stakeholders for a construction project can be seen from Figure 1.3.

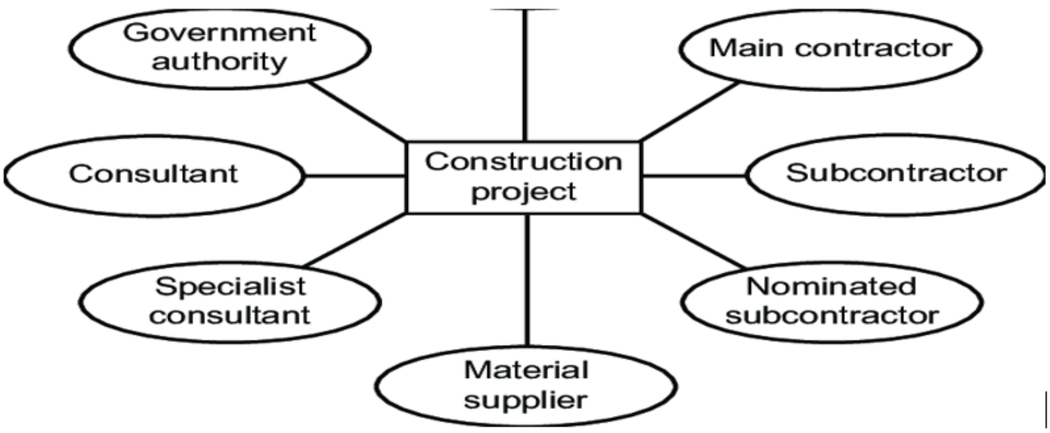

Figure 1.3. Stakeholders of a construction project (Ng and Banaitis, 2017).

If those stakeholders' needs are fulfilled, it is said that the project is feasible. However, projects being feasible can mean different things to different stakeholders. Esmaeili *et al.* (2015) state that each stakeholder may have conflicting or even disparate goals. For instance, an owner might place more emphasis on on-budget completion or construction quality, while a contractor might view speed and profitability as the most crucial success factors. If expectations are not conveyed, these divergent perspectives on success may lead to subpar project performance overall.

There is a gap in the literature for comparing every stakeholder's opinion for the decision-making process. In this study, the most important success factors for FPV projects are going to be determined. The concept of CSF was first introduced by John Rockart in 1979 (Rockart, 1979) and is described as "the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization." It focuses on determining and ranking the critical elements that are necessary to accomplish an organization's goals.

Determination of CSFs would benefit the project as it would allow for facilitating strategic planning, improving stakeholder communication, and identifying and prioritizing critical components. It helps measure performance, identifies gaps in procedures, and offers an organized method for coordinating organizational efforts with goals, all of which improve resource management and decision-making. Finding CSFs is crucial in construction projects as they help identify key elements that ensure project success. The study focuses on optimizing construction operations through improved managerial support, dedication, teamwork, communication, and trust-building.

However, the CSF, along with surveying as qualitative and factor analysis as quantitative analysis, has several drawbacks. It frequently depends on arbitrary expert judgments, which results in uneven factor prioritizing. Furthermore, generalizations are difficult because CSFs might differ throughout various businesses, projects, and geographical areas. The validation of many identified CSFs is further complicated by the fact that they are not supported by empirical evidence. Lastly, it is usually difficult to determine the exact relationship between CSFs and project success, which prevents a more thorough comprehension of how these elements affect total project performance. Even though those limitations exist, this approach is still crucial, especially for construction projects, since it offers an important framework that can be used. However, no such study exists for RE, especially for FPV systems. Moreover, in Türkiye, the main direction that the FPV studies are channeled is to find the most suitable site locations rather than to investigate whether this project is efficient to begin with. These papers provide valuable guidance, but examining the factors influencing FPV systems' success in Türkiye remains essential.

1.3. Aim and Objectives

The paper aims to find CSFs for FPV systems and compare their importance to one another while also providing comparisons between different stakeholder groups. Also, it is aimed that grouping of the CSFs would be accomplished so that factors may be better understood.

In order to determine the CSFs for FPV systems, an approach close to Cooper (2008) should be employed. CSFs are crucial components that have a big impact on project success because they let stakeholders set priorities and distribute resources effectively. Decision-makers may improve the efficiency and sustainability of FPV installations by being aware of these aspects, which will ultimately help RE programs progress.

It is important to assess every stakeholder's needs and their comparison with one another since this would provide a more comprehensive success factor list and would give more reliable information regarding which ones are the most important. Furthermore, it is also critical to compare the relations of every CSF to each other. To give an example, especially in a developing country like Türkiye, there is a high correlation between investment decisions and economic situation, meaning they cannot be inspected alone. Özmen and Özşahin (2023) search for the importance of inflation rates on global energy unit prices and their effect on the investment environment of Türkiye. The study shows that an increase in inflation rates directly results in higher prices of materials and land, which are the main drivers of increased risk while deciding whether an investment is feasible or not.

Risk management for RE investment should be given more importance, as there are different risk factors that might cause the system to not be as efficient as it was planned to be. There are a lot of FPV systems in China and Japan that are not functioning due to overturning of solar panels and other extreme events. This study focuses on CSFs; however, it should be noted that risk management and CSF ranking are related, meaning it would also give important insight regarding the risk perception of the stakeholders while also serving as a base for risk management studies.

Another important aspect that the CSF method allows is grouping since it would reduce the complexity of the study. Grouping CSFs also proves the validity and reliability of the study, and it would be a benchmark project since the finding can be used to analyze CSFs for different countries with minor adjustments. Moreover, identifying relations between grouped CSFs helps to improve the decision-making process as it would help to see how seemingly unrelated CSFs have influence over one another, thus leading to more strategic insights.

Lastly, it is important to compare our findings with the existing literature. Bossi *et al.* (2024) state environmental impact is the most important CSF. However, this is expected to be different in Türkiye since the economic problems that Türkiye faces in recent years greatly affect any study that is being conducted, especially in a sector such as construction, which is dependent on raw materials that are extremely expensive. Those country-specific factors play crucial parts, and it is important to name them properly to not miss out on anything.

This research aims to identify factors critical to FPV systems to provide a guideline. To successfully achieve this, a series of steps will be taken:

- To explain the current RE industry and trends.
- To explain Türkiye's efforts to increase solar energy generation via FPV systems.
- Find and decide the most important critical success factors (CSFs) for FPV systems.

1.4. Methodology

1.4.1. Research Procedure

There are 5 important steps in the research. Those steps can be seen in Figure 1.4. Firstly, a thorough review of the relevant literature, starting from the NRE and RE resources and continuing into FPV systems, will be made. Literature will consist of newspaper stories, journal articles, conference papers, online papers, and official government and professional reports served.

Figure 1.4. Research procedure.

In the 2nd step, the questionnaire survey will be prepared based on the findings from the literature review. The survey will be used as a research instrument to determine the CSFs for FPV systems in Türkiye. In order to survey people, Google Drive will be utilized. In the 3rd step, data collection will be done by mail. It is planned that more than 80 people from the energy sector should respond to the survey so that the survey results would provide insight from the sector.

In the 4th step, the Statistical Package for Social Science (SPSS) program will be utilized to derive quantitative calculations. In the following step, findings of the analysis and their implications will be discussed.

1.4.2. Research Methods

As previously mentioned, the primary research method is a questionnaire survey. The questionnaire is sufficient to cover all of the factors that might affect the FPV system's success.

A mixed-methods approach will be utilized, integrating qualitative and quantitative tools to analyze CSFs. After conducting a thorough literature analysis to develop a theoretical framework, industry experts will participate in interviews to obtain their perspectives and experiences related to FPV systems. The information gathered from the interviews will be examined with statistical tools such as SPSS software. Thus, potential and difficulties related to FPV systems in Türkiye will be better understood by this mix of approaches.

Additionally, we will employ a survey instrument created based on the CSFs found through the literature study and expert interviews to guarantee the validity of our findings. Cooper (2008) explained the significance of structured surveying in determining the importance of several different factors on the project. It is planned that this study would provide a comprehensive understanding of the CSFs that can ensure the effective implementation of FPV systems by methodically examining the data gathered.

This approach made it possible to compare importance for every stakeholder, such as private and public parties, using mean ranking scales. To organize the CSF variables into components using the SPSS software, a multivariate statistical methodology called factor analysis is selected as the statistical analysis method.

1.4.3. Research Questions

Research questions are thought to be the most effective means of expressing the goal of the investigation. This study's primary research question is:

What are the CSFs for FPV systems in Türkiye?

To increase understanding of the FPV topic further, more detailed questions like the ones listed below can be addressed to offer the data required for decision-making:

- How can CSFs that are unique to FPV systems be identified in the literature?
- What elements play a part in FPV systems being regarded as effective?
- How can the elements that go into making FPV systems successful be evaluated?
- What are the important problems that can arise in an FPV system's lifespan, and where can those problems be found?
- What elements have been used in FPV that affect multiple stakeholders' needs positively?

1.5. Significance of the Study

The research project's findings could provide several noteworthy benefits to the way FPV systems are being analyzed, where the consensus of FPV studies focuses on the site selection rather than understanding the factors that may affect its effectiveness. An understanding of the factors that can increase the output of FPV systems while also decreasing their costs. The contributions of this research are summarized in the following.

(i) First study to utilize the CSF and mixed-methods approach specifically for RE.
(ii) This research facilitates a comparison of the needs of various stakeholders.
(iii) It allows for the grouping of CSFs to enhance understanding and clarity.

1.6. Definitions of Terms

Critical Success Factors (CSFs) are a small number of areas that are vital to overall performance, whether in the context of an organization or in project execution. For the company to succeed and for the manager's goals to be met, these are the few crucial areas where everything must go according to plan.

Floating photovoltaic (FPV) systems are solar power systems made especially to float on bodies of water, like lakes, reservoirs, or dams. They offer an alternative RE source that reduces land use and can improve energy efficiency.

Renewable energy (RE) and nonrenewable energy (NRE) are the energy resources that are differentiated from one another by the resources that those energy sources use. In contrast to NRE, which is made up of limited resources that gradually run out, such as coal, oil, and natural gas, RE is energy that comes from naturally replenishing sources, including sun, wind, and hydropower. Global Horizontal Irradiance (GHI) is a crucial metric for assessing the potential for solar power at particular sites, which is the total amount of solar radiation received per unit area on a horizontal surface.

1.7. Organization of Thesis

The thesis is organized into seven chapters, excluding the introduction. The use of FPV systems along with other RE sources will be examined from the literature in the second chapter. The most important CSFs influencing FPV systems will be found in the literature and explained in depth in Chapter 3. The fourth chapter provides an explanation of research technique, covering every step that is taken, including software programs being utilized for the study and the quantitative analysis methods. Later, in the next chapter, the proposed framework is being used to analyze the CSFs in FPV systems in Türkiye. The sixth chapter provides a discussion of the results and a comparison with the literature. In the last chapter, a summary of the thesis and additional recommendations are provided.

2. LITERATURE REVIEW

2.1. Energy Consumption of the World

The global demand for energy is escalating at an unprecedented pace. The population of the entire planet as of 2024 is around 8 billion (U.S. and World Population Clock, 2024). Also, this population is increasing at a pace of roughly 0.9%. Meanwhile, in Türkiye, as of 2024, the population is approximately more than 84 million (U.S. and World Population Clock, 2024). The population of Türkiye has a growth rate of about 0.51% per year. This perpetual increase in the population causes an increase in energy usage as well. Especially in the last millennium, energy consumption and hence its production rose significantly. The main drivers of this increase are population growth, as mentioned above, and technological advancements resulting from industrialization (Li *et al.*, 2019). Figure 2.1 shows the energy consumption of the world starting from the start of the 19th century to 2023.

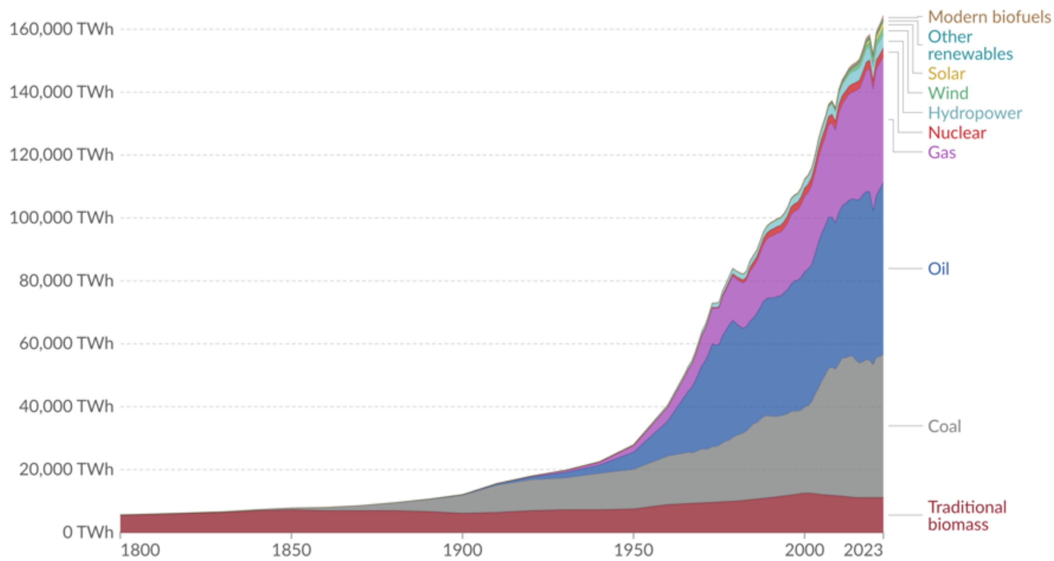

Figure 2.1. Energy consumption of the world throughout years (Institute - Statistical Review of World Energy; 2024) and (Smil, 2017) – with major processing by our world in data.

As energy production and energy usage are the main drivers of the economy, it is crucial for each country to find a situation in which they maximize their energy potential (Strielkowski *et al.*, 2021). For this reason, it is better to observe the energy mix of each country based on their specific conditions since every country has its own unique abilities and disabilities in terms of utilizing different energy sources due to their locations and resource availability. Hence, in this study, in order to observe the importance of country-specific conditions, it is decided that Türkiye will be observed, as its country-specific factors are particularly important due to its unstable economy and its location being suitable for a diverse energy mix (Dilek and Konak, 2022). By doing this, a framework can be created so that country-specific CSFs importance can be better understood.

2.2. Energy Resources

There are different energy resources that can be used for energy generation. Those energy resources can be grouped into 2 main categories based on the resources that they use to generate energy: NRE resources and RE resources. Main NRE sources are coal, oil, natural gas, and nuclear energy. For RE, on the other hand, the four most common sources are solar energy, wind energy, hydropower, and biomass. In the world, in 2020, 79% of the energy created was from NRE resources, while only 21% of it was from their renewable counterparts (Ritchie and Rosado, 2020).

Investments made, mainly for fossil fuel, which is the main contributor to energy generation in the world, are still increasing. This increase is largely due to rising oil and gas prices. Nevertheless, the rate of increase is starting to decline. Total investment for NRE is estimated to be over $1 trillion in 2024, compared to $940 million in 2023. (IEA, 2024). Meanwhile, for the RE resources, this amount is around $2 trillion in 2024, with an 18% increase from 2023.

The main portion of this investment amount is driven by significant spending on solar and wind technologies and their research and development (R&D) (IEA, 2024).

Total investment for renewable resources is substantially higher than for renewable resources, which is testimony to the importance given to the renewable resources.

In the upcoming sections, different types of NRE and RE resources will be further investigated.

2.2.1. NRE Resources

As previously mentioned, the main NRE resources are coal, oil, natural gas, and nuclear energy. Coal is a cheaper energy resource compared to others while also having a higher energy generation capacity compared to oil, around 1 kilowatt-hours (kWh) per kilogram and 0.85 kWh per liter, respectively. Additionally, natural gas can generate 1.1 to 2.5 kWh per cubic meter (HAAB Energy, 2024), depending on the efficiency of its generated power plant. Lastly, recently focused NRE resource uranium, even if its effect on the environment may be catastrophic if precautions are not taken seriously, can be used to produce up to 33,000 kWh per kilogram (HAAB Energy, 2024). This energy output makes nuclear energy by far the most efficient energy resource, even considering its high initial and maintenance costs.

All the aforementioned energy resources have their disadvantages. Despite being abundant in the environment, they are still limited, as one day they will cease to exist. Moreover, coal usage leads to deforestation and contamination, and its greenhouse gas emissions are higher compared to all the other available energy resources. Furthermore, oil may create various hazardous effects, like its spillage, especially in water bodies, which can harm the ecosystem, along with other negative effects, such as respiratory problems caused by its possible ignition. This possibility of ignition can be mentioned for natural gas as well since it is also very combustible, which increases the explosion risk if a leakage occurs even though it is considered a cleaner NRE resource.

Nuclear energy, as it was previously mentioned, requires profound understanding regarding its facilities and also how to dispose of the waste created in such facilities.

Moreover, its investment cost is significantly higher than other options. Nuclear power is gradually being phased out in favor of alternate energy sources as a result of the Fukushima accident, which forced many countries to review their nuclear energy policy. To sum up, it is clear that every NRE resource has its drawbacks, and trade-offs between them should be analyzed so that the most suitable energy source is selected that fulfills the need of every stakeholder (UNEP, 2016).

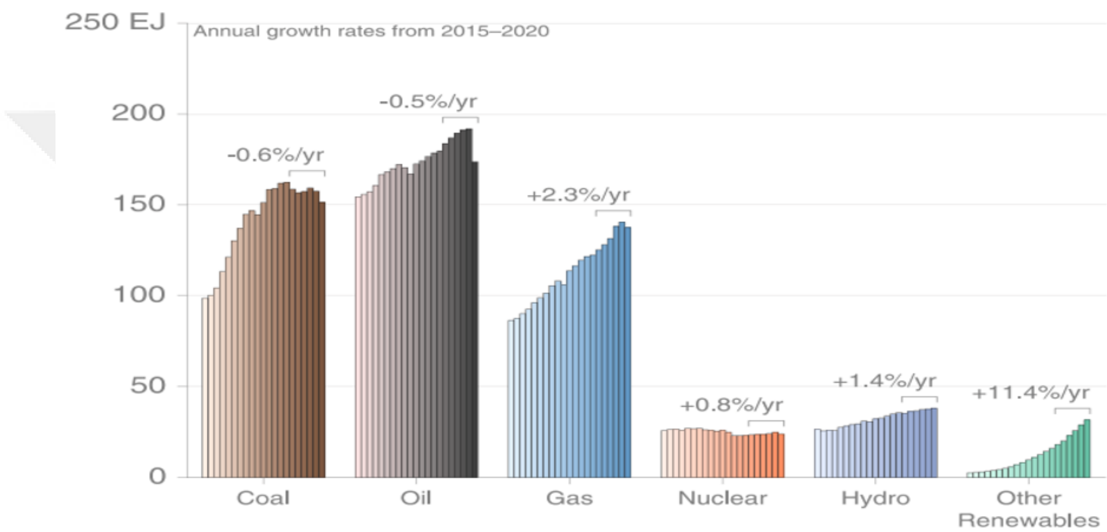

Figure 2.2. Global NRE consumption (Jackson *et al.*, 2022).

Figure 2.2 gives the global NRE consumption from 2015 to 2020. Even though their negative effects are widely acknowledged, their usage is still increasing significantly. However, the decrease in coal energy growth rate shows the importance given to the efficiency of generating energy in recent years. Moreover, there are still a lot of NRE resources in the globe, with 1.65 trillion oil barrels, 1.39 trillion cubic meters of natural gas, and 1.07 trillion metric tons of coal left (BP, 2024). Oil reserves may run out, while gas and coal reserves are expected to last longer because of better extraction and usage techniques. Even though those findings suggest that NRE reserves may not run out in the upcoming years, there is no need to overuse them as they are still limited resources.

Those values are still too general to draw conclusions from. It would be better if a specific region is observed, as one of the main purposes of this study is to see the effects of country-specific conditions, particularly in Türkiye. If we look at the energy mix of Türkiye, natural gas constitutes a higher portion of it compared to other European countries. This is caused by Russia's limitations on their natural gas exports to other European countries. However, Türkiye, on the other hand, benefitted from this situation as they obtained natural gas with decreased prices. This was out of the ordinary and once again shows the importance of studying based on country-specific data. For this study, the energy mix of Türkiye in 2024 can be observed in Figure 2.3.

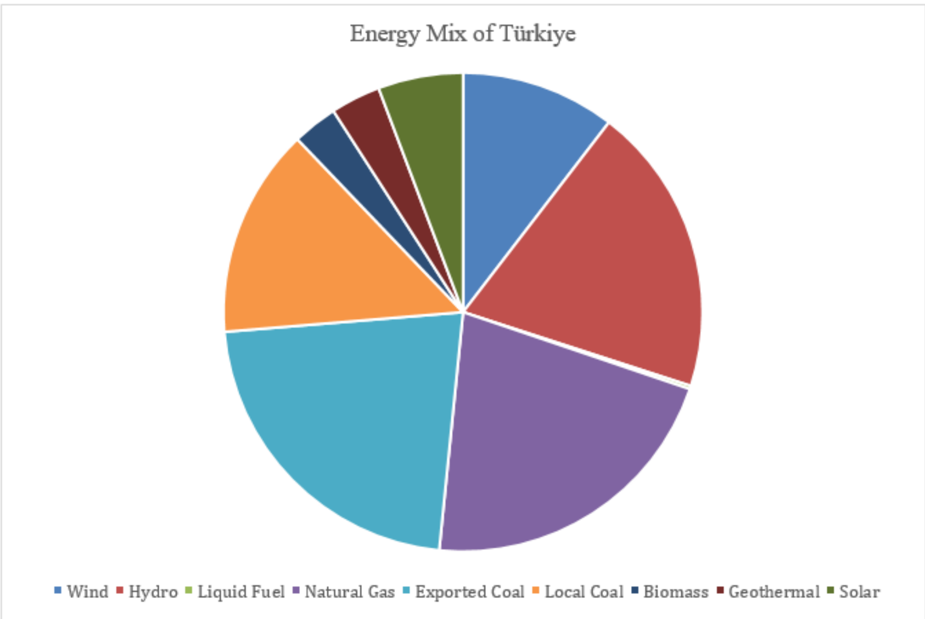

Figure 2.3. Energy Mix of Türkiye (Albayrak, 2024).

In the near future, the dependency on NRE resources will decrease, and it is expected that frontrunners in the RE sector will be in a place in which they will play a significant role in the world's landscape. For example, the frontrunner in the semiconductor industry, Taiwan, is flourishing from their semiconductor investment. Microchip investments have been very beneficial to Taiwan, mainly because they have stimulated strong economic growth by increasing Gross Domestic Product (GDP) and the employment rate. Taiwan's investment shows that it is important to determine what is the new topic that will be crucial for the world in the upcoming decades and focus your full efforts on that subject.

2.2.2. RE Resources

RE resources, like hydropower, wind, solar, and tidal, are naturally renewed resources that are essential for decreasing the effects of climate change as they are sustainable. They are plentiful and can be used as energy resources without running our Earth's supply, in contrast to their NRE counterparts.

There are 5 main advantages that RE systems have compared to NRE systems. The first of them can be explained as their environmental benefits. Due to the fact that their greenhouse gas emissions are limited, they can help to improve the quality of air and can help to create a healthier atmosphere. The second one is sustainability since their main resource can be harvested from Earth, and their ever-presentness guarantees their preservation for future generations (Zhao and Guo, 2015). The third one is that RE resources create job openings for society. Since RE generation is a much more labor-intensive process due to its maintenance, operation, and installation processes, it creates more jobs per energy (Lambert and Silva, 2012). The fourth one is that RE resources help countries gain their energy independence. Much of the NRE resources exist in specific countries, resulting in other countries dependency on those countries. Lithuania, to give an example, shifted their energy usage to RE to eliminate concerns regarding their energy security (Sattich *et al.*, 2022). The last one is that RE resources use considerably fewer water sources overall to operate compared to NRE (Mapes and Larsen, 2023). Since it is foreseen that water resources will be limited and will cause great problems in upcoming generations, it is crucial that every step that helps to reduce water usage should be given significant importance.

It is clear from the aforementioned benefits that RE systems should be the more preferred option for energy creation over NRE systems, and they should be implemented with more ambition since their benefits significantly outweigh their shortcomings. However, one must factor the investment cost and LCOE beforehand to see whether RE resources are feasible even if they come with different benefits to the environment.

Moreover, some RE sources, like hydroelectric energy, are more researched than the others. Hydroelectricity is an area that is more saturated than the rest. In this study, due to addressing the gap in the literature, the focus will be solar energy resources, mainly floating solar, or more commonly known as FPV. Türkiye is using a wide variety of power plants to achieve important energy production amounts from RE resources. With a 100 Megawatt (MW) capacity, the Kızıldere Geothermal Power Plant in Denizli is Türkiye's first geothermal facility. Furthermore, the Aksu HPP is another plant that generates a considerable amount of energy. In addition to these initiatives, Türkiye's largest wind energy producer, Sakarya Wind Farm, with a 99 MW capacity, is active and working smoothly while Türkiye continues to expand its energy generation portfolio by completing Bursa Solar Power Plant, which supports the nation's solar energy goals. When taken as a whole, these facilities demonstrate Türkiye's dedication to lowering its dependency on fossil fuels and diversifying its energy sources. Figure 2.4 shows the per capita RE capacity throughout the years. There is an upward trend that shows the country's dedication to RE. The figure is a clear indication that energy mix and energy independence are important topics on Türkiye's agenda. Lastly, Türkiye continues to explore the possibility of generating energy via different RE resources, with the most notable one being tidal waves. Even though it is still in the exploration stage, a project planned to be built on the Marmara Sea for generating tidal energy is promising to be a feasible project.

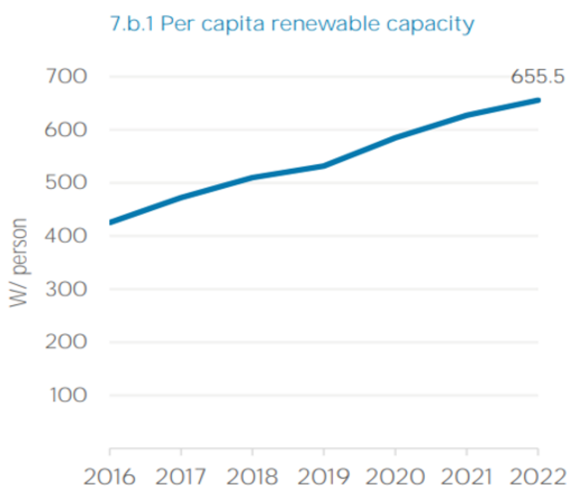

Figure 2.4. Per capita RE for Türkiye between 2016 and 2022 (IRENA, 2024).

2.2.2.1. Hydro Energy. HPPs generate electricity by using the kinetic energy of flowing or falling water to turn turbines connected to generators. Water is typically stored in a reservoir, and when released, it flows through a turbine, causing it to spin and produce electricity. Hydropower has been utilized since ancient civilizations. Back then, it was used as a waterwheel, which helped people grind their agricultural crops. Nowadays, water has been utilized more efficiently as huge dams and reservoirs are built (Munoz-Hernandez *et al.*, 2013). This long history helps hydropower to have more R&D compared to other RE resources, resulting in hydropower constituting an important part of the RE generation. The reason for that is that it is accessible compared to other resources because of its abundance throughout history.

HPPs ensure water storage, allowing it to be utilized when necessary. Moreover, HPP helps to produce energy on demand, causing independence for energy generation. To ensure energy creation from hydropower, governments offer a variety of benefits, including tax exemptions and subsidies that decrease the cost of investment. Moreover, they also help with infrastructure and ease the process of getting permits. Those additional benefits help investors to focus more on hydropower options so that the energy mix can be broadened, and economic expansion is ensured while also important steps are being taken for achieving energy independence.

In Türkiye, the organization that is responsible for permitting and building hydropower energy systems is the General Directorate of State Hydraulic Works (DSİ). They act in a way that promotes hydropower in such a way that its economic viability to investors and project owners would be increased. It is accomplished with the help of other government organizations, such as the Ministry of Energy and Natural Resources, which offers financial incentives through the RE Support Mechanism (YEKDEM). Those mechanisms and organizations support domestically produced energy from RE sources with projects such as RE Resource Areas (YEKA) competitions (Albayrak, 2024).

In 2022, Türkiye had over 42.1 terawatt-hours (TWh) of electricity, which is generated from its hydropower facilities, compared to 44.6 TWh from non-hydro renewable energies. 2022 marked the first year in which total energy generated from non-hydro renewable energies surpassed hydrogen-generated ones (Alparslan, 2022). For generating 1 gigawatt-hours (GWh) of energy from HPP, it is estimated that 29.2 acres of land need to be used (Waldman *et al.*, 2019). It is estimated that Türkiye's hydroelectric capacity is around 64000 GWh (Albayrak, 2024), which totals up to around 7500 kilometer-square (km^2). Lastly, there are considerable variations in the required investment for an HPP based on its location, energy capacity planned based on its technology level, scale, and location; the necessary investment is around \$0.4 million to \$1 million per acre.

HPP can be even more utilized, as dams can be used as the base for other floating renewable resources, such as wind and solar. This would further increase the effectiveness of HPP. HPP's possible interactions with other RE resources will be discussed in later sections.

<u>2.2.2.2. Wind.</u> Wind energy utilizes turbines to capture wind energy and transform it into electrical power. Providing sustainability and reducing environmental impact compared to NRE resources, it is one of the emerging forms of RE resources. However, for wind energy to maximize its potential, it is essential that location-specific resource assessment issues need to be resolved (Reja *et al.*, 2022). Furthermore, wind energy is estimated to generate 3 to 6 MW per km^2 (Howland and Krol, 2023). In order for countries to tap into this potential, since energy capacity for a country can differ significantly due to its location, countries with more wind energy potential should focus on their generation of wind energy and how to maximize it (Howland and Krol, 2023).

Wind energy has its drawbacks as well. One of them is its intermittency, meaning it is hard to generate continuous energy at a certain level. This variation of energy production raises the cost of backup power, or there needs to be additional storage devices, which would drive the cost even higher. Moreover, the implementation of wind energy plants can be halted due to issues including the large land area required, their effect on the environment, and large upfront costs (IRENA, 2019). Even with these drawbacks, it is generally accepted that wind energy is a preferred energy source as its implementation rate is increasing due to its decreasing costs. In Türkiye, wind energy is more suitable compared to solar energy due to a number of reasons. Firstly, from a geographical perspective, its location is well suited for wind generation, particularly along the shores of the Aegean and Marmara, which is also helpful since most of the population lives in nearby areas. Figure 2.5 shows the offshore wind speed in Türkiye, especially for the regions where wind speed is high. As it can be seen from the figure, the wind speed, and hence its energy generation potential, is highest at the shores of the Aegean Sea. Secondly, Türkiye has been utilizing wind energy for a longer period, which caused Türkiye to have more established infrastructure and experience. Lastly, investors for such projects tend to find wind energy-related projects more feasible as government policies and incentives help those projects more. Wind energy was contributing 10% of the energy mix in Türkiye, while this percentage was 5% for solar energy at the end of 2021, according to the Turkish Energy Market Regulatory Authority (EPDK, 2021).

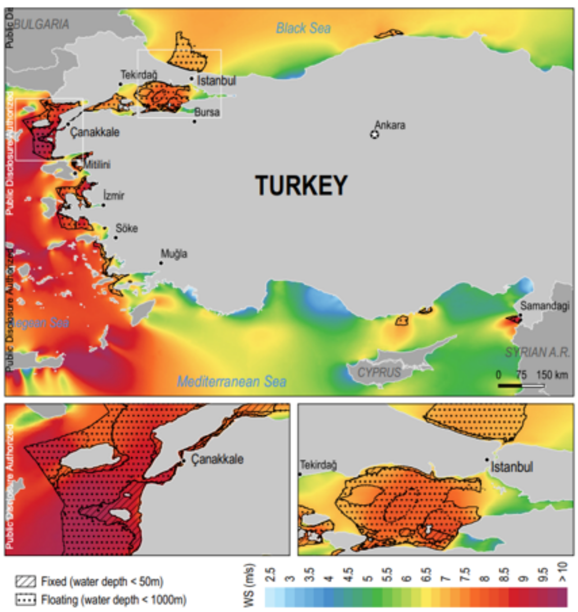

Figure 2.5. Offshore wind speed at 100 meters in Türkiye (Davis *et al.*, 2023).

“Map obtained from the Global Wind Atlas version 3.3, a free, web-based application developed, owned, and operated by the Technical University of Denmark (DTU). The Global Wind Atlas version 3.3 is released in partnership with the World Bank Group, utilizing data provided by Vortex and using funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalwindatlas.info.

2.2.2.3. Solar Energy. Solar energy is the energy that is captured from solar radiation and used for a variety of purposes, such as producing heat or electricity. This RE source is essential to the shift to sustainable energy systems since it lowers greenhouse gas emissions and reduces dependency on fossil fuels. The concept of the sun being an energy resource has gained traction recently, with both investments regarding it and the amount of area covered with it increasing rapidly. (SEIA, 2024). For the generation of this energy, solar panels are utilized.

Photovoltaic cells, which are mostly composed of silicon, are used in solar panels to convert sunlight into electrical power. They lessen dependency on fossil fuels by producing RE for a range of uses. There are 2 key factors to consider with photovoltaic cells. Firstly, the efficiency and performance of solar panels are influenced by their material composition. Although conventional silicon-based cells are the most common, perovskites and other alternatives have great efficiency and absorption rates. Carbon nanotubes and other nanomaterials improve charge transmission, whereas organic photovoltaics offer flexibility and reduced prices (Dada and Popoola, 2023). Secondly, the price of solar panels is essential. The purchase and installation expenses, which continue to be major obstacles to adoption, are included in the initial investment. A clear picture of the long-term financial effects is provided by life cycle costs, which also include continuing maintenance and operating expenditures over the panels’ lifetime.

Türkiye is one of the main facilitators of solar panels in the world. Also, Türkiye’s geographical location allows them to generate a significant amount of energy using solar panels. However, Türkiye has not yet tapped into this power, as energy production from solar energy in Türkiye is still around 5%. The main reason is lack of policies along with its high economic costs. However, the price of solar cells is decreasing rapidly, which results in more solar energy plants being built (Pillai, 2015). This increase in solar energy would eventually make solar energy a primary power resource, as IEA (2022) predicts solar energy to have a share of 22.2%, overtaking coal as the main source by 2027. This conclusion is valid for Türkiye as well.

Solar energy has various advantages compared to the other RE methods. To start with, solar energy panels being adaptable everywhere, ranging from farms to residential rooftops, makes them available to a wide spectrum of customers. Thus, energy decentralization, which is generating energy from different resources, could be accomplished. Moreover, solar panels require less maintenance while not causing noise pollution, unlike wind energy systems. Lastly, compared to other RE resources, it is economically viable since it has a long lifespan, its maintenance costs are significantly lower, and its negative effect on the environment is lower.

Comparing wind energy and solar energy, it can be observed that solar energy outperforms its wind counterpart since its expansion rate is higher, resulting in a decrease in costs. Moreover, solar energy had become one of the main RE sources globally. The International RE Agency (IRENA, 2024) reported that solar energy, especially in countries that have global GHI values higher than the rest, increased the capacity of RE sources worldwide.

2.2.2.4. Land Photovoltaic (LPV) Systems. Photovoltaic installations that are ground-mounted are positioned into the ground as opposed to floating platforms. They come in different sizes, from modest home installations to massive utility-scale solar farms, which provide substantial amounts of electricity.

There are numerous benefits of LPV systems compared to their floating counterparts. Firstly, they do not need marine engineering, which makes them cheaper compared to FPVs. Moreover, there are no surface reflections as opposed to FPVs, which would prevent them from limiting their access to sunlight. Furthermore, they would require easier maintenance and repair since they are easy to access. Additionally, if a significant open space is available, it is possible to generate more energy since those solar panels would not be limited in their land coverage. Lastly, since they do not require water bodies to be built on, they are more practical, especially if the water resource is little or not available.

However, there are major issues concerning LPV systems. The most important effect might be on the ecosystem since the installation process would harm it significantly. This would lead to habitat loss and increased erosion, which would further limit the ecosystem's biodiversity (Nobre *et al.*, 2024). Moreover, large solar panels might change the scenery, and it might not be welcomed by people living nearby. Lastly, LPV systems can pose fire dangers owing to electrical failures or overheating, especially if the condition on which the system is built is having drought-related issues. These possible fires can cause significant harm to the surrounding vegetation and wildlife. Thus, important steps should be taken to evaluate those potential dangers in order for LPV systems to be effective.

<u>2.2.2.5. Floating Photovoltaic (FPV) Systems.</u> FPV systems are solar energy systems that differ from their ground-mounted counterparts by being installed on water bodies such as lakes, reservoirs, and oceans. FPV systems have experienced significant global growth. The total installed capacity of FPV systems from 2007 to 2023 can be seen in Figure 2.6. Even though it is challenging to determine the exact number of FPV systems worldwide and no previous studies have provided precise estimates, data from the World Bank indicates that there were approximately 300 FPV installations globally in 2020 (World Bank, 2020). Considering the increase in FPV capacity from 3,200 MW in 2020 to 7,700 MW in 2023 (Figure 2.6), and assuming a proportional growth in the number of plants, the total number of FPV systems as of 2023 is estimated to be approximately 720 installations. The majority of these installations are concentrated in East and Southeast Asia, which holds the largest share of the global FPV capacity (Ebhota and Tabakov, 2024). This regional dominance is largely due

to land scarcity and high population density, making FPV an attractive alternative to traditional land-based photovoltaic systems. Additionally, the abundance of water bodies suitable for FPV deployment and high solar irradiance levels contribute to the region's leading position in FPV adoption. In Europe, countries such as the Netherlands and Germany have initiated FPV projects, leveraging their extensive networks of water bodies and strong commitments to renewable energy integration (Huang *et al.*, 2023). These developments highlight the increasing recognition of FPV systems as a viable solution for renewable energy generation, especially in areas with limited land availability and ample water resources.

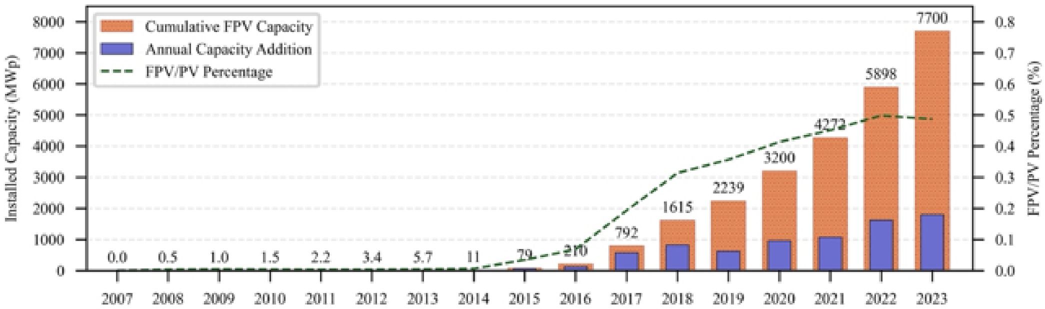

Figure 2.6. Growth of global installed capacity of FPV from 2007 to 2023 (Walpita, 2024).

FPV systems consist of solar panels that are mounted on floating platforms, allowing efficient space usage for RE generation. To increase the effectiveness, solar panels can have a curved, concave shape so that sunlight concentrates into a smaller surface area, which can enhance energy capture and performance. Furthermore, materials being used for solar panels should be carefully selected based on the site-specific conditions. For example, soiling losses, which are caused by the accumulation of dirt, dust, and other debris on the FPV surfaces, can lead to a decrease in efficiency of up to 3% to 4% (Enaganti *et al.*, 2022). In order to eliminate such a decrease in efficiency, it is important that adequate solar panel materials are selected, and on top of that, anti-soiling coating should be applied. However, FPV systems already have the benefit of decreasing soiling-related problems since they are built on water bodies, in which the dirt particles are not most frequently located.

FPV systems include essential components such as grid connections, underwater cables, transformers, and mooring systems, which are critical for their functionality and integration into energy systems. These systems are designed to ensure stable electricity transmission, structural integrity, and compatibility with existing energy grids. A schematic representation of an FPV system is shown in Figure 2.7, illustrating key components such as PV modules mounted on floating platforms, anchoring systems for stability, combiner boxes, inverters, and transformers that connect the system to the main power grid (Gadzanku *et al.*, 2021). While the core components remain similar, there are notable differences between inland and offshore FPV systems. Offshore systems are typically designed to endure harsher environmental conditions, such as high winds, waves, and saltwater corrosion, requiring more robust anchoring and protective measures. In contrast, inland FPV systems, located in calmer environments such as reservoirs and lakes, utilize simpler anchoring systems and face fewer challenges in maintaining structural and operational integrity. These variations highlight the adaptability of FPV technology to suit diverse geographical and environmental conditions.

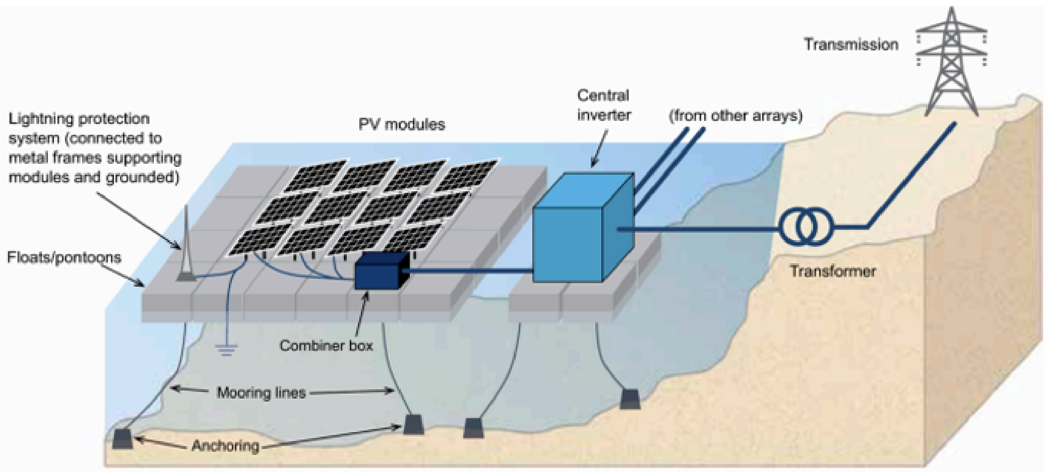

Figure 2.7. FPV system configuration (World Bank Group *et al.*, 2019).

However, since they are located in water bodies, they face additional risks, such as floods (Koondhar et al, 2024). It is resulting from severe weather conditions and increasing water levels, which could cause the panels to become submerged, move, or sustain structural damage. In order to reduce these hazardous effects and guarantee the stability and effectiveness of FPV systems in flood-prone areas, proper design and site selection are crucial (Koondhar *et al.*, 2024). Moreover, humid areas tend to pose significant danger as corrosion on metal components caused by humidity significantly reduces PV cell efficiency along with degradation of connections and wiring. Maintenance is fundamental in order for FPV to reach its maximum potential.

Materials being used for FPV systems are one of the most important success factors. FPVs need buoyant platforms, usually composed of high-density polyethylene, to stay afloat. To maintain their stability in the water, these are tethered and anchored. In order to give the FPV setup stability and long-term functionality, various anchoring techniques such as fixed, catenary, and taut-line systems are employed depending on the water depth and external factors. By reducing displacement and mechanical stresses, these parts make sure the system is safe against a variety of environmental factors, including wind, waves, and currents. For FPV systems to be stable, long-lasting, and effective, necessary research should be made in terms of the materials being utilized for anchoring, mooring systems, cables, and floating platforms. Material selection is essential because these systems need to withstand wear and corrosion.

FPV systems gained significant traction because of their potential to be a significant element for the energy mix. FPV has various advantages compared to its on-land counterparts. FPV systems require significantly less land utilization by using water bodies, which would utilize water as a cooler for the panels while also helping water bodies conserve water. Garrod *et al.* (2024) state those advantages, concluding that FPV systems are a useful option in water-scarce places since they reduce water loss and maximize energy output while conserving land. Amer *et al.* (2023) indicate that the efficiency of FPV systems, compared to their on-land counterparts, can increase up to 12.5% as a result of the cooling effect.

FPV system efficiency can be further improved if it is used in tandem with current HPPs for managing land and water resources as efficiently as possible. Using FPV to cover just 1% of the world's reservoirs might result in a considerable capacity of

404 gigawatt-peak (GWp) for clean energy production (Amer *et al.*, 2023). By providing RE and increased water efficiency, this combination not only helps to coexist together, but it also improves efficiency for both hydroelectricity and solar energy. It also supports carbon neutrality objectives by reducing the environmental effects that energy production causes. Kakoulaki *et al.* (2023) state that up to 557 million m3 of water might be saved by installing FPVs with installed capacities equivalent to those of HPPs. Lastly, it is found that FPV systems can reduce evaporation by almost 70% (Fereshtehpour *et al.*, 2021).

Other advantages that FPV systems provide are that they give aquatic creatures a better environment to live in, which would result in better biodiversity. Moreover, they lower the algal formation by restricting sunlight exposure, which would further increase the quality of aquatic bodies. Those topics help to increase sustainability, which is the main subject that leads to investment in different kinds of energy resources. This can be further achieved by FPV systems since it also helps to lower greenhouse emissions. Furthermore, it may lead to new job opportunities since FPV requires knowledge, and its maintenance and installation require more man-hours compared to other energy sources, hence boosting local economies. Additionally, it helps the energy resilience of a country by broadening the energy mix. Energy independence is a critical factor that is especially gaining traction because of Russia's stand against the usage of their natural gas resources. It also allows creative design options that can be adapted in various conditions.

FPV has been greatly researched by the literature. Koondhar *et al.* (2024) conduct a thorough literature study and qualitative analysis to assess the developments and difficulties related to FPV systems for solar energy production. Their results highlight the potential of FPV technology in enhancing RE policies by demonstrating that it can decrease land competition and increase energy generation efficiency. Irshad *et al.* (2024) examine an ideal large-scale hybrid PV and pump hydro storage system with a focus on FPV applications in a related study. The study uses a number of methods, such as Particle Swarm Optimization and the Gradient Pelican algorithm and comes to the conclusion that adding FPV greatly improves energy yield, dependability, and cost-effectiveness in RE systems. In a similar topic, using Life Cycle Assessment (LCA), Li and Zanelli (2021) investigate the environmental performance of incorporating flexible photovoltaic systems into textile envelopes. They find that this integration improves thermal insulation and lowers energy usage while utilizing solar energy. Lastly, using 2D computational fluid dynamics (CFD) simulations, Ramanan *et al.* (2024) examine how environmental and design factors affect the performance of FPV systems. They discover that for effective cooling, water temperatures must be at least 2^oC lower than air temperatures, and that ideal conditions are at a height of 1500 millimeters (mm) with a tilt angle below 45^oC. This collaborative study confirms the importance of FPV technologies in developing RE solutions and offers crucial insights toward enhancing them.

There are still many limitations and shortcomings of FPV systems. Available areas are limited. The limitation is mostly caused by military areas, bird migration routes, shipping routes, earthquakes, and airport zones (Caceoğlu *et al.*, 2022). Although Caceoğlu *et al.* (2022)'s study focuses on floating wind systems, similar exclusion areas apply to floating solar systems as well. However, most of those limitations cease to exist if such a system is planned to be built on dams, which is the only available water body that is allowed to have FPV systems in Türkiye (Resmi Gazete, 2020). General shortcomings and limitations of FPV are, firstly, even though the payback period is significantly lower than its on-land counterpart, 5.37 years to around 15 years (Amer *et al.*, 2023), upfront costs are highest compared to all other renewable resources. The main reason for this is the technology required for specific materials and systems that would allow the floating of structures. Furthermore, FPV systems preventing sunshine penetration can have negative effects as much as positive effects, such as total organic carbon rising, dissolved oxygen (DO) and pH values dropping, and the algae breaking down to release phosphate (Liu *et al.*, 2023). Lastly, despite the fact that FPV systems can decrease evaporation and hence improve its quality, ill-designed systems have the risk of raising water temperatures, which would harm aquatic life while also decreasing the oxygen level of the water (Yang *et al.*, 2022). However, it is not the paper's aim to discuss whether such a system should be built but rather to investigate CSF and how to create a framework for all future studies while fool proofing our framework using previous cases.

Türkiye, with the rest of the world, began to explore another aspect of renewable energies, which helps the RE resources to be even more effective, with them floating on water surfaces. The main reason why building those energy plants offshore or on water bodies is that they eliminate the land cost, which is the important factor for choosing where an energy production plant should be built. By eliminating an important decision-making factor, those energy production plants could focus on how to increase effectiveness rather than trying to decrease LCOE. Moreover, those energy plants would be located close to grid lines. It is especially important as every country's energy needs are mainly coming from the most populated area or the most industrialized area, which the grid lines are closer to and in which the land cost is high. To give an estimate, the land cost of Türkiye is around 21,777 Turkish Lira (TL) per square meter; however, this number soars to 33,731 TL for Istanbul as of 2023 (NLI, 2023). Istanbul is the most crowded city in Türkiye, with an estimation of 15 to 16 million people living in the city. The city's high demand, constrained supply, and being a major economic center and tourism destination are all contributing factors to the rising cost of real estate there. By eliminating this factor and building the plant near İstanbul, where the energy consumption is higher, FPV would be better utilized than their on-land counterparts.

Türkiye holds an estimated floating solar potential of 80 GW, showcasing the country's significant capacity for future FPV development (Yıldırım, 2024). This highlights the untapped opportunities for renewable energy expansion, especially given the abundant water resources across the nation. Leveraging this potential could contribute substantially to Türkiye's energy independence and sustainability goals.

It is beneficial to build floating RE systems on HPP from an investing standpoint; since it will already have a grid connection system, it does not require any connection lines. Furthermore, the Official Gazette published on 8 March 2020 (Resmi Gazete, 2020) stated that the DSİ would allow a potential FPV system to be built on the dams in which the water level is between the maximum water level and operation level. This would further help investors to build such systems, as DSİ would help their investments. However, in Türkiye, building such systems is only allowed on dams (Resmi Gazete, 2020). Even though it is anticipated that this will change in the upcoming years, this situation hinders the utilization of different aspects of FPV systems.

Türkiye's first attempt to build an FPV plant dates back to around 2014. The first floating solar energy plant, later named Azmak 2, was built at Mersin. This project was a prototype for the HydroSolar system that was going to be used for another FPV plant in Istanbul. Later, the same organization, with the help of Istanbul Municipality, built another FPV plant in the Istanbul Buyukcekmece Lake, which was the largest FPV plant built in Türkiye. The reason why the Istanbul Buyukcekmece Lake was selected is that the lake was already being used as a water purification system that requires an excessive amount of energy, and it was thought that this FPV system would cover part of this energy need. However, its durability was not taken as an important factor, which resulted in the overturning of solar panels, and its lifespan was cut short. That year, another FPV plant was built on the Istanbul Pendik Marine in April. However, its lifespan was also cut short. Those FPV systems can be seen in Figure 2.8. It can be understood from the failed attempts that it is important to analyze if those are feasible investments and what separates a good FPV investment from a bad one. It is important to analyze every aspect of an FPV system in order to determine its success rate. In order to do that, elaborate studies should be undertaken, especially for countries like Türkiye, since a lot of different and country-specific factors may result in FPV's failure.

Figure 2.8. Past and present FPV plants in Türkiye (Yeşil Haber, 2017), (Osborne, 2017), (HSB Marine, n.d.), (Yeşil Ekonomi, 2024), (Asunim Türkiye, 2024).

In 2024, Türkiye's attempts at FPV construction experienced a sharp rise. Türkiye's first successful FPV system has been built. It is built on Keban Dam in Elazig on 6000 m2 of land and creates around 1 MW of energy, which can be seen from Figure 2.8. Moreover, in its opening, it is mentioned that an additional FPV system with an energy creation capacity of 2 MW is planned to be built in 2025 (Öztürk, 2024). The reason why all the existing FPV systems have limitations around 1 to 2 MW is that if this amount is exceeded, environmental impact assessment (ÇED) should be accomplished; on the other hand, the policies for ÇED for FPV systems in Türkiye have not been written yet. Moreover, even though HPP provides gridlines for FPV systems to use, those gridlines and existing infrastructure are constructed specially for HPP, meaning it cannot generate maximum energy for FPV systems. Even with all the possible negative setbacks, Türkiye is focusing extensively on the advancement of FPV as a RE solution, and their attempts will only increase since it is found to be effective and feasible. This thesis aims to help that cause.

As of July 2024, FPV is being constructed on Blue Lake by Ankara Municipality, and it is planned to have 1 MW of energy capacity. More than half of the construction had been completed, the construction can be seen on Figure 2.8. Even though it is a model project, it would provide a comparison between this system and the one built on Keban Dam in terms of their distance to grid lines and major transmission lines. Furthermore, it is said that the land on which the FPV is planned to be built is now being utilized as a grape planting area, which brings around $150,000 per year (Türkiye'de İlk: ASKİ, Baraj Üzerinde Yüzer GES Kurarak Elektrik Üretecek, 2023). It is further proof of the benefits of land optimization.

Moreover, Muğla Metropolitan Municipality has initiated feasibility studies for the installation of an FPV plant on Marmaris Atatürk Potable Water Dam. The feasibility study (TYT, 2020) indicates that the FPV system will meet approximately 10% of the energy needs of the General Directorate of Muğla Metropolitan Municipality. Finally, the latest attempt to undertake such a project began recently, as the news from the 25th of November 2024 states that an FPV that will generate energy around 2 MW is planned to be built on Sakarya Dam (Gazete Enerji, 2024). It is planned to be the first commercial construction for FPV systems in Türkiye.

Investors for FPV systems in Türkiye can also benefit from the governmental incentives since they are helping any organizations that want to undertake such construction. The Scientific and Technological Research Council of Türkiye (TÜBİTAK) provides funding for various projects in areas such as energy efficiency, RE sources, and sustainable technologies. Even though there are not any projects related to FPV as of now, it can be included, particularly in terms of evaluating energy efficiency and the integration of renewable resources. Moreover, the Small and Medium Enterprises Development Organization (KOSGEB) offers R&D Support Programs to support innovative projects of small and medium-sized enterprises (SMEs). SMEs that are developing innovative and environmentally friendly energy solutions like FPV can benefit from these programs. KOSGEB's Innovative Product and Service Development Support Program may be suitable for businesses operating in strategic sectors such as the energy industry. Projects developed on FPV technologies can receive financial support under this program.

In Türkiye, from an academic perspective, the topic did not gain the same attraction as it does in the world. However, there are still various studies that mainly focus on the site selection of FPV systems. A fuzzy sine trigonometric decision-making model is used by Haspolat *et al.* (2024) to choose locations for FPV installations on Turkish HPPs. The study ranks 15 HPP reservoirs by evaluating 14 sub-criteria in technical, environmental, economic, and social categories using Geographic Information System (GIS) and Multi-Criteria Decision Making (MCDM) techniques. This study does not include factors for FPV systems that are not directly related to site selection. Despite having lower global horizontal irradiation values, the paper concludes that the Sarıyer reservoir is the best location for FPV installation. Moreover, Melek *et al.* (2024) used a different method for choosing sites for FPV systems in Türkiye and created a fuzzy Einstein-based decision-making model that assesses 41 sub-criteria in the areas of economics, technology, the environment, and social/regulatory considerations. The economic criteria are given the highest ranking, followed by technical, environmental, and social/regulatory considerations. However, grouping was done using expert opinions rather than the factor analysis. Furthermore, a GIS-based MCDM methodology is presented by Aydin *et al.* (2013) for the purpose of choosing locations for hybrid wind and solar PV systems in western Türkiye. This model suggests that hybrid systems improve energy stability over single renewable systems by integrating fuzzy set theory to evaluate economic and environmental goals, such as proximity to transmission lines. When taken as a whole, these studies demonstrate a sound method for choosing locations for RE systems in Türkiye, highlighting the incorporation of multiple factors to maximize energy output.

As can be seen from the above-mentioned papers, it is clear that even though literature is quite strong in the world, the studies in Türkiye are only focusing on the site selection or its economic feasibility. They lack the different perspectives, meaning they only focus on "what is good for the environment" or "would the owner be satisfied" rather than evaluate every aspect of FPV. By extending the focus beyond site selection to include a wider range of crucial success variables, this study expands on previous research and provides a comprehensive framework for the success of FPV projects.

To be able to understand FPV's effectiveness, it is important to find CSFs. CSFs should be inspected in order to accomplish strategic objectives. They set priorities for allocating resources, direct planning, and offer performance standards. By concentrating on CSFs, firms may communicate about strategic priorities and continuous improvement, manage risks, and align stakeholders and collaborate. It is being utilized in the construction sector by the articles that have been given previously in this article.

In order to fill these gaps, a framework for assessing FPV studies is created. This can help to evaluate feature FPV endeavors and would provide what the most critical factors might be. Lastly, it must be noted that this would be a framework, meaning country or land-specific factors might change the outcome.

3. CRITICAL SUCCESS FACTORS FOR FLOATING PHOTOVOLTAIC SYSTEMS

Critical Success Factors (CSFs) are critical for project and organizational success since they highlight the crucial components that need to be given priority. They give decision-makers a framework for efficiently allocating resources, managing possible risks, and concentrating efforts on areas that have a direct impact on project results. Organizations can improve stakeholder communication, increase efficiency, and streamline operations by precisely defining CSFs. This is especially crucial for complex or creative projects where several variables need to be controlled at once, such as large-scale infrastructure development or RE. Overall, comprehending and utilizing CSFs helps to achieve long-term sustainability and competitiveness and facilitates improved strategic planning.

3.1. Stakeholders

There are various stakeholders in construction projects. Those stakeholders should collaborate in order to maximize the success of construction projects. Rahman *et al.* (2014) also mention the importance of this collaboration. It can encourage teamwork, increase information sharing, and improve communication between stakeholders, which would result in increased quality and timely project completion while enhancing the service level.

Prior to talking about specific stakeholders for RE, it is critical to understand that such projects usually have a wide variety of participants who help to make it successful. Throughout the course of a project, these internal and external stakeholders have different roles, duties, and degrees of influence. To effectively collaborate, manage resources, and accomplish project objectives, it is essential to comprehend their roles and the relationships between them. The summary of main stakeholders and their individual contributions to the success of FPV systems will be given below.

3.1.1. Investor

The first stakeholder is the investor. Since they supply necessary funds to design, build, and run the FPV systems, they are vital for FPV projects. Their participation and collaboration with other stakeholders while also guaranteeing financial support is essential to the project's success. Even though the investment cost of FPV projects is decreasing due to the decreasing cost of materials, it is still a RE system that has high initial costs, so timely delivery of upfront payment is critical. Investors are particularly interested in cost efficiency due to this reason. A safe environment for them should be ensured by conducting risk management.

3.1.2. Project Developer

The second stakeholder is project developers. They oversee planning, designing, and executing FPV initiatives. Their success can directly result in the success of FPV projects. They are responsible for finding appropriate locations, making sure regulations are followed, obtaining permissions, and liaising with contractors and other interested parties. Their effective project management, along with cost control initiatives and usage of new technologies, would enhance FVP efficiency even more. Moreover, in order to ensure that the project satisfies expectations of the investors and sustainability goals are reached, developers should find a balance between environmental concerns and technical and financial constraints.

3.1.3. Contractors

The third stakeholder is contractors. Their contribution and success factors are similar since they manage engineering, building, and installation duties together. They are the most important elements for the physical implementation of FPV systems. Their technical know-how, project management abilities, and capacity to do what is required within the allocated budget and schedule are extremely important for project success. However, in order to accomplish the aforementioned goals, they should collaborate internally, so that any possible risk factors are eliminated. Also, they should ensure that the project satisfies safety and operating standards while also addressing site-specific issues that FPV projects may have.

3.1.4. Suppliers

The fourth stakeholder is suppliers. As suppliers provide the project with necessary components, they play a critical role in project success. FPV-specific components are not as common as other materials; the availability and dependability of those materials can have a big impact on project budgets and schedules. In order to guarantee prompt delivery and stable quality, suppliers must keep solid ties with manufacturers and logistics companies.

3.1.5. Consultants

The last stakeholder that will be mentioned in this article is consultants. They are especially important in FPV projects, as they contribute substantial technical knowledge and experience that many stakeholders might not have. Due to the complexity of FPV systems, their importance of involvement in such projects should not be underestimated. In a subject that is changing quickly, their insights can improve design and implementation, increasing project viability and success while ensuring legal requirements are to be fulfilled.

As it is explained in upper paragraphs, for FPV projects, cooperation between aforementioned stakeholders is vital. Every stakeholder is essential, as they contribute to different aspects of FPV projects. While suppliers guarantee availability of materials, contractors handle the construction, investors handle the cash, developers supervise the design, and consultants provide necessary information. Their combined efforts increase the chances of successful implementation and enable efficient project execution, which eventually accelerates the development of FPV technology.

3.2. Critical Success Factors

In order to decide the most important CSFs, a comprehensive literature review has been conducted. 40 articles were selected for this study, with 20 being international and the remaining 20 from Türkiye. Excluding one study that is on floating wind systems, they are all related to FPV systems and their optimization. The reason for the inclusion of the article regarding floating wind systems is that it gives valuable insight regarding floating system success factors. From those 40 articles, 48 CSFs were found. However, to eliminate repetitiveness and try to make every CSF as independent as possible, CSFs are examined further, and groupings of CSFs have been done.

In order to group success factors and make sure that every aspect of the FPV projects is evaluated, an expert team is formed, and their opinions regarding the CSFs are asked to further error-proof the remaining CSFs. Expert #1 is an associate professor who has previously worked on floating hybrid system design. Expert #2 is an electrical systems specialist from a private company whose job is to analyze the feasibility of solar panel installation on the roofs of company facilities. Expert #3 is a project finance supervisor who is working for a construction company as their energy projects expert. Lastly, Experts #4 and #5 are people from academia who have combined 5 articles related to the floating RE subject. The expert team can be further analyzed from Table 3.1. Their opinions are gathered, and with the help of their critical insight, CSFs are further reduced to 17.

Table 3.1. Expert team.

Expert No	**Title**	**Experience**	**Expertise Subject**
1	Associate Professor	15 years	Geotechnical Engineering
2	Electrical Systems Specialist	10 years	Land Photovoltaic Systems
3	Project Finance Supervisor	7 years	Energy Systems
4	Civil Engineer, MSc	3 years	Floating Wind Systems
5	Civil Engineer, PhD	6 years	Floating Photovoltaic Systems

It is believed that those 17 CSFs do not overlap with each other significantly while covering all the important aspects for FPV systems to be successful. In Table 3.2, 17 CSFs that are selected for this study can be seen. Furthermore, for each of the 40 articles, the specific CSFs mentioned in each article can be identified. The table includes article numbers, but not their titles or in-text references. To identify which number corresponds to which article, please refer to Appendix A, where it is also indicated whether an article originates from Türkiye or is of international origin.

Table 3.2. Critical success factors.

	Literature Source																			
Critical Success Factors for Floating Photovoltaic Systems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Accessibility and Proximity of Infrastructure		x	x	x				x										x		
Achieving Energy Independence																x				
Ensuring Economic Feasibility through Cost Reduction and Competitiveness						x					x	x		x			x		x	x
Ensuring Energy Safety											x						x	x		

Table 3.2 Critical success factors. (cont.)

	Literature Source																			
Critical Success Factors for Floating Photovoltaic Systems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Increased Usage of Remote Sensing Technologies			x	x	x					x	x									
Increasing Interest for Renewable Energy				x					x				x		x	x			x	
Innovative Approaches to Enhance Material Properties									x						x					
Mitigating Negative Environmental Impacts	x		x					x	x				x	x				x		
Panel optimization for Yield Enhancement							x							x						x
Reducing Water Evaporation			x	x			x					x		x		x	x		x	x
Resilient Structural Design and Robustness for Successful FPV Systems		x												x						

Table 3.2 Critical success factors. (cont.)

	Literature Source																			
Critical Success Factors for Floating Photovoltaic Systems	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Site Selection for Maximizing Energy Potential	x	x	x		x				x		x	x			x			x		
Social Acceptance		x									x	x						x		
Stakeholder Collaboration and Engagement						x				x	x				x					
Successfull Site Selection to Avoid Location-Based Extremes					x	x	x	x					x							
Supporting Environmental Sustainability Objectives				x	x	x			x		x				x	x		x		
Supportive Government Policies and Regulations		x		x		x			x						x					x

Table 3.2 Critical success factors. (cont.)

	Literature Source																			
Critical Success Factors for Floating Photovoltaic Systems	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Accessibility and Proximity of Infrastructure	x								x		x			x						
Achieving Energy Independence									x											
Ensuring Economic Feasibility through Cost Reduction and Competitiveness		x		x	x	x					x			x		x		x		x
Ensuring Energy Safety			x			x					x	x						x	x	
Increased Usage of Remote Sensing Technologies	x				x		x							x					x	x
Increasing Interest for Renewable Energy					x	x			x						x					
Innovative Approaches to Enhance Material Properties			x	x		x		x		x					x		x			

Table 3.2 Critical success factors. (cont.)

	Literature Source																			
Critical Success Factors for Floating Photovoltaic Systems	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Mitigating Negative Environmental Impacts	x	x				x			x		x	x	x	x		x	x		x	
Panel optimization for Yield Enhancement		x																		
Reducing Water Evaporation				x	x	x			x					x	x			x		
Resilient Structural Design and Robustness for Successful FPV Systems			x	x										x			x			
Site Selection for Maximizing Energy Potential	x	x																	x	x
Social Acceptance				x							x	x	x							
Stakeholder Collaboration and Engagement	x																			

Table 3.2 Critical success factors. (cont.)

	Literature Source																			
Critical Success Factors for Floating Photovoltaic Systems	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Successfull Site Selection to Avoid Location-Based Extremes							x	x					x	x		x			x	x
Supporting Environmental Sustainability Objectives						x				x					x			x		
Supportive Government Policies and Regulations				x					x		x		x					x		

Below, the CSFs and their detailed explanations are presented, along with the corresponding sections of the articles where these CSFs are referenced. This allows for a clear understanding of how each CSF is discussed and cited within the selected articles.

3.2.1. Accessibility and Proximity of Infrastructure

FPV systems have high initial costs, which creates resistance among stakeholders who initiate the application of such systems. However, as Ranjbaran *et al.* (2019) state, if FPV systems are integrated with existing infrastructure, especially HPPs, their high initial cost can be reduced significantly. Moreover, the article also mentions HPP's adaptability with FPV systems, stating that both of their efficiencies can be further increased if they are to be combined. This theory is further supported by Ali *et al.* (2024), stating that developing FPV systems close to existing infrastructure can reduce costs such as operational, development, and maintenance costs. Lastly, Ateş (2022) states that combining HPP infrastructure with FPV ensures correct utilization of resources.

Accessibility of infrastructure is not only limited to building FPV over dams; however, there is another aspect that is as important. It is the accessibility of the electrical grid and main roads. Haspolat *et al.* (2024)'s study regarding finding the most important criteria for site selection for FPV systems showed that distance to substations is the 3rd most important criterion. Regardless of whether such a system is to be built on dams or not, it is crucial that the system is close to the main electrical grid. Karipoğlu *et al.* (2024) also point this out, while also adding that being closer to main roads, such as highway roads, is important in terms of maintenance and installation efforts of FPV systems.

If such a system is planned to be built on the sea rather than on water bodies such as dams, instead of being closer to gridlines, another element, which is being closer to ports, is gaining importance. Caceoğlu *et al.* (2022) state the importance of this in their article, adding that energy produced should be transferred to the closest substations, and from there, it should be transmitted to areas where the energy need is significant.

In Türkiye, as of October 2024, FPV systems are only allowed to be built on dams. (Resmi Gazete, 2020). As it is already mentioned, it limits the efficiency of FPV systems as they can be utilized for different conditions to generate maximum energy yield. Compared to the other countries, where 10% to 50% of the dam surface area is covered with PV panels, DSİ is limiting this to only 1% in Türkiye. However, this situation is expected to change in the upcoming years. All the planned or already existing FPV systems are covering small surface areas. The main reason for this is that HPP's grid is not a perfect match for FPV grid connection. Thus, the grid only allows

FPV to generate a small amount of energy due to its mismatch with FPV's point of interconnection (POI). However, this can easily be fixed if DSİ changes the regulations regarding dams, making HPP POI able to maintain high energy transmission generated from FPV systems.

3.2.2. Achieving Energy Independence

Achieving energy independence from FPV systems requires planning and putting a system in place so that a dependable, independent energy source that lessens reliance on outside power sources can be generated. Temiz and Javani (2020) state the importance of energy independence, saying that ensuring an uninterrupted electricity supply for communities is a key objective of the system design. If done properly, the whole system is feasible, and electricity demand is reasonably satisfied. Moreover, Sattich *et al.* (2022) mention Lithuania's efforts to reduce energy dependency. They are investing more in RE resources to eliminate their lack of NRE resource availability.

RE resources can also be utilized even more by storing the energy created. There can be extreme conditions where energy resources are not available in the country. For example, there can be a power outage, or there might be some problem with the imported energy supplier. In those conditions, stored energy from the FPV systems can be used to deal with those extreme cases. Garrod *et al.* (2024) say energy storage through compressed air energy storage (CAES) and battery energy storage systems (BESS) increases the reliability of FPV systems.

FPV systems can support local energy resilience by directly supplying power to surrounding people or enterprises by capturing solar energy. Particularly in rural locations or areas with limited access to traditional grid power, energy independence through FPV can help stabilize energy costs, boost energy security, and lessen dependency on NRE sources.

In Türkiye, implementation of FPV systems can substantially reduce Türkiye's reliance on the imported NRE resources. Kulat *et al.* (2023) made the necessary calculations and found out that for Türkiye, if 10% of the reservoir surface areas are covered with FPV, 125 TWh of electricity can be generated, which would help Türkiye to reduce its reliance on imported NRE resources.

3.2.3. Ensuring Economic Feasibility through Cost Reduction and Competitiveness

Ensuring economic feasibility is a CSF that includes every other CSF. For example, the abovementioned infrastructure availability will help to decrease the high initial cost as a secondary effect. To separate economic factors, it is decided that actions or factors that are directly related to ensuring economic feasibility are factored into this CSF. However, it must be remembered that every other factor affects the cost of the FPV systems one way or another.

In order to compare the cost of FPV systems with other RE sources, LCOE is utilized. Elminshawy *et al.* (2024a) compare the LCOE of FPV and LPV systems, finding their LCOEs as 0.059 $/kWh and 0.045 $/kWh, respectively. Moreover, as Djalab *et al.* (2024) mention, FPV systems are more costly than LPV systems, especially in their development period, due to high investment costs. For example, Ranjbaran *et al.* (2019)'s finding showed the net present value (NPV) of FPV systems is around $900,000 with a payback period of 12.3 years. Even though its LCOE is higher than other energy generation systems, it is still worth it to have a steady supply of electricity with no carbon emissions, particularly in rural and isolated places (Temiz and Javani, 2020).

Before continuing with ways to reduce costs so that the competitiveness of FPV systems can be achieved, it is important that side benefits of FPV systems, such as their effect on the environment, water preservation, and employment opportunities that FPV systems would generate, are considered while finding the feasibility of FPV systems. Since those are qualitative aspects of FPV systems, it is hard to put monetary values on them. However, they must be factored in, nonetheless.

It is important for FPV systems to keep their expenses under control so that they can compete with LPV and other RE sources. Yılmaz *et al.* (2023) state the importance of this while also adding that those high costs can be converted into high energy generation via careful planning and selection of installation sites. Furthermore, high investment costs can be reduced by simpler panel assembly, and maintenance costs can be reduced with panel cleaning through available water (Gunes and Balog, 2024). Moreover, Koca (2024) showed that with different system configurations, system cost can change significantly.

By utilizing economies of scale, large-scale deployments can reduce the LCOE and increase competitiveness. Furthermore, FPV's financial viability can be further enhanced by obtaining government grants, subsidies, or advantageous financing, which will increase its appeal as an investment in the RE sector.

In Türkiye, economic factors are especially crucial. Melek *et al.* (2024) found out that the most important criterion is economic conditions. This is no surprise, as investors have been reluctant to invest in such projects in Türkiye due to its unstable economy.

3.2.4. Ensuring Energy Safety

Implementing efficient operations and maintenance (O&M) techniques to sustain steady energy generation is the major goal of ensuring energy safety in FPV systems. Djalab *et al.* (2024) mention the importance of maintenance and monitoring, stating that addressing structural fatigue and corrosion, particularly at mooring lines and connection points, is extremely important. Moreover, FPV modules should have proper maintenance because of the fact that in over a 25-year period, the nominal power of the module decreases by 13.9% (Ranjbaran *et al.*, 2019).

However, Nagababu *et al.* (2024) state the challenge of maintenance associated with FPV systems since they are floating on water surfaces, and they have complex mooring and waterproofing requirements. Furthermore, rainfall can cause water to splash onto installed equipment, which can cause corrosion. This impact could raise the cost of system maintenance and harm the environment. Moreover, dust particles can cause FPV systems to reduce their efficiency if the maintenance for these conditions is not undertaken. However, dust particles are site-specific, meaning their effect on FPV systems depends on the location in which they have been built. For a country like Türkiye, dust particles do not affect FPV systems significantly.

In order to reduce the challenges, innovations such as lightweight structures should be adapted, which is essential for maximizing operational effectiveness, as Kaymak and Şahin (2021a) state. Moreover, in order to cancel factors that might affect energy safety, procedures such as routine inspections, prompt repairs, and preventive maintenance should be made. Moreover, systems should be built to withstand environmental pressures that would lead to the failure of FPV systems. Furthermore, Yilmaz *et al.* (2023) give specific importance to water levels, as the angular change of sunbeams based on the position of the sun influences the fluctuation in water level, implying that ongoing monitoring can improve operational effectiveness. Automated diagnostics and monitoring can be crucial in spotting problems early and enabling prompt fixes that guarantee safe, ongoing energy output.

Energy safety should not only be inspected from an FPV perspective. However, the safety of the dams on which FPV is built on top of is also essential. The United States Bureau of Reclamation (USBR) report (USBR, 2021) states that when determining the dam on which the FPV system will be built, certain factors, such as spillway operations, possible collisions, embankment stability, and operations and inspections, must be taken into account for the dam's safety.

Lastly, in order to achieve the above-mentioned implementations to ensure energy safety, it is also important that skilled manpower be hired to face those challenges.

Haspolat *et al.* (2024) state that the success and feasibility of the project depend on having an adequate staff. This element is essential for efficient project administration and operation.

3.2.5. Increased Usage of Remote Sensing Technologies

Increasing the use of RS technologies for FPV systems can lead to utilizing cutting-edge instruments such as satellite imaging, drones, and on-site sensors to improve system administration and monitoring. It can help to evaluate various criteria effectively. Yılmaz *et al.* (2023) agree with this, while also stating accurate coastline characterization and identifying the proper installation zones for FPV systems depend on the use of remote sensing (RS) and GIS technology. Furthermore, Deveci *et al.* (2022) give importance to the discovery and assessment of appropriate locations for FPV systems by using GIS for spatial analysis, which raises the overall efficiency.

This real-world data integrated with FPV systems to understand site suitability and efficiency is critical for such systems. Also, it can be used to evaluate a country's energy generation potential for the RE system investigated. Ateş (2022) used the latter advantage of RS technologies to understand FPV potential on the idle water surfaces of HPPs.

Real-time monitoring of FPV arrays is made possible by RS, which may identify problems including debris buildup, biofouling, panel misalignment, and possible electrical failures. These technologies lower labor costs, increase worker safety, and enable quicker reactions to operational problems by eliminating the need for frequent manual inspections. Furthermore, useful environmental information from RS, like temperature, humidity, and water levels, can influence the performance of FPVs. The system's operational lifespan is increased, maintenance effectiveness is increased, and energy output optimization is supported by access to this constant stream of data.

However, it must be noted that technological readiness also plays an important role, as spatial data for some countries is not available. Luckily, in Türkiye, most of the data required for spatial analysis is available. In Caceoğlu *et al.* (2022), spatial data such as offshore wind speed at 100 m, commercial fishery, distance to shipping routes, water depth, earthquake hazard, distance to bird migration routes, distance to key biodiversity areas, length of onshore and offshore cables, military areas, distance to civil aviation devices/airports, shipwrecks, offshore petroleum and natural gas wells, subsea communication cables, and subsea pipelines were being utilized for Türkiye.

3.2.6. Increasing Interest for Renewable Energy

The market's increasing need for sustainable energy solutions is highlighted by the growing interest in RE. In Koca (2024), it is said that the world is focused on a possible strategy to replace energy resources originating from fossil fuels with renewable solar energy. Moreover, it is emphasized how urgent it is to switch to RE sources to sustainably satisfy future energy demands. Stakeholders are looking for more creative methods to use renewable resources since environmental concerns and climate change gain international attention. Because of their small carbon footprint and capacity to produce clean energy on bodies of water, FPV systems are an attractive alternative. Durmaz and Üçgül (2023) agree with this, pointing out that water surfaces allow for large-area usage for energy sources such as solar. This enthusiasm is especially strong in areas with expensive or limited land, which makes FPV a practical way to boost energy independence and satisfy RE requirements.

Apart from FPV's independent advantages, hybrid RE systems, which integrate FPV technology with other sources, are gaining popularity. Garrod *et al.* (2024) state their findings by saying that although FPV hybridization with other RE sources is still in its infancy, HPPs appear to be the most viable application. FPV integration with HPP can increase overall energy generation efficiency. Likewise, in offshore settings, FPV systems and floating wind turbines can work in concept to maximize energy production from solar and wind resources. In line with global trends toward sustainable energy solutions, this hybrid approach not only diversifies energy generation but also boosts resilience and reliability in the RE supply chain. Irshad *et al.* (2024) also mention this benefit by stating complementary effects of water inflow and solar radiation. Also, better management of energy resources can be made possible because of the resource complementarity between solar irradiation and reservoir water inflow.

3.2.7. Innovative Approaches to Enhance Material Properties

Developing cutting-edge materials and coatings, especially for the difficult circumstances faced by FPV systems, is the main goal of material selection. The structural integrity of the FPV systems is enhanced by improvements such as the usage of lightweight, long-lasting composites, UV-resistant polymers, and anti-corrosive coatings. Li *et al.* (2024) also mention that the use of lightweight and flexible materials like organic solar cells (OSCs) and ethylene tetrafluoroethylene (ETFE) can increase the flexibility and adaptability of FPV systems. Moreover, specialized solar panels and steel legs are examples of innovative materials for FPV systems. Concrete blocks are used for anchoring, and flexible mooring ropes are used to adapt to changes in water level. Manufacturers may greatly improve the performance and dependability of FPV systems by implementing these cutting-edge strategies.

Quality and durability of materials are crucial to maintaining FPV systems' steady performance over time. Durability, resilience to environmental stresses, and capacity to tolerate extended exposure to sunshine and water must all be taken into consideration when choosing materials. Korkmaz *et al.* (2023) state that the ability of specific materials to endure a range of harsh or natural environments is essential to a facility's success. High-quality materials lower the possibility of failures such as structural deterioration or decreased energy efficiency.

By prioritizing quality and durability in material selection, stakeholders can guarantee that FPV systems continue to be dependable and effective for the duration of their operational lives, ultimately helping create a more sustainable energy future. Kaymak and Şahin (2021a) agree with this, while also adding that high-density polyethylene (HDPE) increases the long-term robustness and functionality of FPV systems. However, this material should be used with caution due to UV exposure and weathering effects. This highlights the significance of material selection and evaluating both the positive and negative effects that different materials can have on energy generation.

3.2.8. Mitigating Negative Environmental Impacts

The goal of using FPV systems to mitigate negative environmental impacts is to lessen the damage that traditional energy sources usually cause to the environment. Melek *et al.* (2024) conducted a site selection analysis, and in their analysis, ecological impact on marine life was found to be one of the most important criteria. However, as Nobre *et al.* (2024) mention, lack of empirical studies evaluating the ecological impacts of FPV on freshwater biodiversity and lake ecosystems is a critical problem related to the implementation of such systems.

In contrast to fossil fuels, which increase greenhouse gas emissions and air pollution, FPV produces clean energy with a low carbon impact. Elminshawy *et al.* (2024a) compare the CO2 emissions of FPV and LPV systems, coming to the conclusion that FPV systems with an optimum tilt angle have been causing less greenhouse gas emission compared to their on-land counterparts.

Furthermore, countries can lessen their dependency on coal, oil, and gas by substituting or adding FPV to their energy mix as an alternative energy source. This will reduce emissions and, hence, the amount of dangerous pollutants discharged into the atmosphere.

Moreover, FPV installations avoid deforestation and habitat loss, which are frequent with several other renewable sources like HPPs and LPVs. Durmaz and Üçgül (2023) researched the potential effects of FPV and found out that underwater reservoirs and ecosystems are unaffected by floating structures and energy systems. Moreover, in Shi *et al.* (2023), it is mentioned that there is disagreement over how FPV systems affect water quality in terms of shading. Still, it can be said that its negative effect is relatively low compared to NRE sources.

FPV systems not only lessen environmental damage but also provide special environmental advantages. By blocking sunlight, FPV can help lessen the growth of algae on water surfaces, fostering better aquatic environments. However, as Koondhar *et al.* (2024) mention, this shading effect may cause habitat loss that might disturb aquatic ecosystems if mitigating techniques, including choosing locations with little possibility of ecological damage, are not undertaken. Additionally, FPV arrays can provide artificial habitats, giving some aquatic organisms cover and shade. In addition to meeting energy demands responsibly, FPV systems benefit the environment by promoting biodiversity in water bodies and lowering greenhouse gas emissions.

3.2.9. Panel Optimization for Yield Enhancement

The goal of panel optimization for yield enhancement in FPV systems is to optimize design elements to optimize performance and energy production. Optimizing the tilt angle of solar panels is one of the most important parts of this CSF. Since tilt angle affects how much direct sunlight panels receive during the day and over the seasons, FPV systems' energy generation can be greatly increased by modifying the angle to better capture sunlight. Elminshawy *et al.* (2024a) also discuss tilt angle, stating the importance of it for FPV systems to maximize power production and reduce thermal stress on the panels. Article finds out that the ideal tilt angle should be chosen. In its example, a fairly low tilt angle of 20^o has been demonstrated to be more useful in producing the highest output power from the FPV system. However, 20^o as a tilt angle cannot be generalized as it highly depends on the site-specific conditions. For example, in the study from Kassem *et al.* (2021), the ideal tilt angle is found to be 35^o.

Yield optimization is influenced by tilt angle as well as other elements, including panel placement, reducing shadowing between rows, and maintaining stability in fluctuating water conditions. In Chile, a study from Jung *et al.* (2024) considered optimized FPV systems for cooling effects. They found out that the cooling impact has the potential to boost productions from FPV in Chile by 1.7% on average. Lastly, as Kulat *et al.* (2023) mention, using easy-to-build panels can optimize yield as the construction stage could take less time, enabling FPV to be effective sooner. By improving these design elements, FPV systems' efficiency can be increased, which would make them a more economical and efficient choice for producing RE.

3.2.10. Reducing Water Evaporation

Reducing water evaporation affects issues like agricultural productivity, urban water supply, and regional climate resilience; hence, it has been isolated from the "Supporting Environmental Sustainability Objectives" CSF. By reducing evaporation and providing shading for the water's surface, FPV systems reduce water loss. This works particularly well for reservoirs in hot, dry locations where sunlight and high temperatures cause water to evaporate quickly. Ranjbaran *et al.* (2019) discuss the water preservation effect of FPV systems in an arid country like India and conclude that FPV cover could reduce the evaporation by 90%. Also, Koca (2024) statistically defined the benefit of water preservations, concluded that an FPV system eliminates around 80% of the land surface evaporation on which it covers. Moreover, to give an estimate, a 1 MW FPV power plant is found to be capable of lowering the evaporation by 37 million liters of water in India. The water saved by using FPV panels on four lakes in Rajasthan was reported to be 64 million liters to 496 million liters yearly, with a dam lake coverage between 5% and 20%.

The advantages of conserving water go beyond the immediate availability of resources; they also support stable agricultural systems, preserve dependable urban water supplies, and save ecosystems that rely on steady water levels. Ramanan *et al.* (2024) mention the cooling effect that water bodies and wind speed have over FPV systems. For wind velocity, it is mentioned that higher wind velocity promotes the flow of heat to the surroundings and decreases the solar cell temperature. Lastly, Jung *et al.* (2024)

add that this water preservation effect should be considered while deciding the feasibility of FPV projects, as it is a key factor, especially for water-scarce nations like Iran, where conserving water is of utmost importance, with energy production coming second to water conservation. These nations experience extreme droughts, which makes water loss reduction measures even more urgent. By keeping water in reservoirs, FPV systems guarantee that supplies are available for vital industries like household and agricultural use.

Water conservation is thought to be essential in Türkiye's semi-arid environment, particularly in areas that are experiencing shortages (Ertek and Yilmaz, 2014). With research indicating a potential yearly savings of 1.242 hm^3, FPV systems contribute to lowering reservoir evaporation while generating energy (Kulat *et al.*, 2023). However, this might not be true. Although hydroelectricity's LCOE is higher all around the world, hydroelectric energy is reasonably cheap in Türkiye due to the water availability. Thus, water preservation is not as hot a topic as compared to other countries. Because of this, FPV systems, which would reduce water evaporation, only cover 1% of reservoir regions.

3.2.11. Resilient Structural Design and Robustness for Successful FPV Systems

Since FPV systems must endure environmental difficulties specific to water-based installations, robustness and resilient structural design are essential to their performance. Long-term performance and dependability are ensured by robust structural designs that enable FPV systems to withstand elements like fluctuating water levels and weather variations. Kaymak and Şahin (2021a) agree with the aforementioned elements for FPV installation and say FPV systems need to be built to survive challenging environmental factors such as strong winds and waves.

For FPV installations, which are supposed to operate at their best for years in spite of challenging circumstances, high design resilience reduces the need for regular repairs and guards against structural deterioration. Setting resilience as a top priority lowers maintenance expenses and downtime while also increasing operational efficiency.

FPV systems are vulnerable to failure if structural robustness is not given enough attention, which has already impacted a number of installations globally. Particularly in the event of severe weather or variable water conditions, weak FPV installations can result in problems including panel misalignment, disconnections, and even total structural collapse. The feasibility of FPV technology as a dependable energy source is eventually impacted by these failures, which not only result in significant maintenance costs but also lower energy generation. For FPV systems to operate sustainably and continuously, resilient design is essential, especially in areas that are subject to harsh weather. Moreover, as Shi *et al.* (2023) suggest, innovative structural design along with robust mooring system design can be implemented to avoid efficiency drop of FPV due to extreme events.

In Türkiye, the lack of established design codes and standards for FPV systems further complicates the development of resilient structures. With no specific guidelines to address the unique challenges of water-based solar installations, developers often rely on generalized or imported standards that may not fully account for local environmental conditions. Due to this, the FPV system in Büyükçekmece Lake has overturned. This gap in regulations highlights the need for Türkiye to establish FPV-specific design codes that consider the country's unique climate and water conditions to support robust, long-lasting installations.

3.2.12. Supportive Government Policies and Regulations

Supportive government policies and regulations are crucial for the effective development and deployment of FPV systems due to the fact that they foster an environment that is favorable to investment and innovation. Clear laws and supportive policies are essential for the successful deployment of FPVs. Kulat *et al.* (2023) highlight the significance of a supportive regulatory environment by stating that a new law, particularly developed for FPV, is required, and this legislative instrument will need to address any barriers in the subsequent years. Moreover, policies became even more important as the scale of such projects grew. Frehner *et al.* (2024) emphasize that it is important that laws and frameworks are established, addressing social, environmental, and technical problems, in order for FPV installations to be deployed at a broader scale.

Adoption of FPV technology is encouraged by favorable regulations that offer financial opportunities, faster permitting procedures, and incentives for RE projects. Tax credits, grants, and subsidies that are especially designed to encourage the incorporation of FPV systems into the energy mix can also be included in these programs. It is emphasized in Temiz and Javani (2020)'s study that in order to encourage the implementation of FPV technology, public subsidies and incentives are required. This environmentally beneficial application requires some benefits from governmental subsidies, like tax incentives or giving surfaces from public water reservoirs. Governments can boost public trust, draw in corporate capital, and quicken the shift to sustainable energy sources by defining precise rules and regulations for FPV projects.

Some private companies offer quality assurance and risk management services to various sectors, including RE systems such as solar, wind, and FPV projects. For FPV systems, these organizations provide technical evaluations, project certifications, and advisory services to ensure that installations meet performance, safety, and environmental standards. Regulations are often shaped by tracing the pathways established through the practices and expertise of these firms. However, relying solely on such entities can have drawbacks, and the lack of standardized regulations may hinder the growth of FPV systems and lead to adverse consequences. In the absence of clear guidelines, developers may face challenges with site selection, environmental assessments, and safety protocols, resulting in poorly planned or inefficient installations. This uncertainty could undermine the apparent benefits of FPV technology, discouraging investment, creating barriers for new entrants, and leading to inconsistencies in project quality.

In Türkiye, supportive measures were created to increase the proportion of RE sources in the generation of electricity. For example, since 2012, investments in RE have been free from value-added tax. Furthermore, since 2011, a feed-in tariff under the RE Support Mechanism has encouraged the production of electricity from renewable resources. Solar energy has the highest tariff among renewable resources. However, as Ateş (2022) states, no plans or policies have been revealed for FPV installations in Türkiye, highlighting the necessity of a supportive policy environment to encourage FPV usage. Regulations and incentives might greatly improve the investment climate for FPV systems and promote their expansion. Governments must enact thorough rules that address these issues as quickly as possible in order to maximize the benefits that FPV systems provide, a strong foundation for growth, and promote a sustainable energy future.

3.2.13. Site Selection for Maximizing Energy Potential

Site selection is important because the amount of solar radiation received at a location has a big impact on the energy output. Since high GHI levels show a region's potential for solar energy capture, they are crucial for optimizing energy generation. Both Yilmaz *et al.* (2023) and Karipoğlu *et al.* (2024) state the importance of solar radiation potential in a region that FPV is planned to be built, while the latter takes this to another level, saying that the most important requirement for FPV installation was found to be high GHI potential. Haspolat *et al.* (2024) also agree with the latter article by saying GHI potential is the most significant factor. Moreover, a location's potential for solar energy generation is also affected by its average sunshine duration, which calculates the average number of hours of direct sunshine it receives. Furthermore, clear days per year, which is similar to average sunshine duration but different since clear days per year focus on cloud covering and shading, is an important factor to analyze the energy potential of FPV systems.

Developers may guarantee that FPV systems run as efficiently as possible, increasing energy production and improving return on investment, by locating locations with continuously high GHI values. Therefore, a key element in the overall viability and success of FPV projects is site selection.

For Türkiye, Durmaz and Üçgül (2023)'s research showed the high energy potential of Türkiye's coasts for floating RE power plant installations.

3.2.14. Social Acceptance

Social acceptance is a critical component of FPV project success, as the viability and durability of these installations are greatly influenced by local community support. It is suggested from Haspolat *et al.* (2024) that the project's public approval may be assessed through surveys or interviews. Residents and stakeholders are more likely to support and cooperate with FPV initiatives when they are in line with local values, needs, and objectives, such as employment opportunities, environmental protection, and sustainable energy production. Moreover, encouraging FPV technology-related educational activities is essential. Djalab *et al.* (2024) suggest establishing educational initiatives to stimulate inquiry and investigation of FPV technology in order to increase awareness of the technology's feasibility. Furthermore, as Nagababu *et al.* (2024) mention, active community engagement and making sure project benefits match local interests while also building trust and creating a sense of shared benefit are the methods that can increase community acceptance of FPV projects.

Nobre *et al.* (2024) mention aesthetic impact, along with the scale of the project, as the biggest influencers of social acceptance since FPV installations may be viewed as visually invasive in tourist attractions or picturesque settings, making societal acceptance more difficult. Large FPV arrays may change the natural beauty that draws tourists, which might be an aesthetic concern in areas that depend significantly on tourism. FPV developers should carefully select site location and designs that limit visual effects in order to allay these worries. They should also balance local economic and cultural interests with RE ambitions in order to guarantee wider community acceptance.

3.2.15. Stakeholder Collaboration and Engagement

Stakeholder collaboration and engagement is crucial to the effective planning and execution of FPV projects because it brings together a wide range of participants, including local communities, industry leaders, and government agencies. Every stakeholder has a distinct role to play:

- Communities offer insightful local perspectives and support,
- Industry professionals contribute technical knowledge and innovation,
- And government agencies offer regulatory direction and incentives.

A thorough approach to FPV development that takes into account the technical, social, and regulatory factors should be undertaken. This would affect project feasibility significantly as it would contribute to all parties working together. As Djalab *et al.* (2024) state, it is essential to cultivate collaborations between academia, business, and government. Government-industry partnerships on research projects can lead to knowledge transfer and innovation in FPV technology.

Early stakeholder engagement in the planning phase also fosters confidence, lowers the likelihood of disputes, and harmonizes project objectives with the values and requirements of the community. FPV developers can foresee and resolve issues regarding potential disruptions, visual aesthetics, and environmental effects by encouraging open communication and transparency. In addition to increasing project acceptance, active stakeholder participation fosters shared ownership and accountability, both of which are essential for the long-term viability and sustainability of FPV systems.

3.2.16. Successful Site Selection to Avoid Location-Based Extremes

Site selection must be done carefully to avoid location-based extremes if it is desired for FPV systems to be long-lasting and effective. Nobre *et al.* (2024) draw attention to the fact that the great variety in FPV coverage worldwide suggests a high context-dependency of their ecological impacts. Developers can lessen the chance of structural damage and operational disruptions by choosing locations that are naturally protected from severe weather conditions, such as strong winds, intense storms, and extremely high temperatures. In order to accomplish that, Korkmaz *et al.* (2023) suggest that one of the foremost tasks is the identification and interpretation of meteorological extremes, which is essential for the implementation of FPV systems. This highlights the necessity of thorough meteorological investigation in order to anticipate possible weather-related difficulties. Moreover, Elminshawy *et al.* (2024b) also mention the importance of site selection by saying utilization of GIS has effectively maximized the power of FPV systems in a variety of scenarios, including fluctuating load requirements and random local environments. The long-term effectiveness and dependability of FPV installations are supported by the fact that locations in calmer bodies of water, such as protected reservoirs as opposed to open seas, are typically more resistant to weather extremes. Weather extremes could have significant results. Furthermore, locations with high wind speed, high proximity to seismic fault lines, bird migration routes, airports, military zones, and protected areas should not be selected.

Topography of the site selections also plays a critical role, as Yilmaz *et al.* (2024) mention. Additionally, selecting regions with milder climates protects the infrastructure and maximizes energy production because the systems can sustain a consistent output with fewer disruptions. Lastly, in addition to minimizing the need for expensive, reinforced structural components, choosing a location that stays away from environmental extremes also lowers the need for continuous maintenance. By reducing the initial setup costs and the probability of future expensive maintenance, careful site selection improves the project's economic viability.

3.2.17. Supporting Environmental Sustainability Objectives

Using FPV systems to support environmental sustainability goals has a number of environmental benefits. Because FPV installations block excessive sunlight, they help reduce nutrient overgrowth in aquatic bodies and decrease the establishment of toxic algae blooms in reservoirs, thus contributing to ecological balance. This encourages biodiversity and keeps aquatic habitats healthy. Moreover, Ateş (2022) implies that by restricting algae development and minimizing sunlight exposure, FPVs can improve the quality of water. The pollution process slows down by lowering the amount of sun radiation landing on the water surface, therefore slowing photosynthesis. Additionally, by maintaining consistent temperatures, FPV systems help local flora and fauna by preventing water bodies from becoming overheated. Lastly, Garrod *et al.* (2024) analyzed the fish yield of FPV-covered ponds with non-FPV-covered ponds and found that FPV-covered ponds yield significantly more fish. All things considered, FPV technology contributes to the preservation of natural ecosystems while producing clean energy by being in line with sustainability objectives.

FPV systems are also perfect for preserving valuable land resources that may otherwise be cleared for traditional solar farms or other developments because they do not require any land use. This is especially helpful in areas with limited land in which land is either too expensive or unavailable, which makes them perfect for nations with a shortage of land (Koondhar *et al.*, 2024). In locations that are heavily populated or agriculturally significant, FPV's use of water surfaces eliminates the necessity for deforestation or the removal of agricultural grounds. In addition to encouraging sustainability, this feature lessens land competition between conservation, agriculture, and energy production (Temiz and Javani, 2020). FPV systems release land for tourism, agriculture, housing, and other uses, resulting in a more balanced approach to resource management and supporting larger environmental goals. The 17 CSFs that have been decided to be included in this study provide a thorough framework that emphasizes the essential elements required for FPV initiatives in Türkiye to succeed. These elements cover environmental, economic, and technical aspects that are crucial for the nation's particular situation and go beyond site selection. By concentrating on these CSFs, the study offers a basis for well-informed decision-making, guaranteeing the efficient distribution of resources and resolving issues unique to Türkiye's RE industry. The overall research objective of promoting the nation's FPV system deployment is directly supported by this framework.

4. METHODOLOGY

4.1. Introduction

This chapter is separated into two parts. In this part, the methodology used for research will be explained in detail. It is crucial to decide the correct methodology to analyze so that the results will be best interpreted.

It is believed that the best approach to finding what the most crucial CSFs is surveying. Salykova and Abylova (2019) explained that qualitative methods such as surveying, along with quantitative methods such as factor analysis, should be used to successfully analyze CSFs. In this research, the survey is divided into two parts. In the first part, personal information is asked. In order to maintain the anonymity of the survey, no question such as their name or the name of the organization in which they work is asked. In the second part, it is asked of surveyees to give their opinions regarding CSFs. They are asked to rate each CSF from 1 to 5.

After enough surveys were filled, the SPSS software was utilized to analyze the survey results. They are ranked based on mean value. Moreover, different means for CSFs between different types of organizations are analyzed with the help of analysis of variance (ANOVA). Lastly, factor analysis was used to group 17 CSFs into three so that grouped CSFs would give compact, meaningful, and independent key elements.

4.2. Research Method Selection

There are various methodologies that have been frequently used in RE and construction-related research. Firstly, to obtain a thorough grasp of organizational culture, practices such as ethnographic methods that involve observing and interacting with employees, stakeholders, and work processes directly at the site should be adapted. For example, ethnographic methods have been applied to problem-based research on building sites (Pink *et al.*, 2010). Secondly, in order to identify the best places for RE installations, case study methodologies are used to examine particular site selection projects, weighing variables including resource availability, environmental impact, economic viability, and community acceptance. For example, case studies have been used to examine the application of change management in project-based situations (Chen *et al.*, 2014).

In RE, LCA provides a thorough understanding of the sustainability of energy systems by analyzing the environmental effects from each stage of their life cycle, from resource extraction and production to operation and disposal. LCA helps to determine whether energy systems are sustainable by analyzing the environmental effects of a product at every stage of its life (Singh *et al.*, 2013). Moreover, optimization modeling in RE results in the use of mathematical and computational approaches, which helps with the design and management of energy systems. As demonstrated by studies, improving energy systems for cost, efficiency, and environmental impact uses mathematical tools to identify the most effective solutions (Yu *et al.*, 2023).

A questionnaire survey is one of the most common methods to gather the data. Many article journeys, including construction-related but not limited to, have employed this approach as an instrument to examine their research topics. Data collected by surveying can be interpreted by quantitative methods to better understand the survey results. Salykova and Abylova (2019) state the importance of using quantitative tools to interpret data obtained from surveying. This study creates and applies a methodical framework for evaluating RE sources and determining urban energy choices.

This research is aimed at finding the mean ranks of CSFs for FPV systems. By doing this, it is planned that every stakeholder's needs are found so that actions can be undertaken to ensure the effectiveness of such systems while also keeping all the stakeholders happy.

In this research, it is selected that a questionnaire survey be performed in order to collect the data. The main reason why this method is selected is that by applying this method, different opinions from the people working in this sector can be obtained. This makes the method more reliable, as there would not be any group whose opinions are not taken into account. Moreover, surveying would also help to see different opinions from different groups in terms of their importance assessment related to each CSF. By analyzing this, this research can compare different groups, and hence, crucial insights for every stakeholder can be extracted.

When it comes to gathering data, surveys provide a number of noteworthy benefits. The first benefit is their capacity to produce data based on actual observations, guaranteeing that the results are supported by useful and concrete insights. Because surveys rely on real data obtained directly from respondents, this aspect makes them very useful for empirical research. According to Kelley *et al.* (2003), surveys yield data that is grounded in real-world experiences and activities, which increases its dependability. Moreover, the second benefit is the possibility of achieving generalizability. Surveys that cover a large number of people or events frequently produce results that are representative of the general community, which facilitates the drawing of conclusions that have wider applicability. Kelley *et al.* (2003) highlight this characteristic by pointing out that surveys have a higher chance than many other methods of producing data that accurately represents the population as a whole. Lastly, surveys are recognized for their efficiency and cost-effectiveness. They enable researchers to collect significant volumes of data in a short time frame while keeping costs manageable. As noted by Kelley *et al.* (2003), this practicality makes surveys an excellent choice for projects with constrained resources and timelines.

Although surveys have many benefits, researchers should be aware of their significant drawbacks. Excessive attention to detail may cause researchers to overlook the implications of the data they have gathered for addressing particular problems or advancing pertinent hypotheses. This bias can reduce the findings' value and application (Kelley *et al.*, 2003). The shallowness of the data generated by surveys is another drawback. They are great at identifying general patterns, but they frequently lack the in-depth knowledge required to comprehend more complex or subtle subjects. The authors point out that the explanatory value of survey data may be limited due to its generally lower level of detail. Lastly, it can be difficult to get a high response rate, especially when conducting surveys by phone, mail, or in person. According to Kelley *et al.* (2003), poor participation can compromise the results' representativeness and dependability, and response rates are sometimes hard to regulate.

In order to get data that can be analyzed in a quantitative manner, people related to the energy sector, from organizations such as academia, non-governmental organizations (NGOs), and public and private organizations, were asked to rate the significance of the CSFs for FPV systems. Since the FPV sector is not yet fully grown in Türkiye, it is decided that opinions of people in the energy sector, along with people who have written journal articles regarding the FPV subject, are to be chosen. By doing this, it is selected that representative sampling is being utilized rather than random sampling since it precisely reflects the characteristics of the target population, while random sampling may not always provide such representativeness (Rudolph *et al.*, 2023).

Upon conducting extensive literature research, a list of 48 CSFs was condensed to 17. Following the inclusion of this final list in the questionnaire, the responses were examined using the factor analysis technique to classify the replies into groups based on the mean values.

4.3. Population and Sample

The study's target population included energy companies, NGOs, academics who have relevant publications, and public and private firms. Members of the Southeastern Energy Research Association (GEADER), DSİ, Turkish Contractors Association (TCA), Solar Energy Industrialists and Industry Association (GENSED), and Solar Energy Research and Application Center (GÜNAM), as well as solar energy-related companies and governmental bodies that focus on solar energy systems, are included in the surveying process. Firstly, personal information is obtained from the respondents as below:

- Type of Organization
- Position in the Organization
- Experience in the Industry
- Previously worked or currently working in the renewable energy sector?

It is taught that with those questions, comparisons between results can be made to understand the priority assessment of different answer groups. For the type of organization, academia, client, consultant, designer, government, investor, and contractor are the options. For positions in the organization, options are consultant/advisor, engineer/technical specialist, executive/director, manager/supervisor, professor, and researcher/analyst. For experience in the industry, it is asked of participants to choose their experience based on 5-year intervals.

Eggleston (2024) mentions the importance of response rate, stating that due to the COVID-19 pandemic, most surveys are being done online, resulting in a decreased rate of response. He mentions that as of 2024, response rates above 15% can be deemed acceptable. In this study, the above-mentioned response rate is achieved. Below, the positions of the respondents are explained in detail.

4.3.1. Types of Organizations Employing the Respondents

Consultants significantly contribute to the acceleration of the adoption of RE by providing stakeholders with strategic direction and implementation assistance. They offer clients useful information and insights that help them understand nuances of market dynamics, regulatory frameworks, and RE technology (Avwioroko and Ibegbulam, 2024). According to the article, consultants help with RE project identification, risk mitigation, and the creation of tailored strategies (Avwioroko and Ibegbulam, 2024). By tackling obstacles including financial limitations, technological difficulties, and public opinion, these initiatives guarantee that businesses may successfully undertake RE projects.

Engineers are crucial problem solvers who create, implement, and manage technology solutions in order to solve social issues related to RE. By developing and expanding tools and technologies that promote sustainability, they significantly contribute to the acceleration of the transition to sustainable energy sources. According to the article, engineers' knowledge makes it possible to integrate cutting-edge systems and solutions, guaranteeing that the switch to RE is dependable and reasonably priced (Swarup and Armstrong, 2023). These contributions are essential to effectively and significantly accomplishing sustainability goals.

Executives and directors play a crucial role in the development of RE projects by managing and guiding the strategic direction of initiatives. They are in charge of overseeing the distribution of time, money, and political resources, as well as controlling major risks in order to handle the difficulties of project execution (Springer, 2013). According to the article, their leadership plays a crucial role in directing teams through uncertainty and influencing the entrepreneurial activities of project development in order to produce effective results (Springer, 2013). To sum up, delivering finished projects that meet organizational goals and sustainability objectives depends on their efforts.

Managers and supervisors play a crucial role in RE-related projects as they monitor the effective use of resources and guarantee compliance with project specifications. They are essential for risk management, meeting deadlines, and organizing teamwork to deal with problems (Springer, 2013). According to the article, their leadership makes sure that every project component is coordinated and in line with the intended results, which greatly enhances the sustainability and success of RE projects (Springer, 2013).

Professors are essential in developing the next generation of professionals and expanding our understanding of RE. They carry out research to solve important issues, create sustainable energy solutions, and influence laws and business procedures. Through instruction, they give students the knowledge and abilities they need to meet the expectations of the RE industry. Through publications and scholarly partnerships, professors also spread knowledge, promoting advancement and creativity in RE projects.

Researchers and analysts are important in the field of RE because they offer thorough assessments and insights that guide strategic choices. This is especially important as RE projects require know-how. To find local resources, improve resilience, and advance energy independence, they conduct case-by-case economic potential evaluations (Cox *et al.*, 2018). According to the article, these experts provide crucial data and analysis that inform investment and policy choices, guaranteeing the viability and effect of RE projects (Cox *et al.*, 2018). Their input is essential to promoting RE projects and encouraging well-informed decision-making.

4.4. Survey Design

4.4.1. Survey Structure

The survey was created to address the CSFs for FPV systems while also providing general information on the respondents. It is divided into two sections (Appendix B):

- Section 1 captures specific information regarding the respondents. They include the type of organization, their position within the organization, their experience in the sector, and if they have previously worked or are still working in the energy sector.
- Section 2 lists the CSF along with a brief explanation for each of them while also providing how many of the selected 40 articles mentioned that specific CSF. Then, it is asked of the respondents to give a degree of importance to all of the CSFs based on their experience and knowledge.

4.4.2. Rating Scales

In order to capture respondents' degree of importance assigned to every CSF, a Likert scale has been utilized. The Likert scale is a common scale, especially in construction-related articles. As Holt (2014) mentions, Likert scales, Likert items, and "Likert-type" items are commonly used in construction management research (CMR) surveys to collect respondents' self-reported opinions. The survey uses a five-point rating system, which ranges from 1 to 5, to gauge the level of criticality for each CSF mentioned in Chapter 3. This scale can be seen in Table 4.1.

Table 4.1. Likert scale.

Likert Scale	Level of Criticality
1	Not significant
2	Fairly significant
3	Significant
4	Very significant
5	Extremely significant

4.5. Statistical Methods

The techniques used in this study include factor analysis, ANOVA, and mean ranking. They were used to examine the data gathered from the questionnaire. SPSS software was used for data analysis. The next sections provide a description of the statistical analysis that was conducted.

4.5.1. Mean Ranking

One of the most popular statistical strategies for evaluating and ranking CSFs is the mean ranking method. It involves evaluating the factors in accordance with the average score determined by the respondents. By using this method, researchers can methodically find and assess the most important elements, assisting decision-makers in concentrating on the crucial elements that contribute to project success,

$$Mean = \frac{\sum_{S=1}^{S=5} f(i) \times S}{N}, \tag{4.1}$$

where f is the frequency of responses for each success factor, s is the score assigned to each success factor by the respondents, from $s = 1$ (not significant) to $s = 5$ (extremely significant), and N is the total number of responses in the survey. Hence, $f(1)$ represents the number of respondents assigning a score $s = 1$ (not significant) to the variable, $f(2)$ represents the number of respondents assigning a score $s = 2$ (fairly significant) to the variable, $f(3)$ represents the number of respondents assigning a score $s = 3$ (significant) to the variable, $f(4)$ represents the number of respondents assigning a score $s = 4$ (very significant) to the variable, and $f(5)$ represents the number of respondents assigning a score $s = 5$ (extremely significant) to the variable.

It is particularly useful for evaluating stakeholder views in industries like RE and construction because of its efficiency and clarity. Equation (4.1) should be applied to successfully calculate the mean.

4.5.2. One-Way ANOVA

The ANOVA is a statistical technique designed to evaluate the variability of data across different subgroups. It is particularly useful for identifying whether significant differences exist between the means of three or more groups. ANOVA operates under the assumption that the data are normally distributed and exhibit homogeneity between variances. When comparing only two groups, a t-test is typically more appropriate. There are two main types of ANOVA: one-way ANOVA, which examines the effect of a single independent variable, and n-way ANOVA, which explores the impact of multiple factors. This method helps determine whether variations in group responses are statistically significant. In this study, one-way ANOVA was applied to examine differences among the means of the above-mentioned respondent groups based on the importance assigned to every CSF. The null hypothesis, which posits that the group means are equal, was tested. Additionally, a t-test was used to evaluate the differences in CSF significance between two distinct groups: people who have worked in the energy sector and people who have not worked in the energy sector. The analysis provided insights into whether the responses varied significantly between these groups, assuming the data met the normality requirement. It refers to the assumption that the data in each group being compared are drawn from a population that follows a normal distribution. The F-test is a statistical method used to compare variances between groups to identify significant differences. In repeated measures ANOVA (RM-ANOVA), the F-statistic determines statistical significance under certain assumptions, including normality and sphericity. Research has shown that the reliability of the F-test is not compromised by deviations from normality as long as the sphericity assumption is met. This makes the F-test a robust tool for analyzing variance in grouped data (Blanca *et al.*, 2023). F-ratio is the variance of the group means divided by the average variance within the groups. This ratio is then assessed against critical values in the F-distribution table, considering the degrees of freedom for both the numerator and denominator. A small p-value, typically below 0.05 or 0.01, indicates that the null hypothesis-stating there is no difference among the groups—should be rejected. This suggests that the group means differ significantly, making the F-test a powerful tool for analysis in variance studies,

$$F = \frac{SS_A/(k-1)}{SS_{error}/(N-k)}, \tag{4.2}$$

where $SSA = Sum$ of mean squares between groups; $SSerror = Sum$ of mean squares within groups; $(k-1)$ degree of freedom for SSA; $(N-k)$ degree of freedom for SSerror; N number of observations; k number of categories.

4.5.3. Reliability Test

A reliability test uses a reliability coefficient to assess whether several items measure or have the same construct in the population being administered. In order to evaluate internal consistency, a preliminary reliability analysis usually involves computing Cronbach's alpha for the complete scale (Du , 2024).

This test is carried out to give an indication of the consistency or dependability of the data collected based on the differences in the respondent profiles. After making revisions to the scale based on exploratory factor analysis, Cronbach's alpha is frequently recalculated to evaluate internal consistency.

- When α= 0, it indicates that there is no correlation, or dependability, between the items.
- Total dependability, or 100% correlation between the elements, is indicated by a value of α= 1, α equals to,

$$\alpha = \frac{N \times \bar{c}}{\bar{v} + (N-1)\bar{c}}, \tag{4.3}$$

where N is the number of items; $\bar{c}$is the average covariance between items; $\bar{v}$is the average variance.

An acceptable reliability level of greater than 0.70 is the goal (Du, 2024). Calculation for α can be seen in Equation (4.3).

4.5.4. Factor Analysis

One technique for determining if a number of observed variables can be described by fewer unobservable elements is factor analysis (Tryfos, 1997). This method makes data easier to analyze by simplifying datasets while preserving important information. According to Tryfos (1997), loadings are the parameters of these relationships that show how much each observable variable contributes to the common factors.

Factor analysis is frequently used to reveal hidden patterns and make sense of data correlations in domains including psychology, economics, and RE. These relationships between sets can be seen in Figure 4.1.

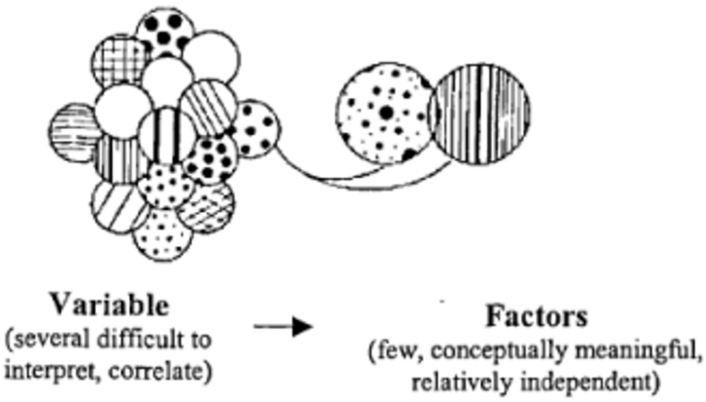

Figure 4.1. Factor analysis representation (Kleinbaum *et al.*, 2008).

There are 2 types of factor analysis. Firstly, confirmatory factor analysis, or CFA, is mostly utilized to determine if a data set fits an expected factor model. To verify that a proposed model is consistent with observed data, CFA uses predetermined relationships and structured assumptions (Goretzko *et al.*, 2019). It is frequently employed to validate hypotheses that have been developed through exploratory analysis or earlier research.

Secondly, exploratory factor analysis (EFA) method can be used to determine the underlying structure of a collection of observed data without making any assumptions beforehand. By modeling variables with latent components, it seeks to investigate correlations between them (Goretzko *et al.*, 2019). EFA uncovers hidden patterns by assuming a causal relationship between latent variables and manifest indicators (Goretzko *et al.*, 2019). Exploratory Factor Analysis (EFA) can be carried out in five primary steps, which are:

4.5.4.1. Step 1. Determining if the data is suitable for factor analysis. This entails assessing the dataset's sample size, variable intercorrelations, and the results of tests such as the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) test. According to Williams *et al.* (2010), this step guarantees that factor analysis is appropriate for the dataset. Moreover, a correlation matrix has been generated. This stage involves computing a single set of loadings that produce theoretical variances and covariances that, based on a certain metric, fit the actual ones as closely as possible. These matrix loadings could not, however, produce the anticipated factor correlations. Bartlett's test of sphericity; To ascertain whether the dataset's correlation matrix differs considerably from an identity matrix, which would suggest that correlations between variables are enough for factor analysis, Bartlett's Test of Sphericity is employed. The data is appropriate for factor analysis if the Bartlett's test yields a significant result, meaning its p-value should be lower than 0.05, which indicates that the variables have meaningful correlations. By verifying that there is sufficient shared variation among the variables to create underlying factors, this test guarantees that factor analysis is appropriate. Kaiser-Meyer-Olkin (KMO) test; A test of sampling adequacy called the Kaiser-Meyer-Olkin (KMO) test assesses the percentage of variance among variables that may constitute common variance. A score closer to 1 indicates that factor analysis is probably going to be helpful for the dataset. The KMO statistic has a range of 0 to 1, and equals to,

$$KMO = \frac{\sum\sum_{i\neq j} r_{ij}^2}{\sum\sum_{i\neq j} r_{ij}^2 + \sum\sum_{i\neq j} \alpha_{ij}^2}, \tag{4.4}$$

where r_{ij} is the simple correlation coefficient between variables i and j, and r_{ij} is the partial correlation coefficient between variables i and j. A small value of the sum of the squared partial correlation coefficients between variables relative to the sum of the squared simple correlation coefficients indicates that the KMO statistic is close to 1. The higher the KMO value is, the more correlations between pairs of variables can be explained by other variables. Basically, the Kaiser-Meyer-Olking (KMO) measure should be more than 0.6, and the Bartlett's test should be significant (e.g., $p < 0.05$) (Starkweather, 2018).

Factor analysis can be performed only when the KMO value is high. Therefore, KMO values less than 0.5 are not satisfactory; values between 0.5 and 0.7 are average; between 0.7 and 0.8 are good; between 0.8 and 0.9 are great; and above 0.9 are terrific.

Generally speaking, factor analysis can proceed with a KMO value larger than 0.6. The KMO test aids in determining whether there are enough appropriate items in the dataset to support factor analysis. The KMO measure can be seen from the below equation in Equation (4.4):

4.5.4.2. Step 2. Factor extraction is the second step. Using techniques such as principal component analysis (PCA) or principal axis factoring (PAF), factors are extracted in this step. Finding the number of latent factors that account for the correlations between variables is the aim (Williams *et al.*, 2010),

$$z_j = a_{j1}F_1 + a_{j2}F_2 + ...a_{jn}F_n, \tag{4.5}$$

where z_j normalized original variable (all variables are normalized before the analysis starts), a_{ji} Factor Loadings (like standardized multiple regression coefficient), F_i Component (Common Factor).

The variance is 1 after all initial variables have been standardized, which can be calculated from,

$$\%Variance(F_i) = (\frac{Eigenvalue(i)}{TotalVariance}) * 100. \tag{4.6}$$

The number of variables equals the total variance, and Equation (4.6) can be used to get the percentage of variation explained by each component, Out of all the conceivable linear combinations of variables, the first principal component explains the greatest amount of variation, followed by the second principal component, which explains the highest variance if it is uncorrelated with the first component, and so forth. The factor pattern matrix is sorted in a way that gathers variables with high loadings on the same factor. Loadings less than 0.5 are deducted to make the factor a representation of the significant correlated variables.

4.5.4.3. Step 3. Rotation and Interpretation of Factors. Rotation techniques like Varimax or Oblimin are used after extraction to further distinguish the factor loadings. In this study, the Varimax correlation method is selected. According to Williams *et al.* (2010), rotation makes it clear which variables are connected to each factor.

4.5.4.4. Step 4. Labeling and Interpretation. In order to give the factors meaningful labels based on the variables that heavily weigh on them, the rotated factor matrix is analyzed. In order to summarize the data patterns, this phase allows assigning components descriptive labels (Williams *et al.*, 2010). The calculation of factor scores for each case for future use is the focus of this stage and can be seen below,

$$F_j = \sum_{(i=0)}^{p} W_{ij} X_{ij}, \tag{4.7}$$

where X_{ik} standardized value of the i_{th} variable for case k, W_{ji} Factor score coefficient for the j_{th} factor and the i_{th} variable.

4.5.4.5. Step 5. Validity and Reliability. This step evaluates internal consistency using metrics such as Cronbach's alpha to determine the validity and dependability of the components that have been identified. According to Williams *et al.* (2010), dependability assessment guarantees that the factors are genuine and consistent for additional study.

The chosen methodology offers a well-rounded strategy by fusing quantitative rigor with qualitative insights. The study guarantees a thorough grasp of the crucial success criteria for FPV systems by utilizing powerful statistical analysis and surveying stakeholders to gain their opinions. With practical insights catered to Türkiye's particular situation, this method directly advances the study's goals.

5. RESEARCH RESULTS

5.1. Introduction

In this chapter, it is planned that the answers from the questionnaire survey for CSFs for FPV systems are analyzed. In the first part, information regarding survey participants is analyzed. In the second part, CSFs are investigated along with methods for data collection. Moreover, a reliability test is performed to see whether the data obtained can be used for the analyses that were explained in the previous chapter. If the data is deemed to be usable, quantitative analyses are performed using SPSS software.

To perform the quantitative analysis, firstly, mean values are found for every CSF to see their mean rankings. Also, a t-test is performed to see the correlation and miscorrelation between comparable groups. Groupings and their details will be mentioned in the relative section. Later, for every factor, means of them are compared based on survey respondents' type of organization. This analysis will be made by the ANOVA technique. Lastly, factor analysis will be utilized to group CSFs based on their correlation with one another. This will help to understand the concealed relationship between CSFs. This will be made possible by PCA.

5.2. General Information of Survey Participants

As Eggleston (2024) mentions, a response rate above 15% can seem applicable. Moreover, the paper also claims that if you survey a group consisting of people who have significant knowledge about the survey topic, a lower response rate can also be acceptable. In this study, among the 412 surveys sent, 90 responses have been received, resulting in a 22% response rate. This is valid, especially for representative sampling. This response rate is made possible by carefully selecting academic papers related to the subject and e-mailing them. This allowed people to respond since they are already interested in the topic and they are already being referenced in the thesis. Moreover, people who are working in energy-related organizations are also carefully selected on LinkedIn and asked to fill out the survey. Reminders were sent one week after the first message was forwarded.

5.2.1. Personal Information of Survey Participants

To find the average of the survey respondent's experience within the energy sector, since it was only asked them to categorize it among the 5-year spans, the average of each span is taken. For example, for the 37 people whose experience in the energy sector varies between 0 to 5 years, 2.5 years are selected as their average. For the people whose experience exceeded 20 years, 25 years is taken as the average. Based on those limitations, the average experience of the survey respondents is around 9.5 years with a standard deviation of 7.68.

In Figure 5.1, how many people selected which category, along with their percentage, can be seen. It is clear from the table that while most of the survey respondents have between 0 to 5 years of experience, there are still a significant amount of people who are experienced. This result, along with the return received from the survey, indicates that the energy sector consists of young people who are eager to learn new topics such as FPV systems.

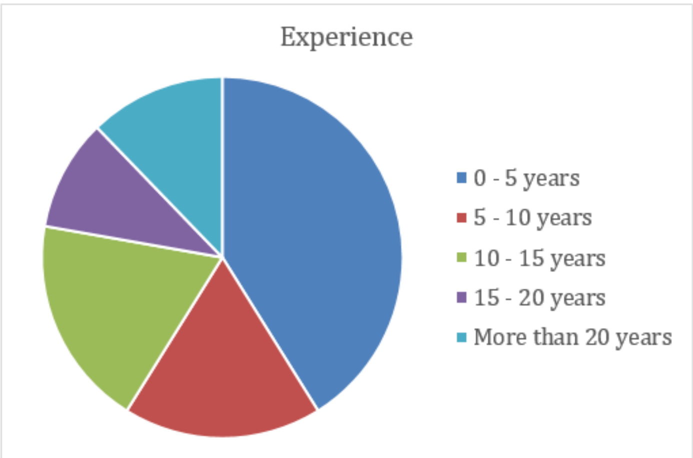

Figure 5.1. Years of experience of survey respondents.

Positions of the survey respondents within their respective organizations can be seen in Figure 5.2. Those positions are professor, researcher/analyst, executive/director, engineer/technical specialist, consultant/advisor, and manager/supervisor. It is important to understand and be able to compare different responses received from people who are affecting different aspects of the energy sector. This is especially important for FPV since even the people who are not directly working in the technical aspect of FPV systems should know the needs of FPV systems in order to create maximum efficiency. However, among the survey respondents, nearly one-third (29 people, 32.2%) of them were related in the technical aspect of RE systems. This is also due to surveying being done to people who are working on the technical side of RE sector in order to have a more reliable dataset. Moreover, people working in academia are around 31%, with 13 people as professors and 15 people as researcher/analysts, which are 14.4% and 16.7%, respectively. This shows the importance of R&D for FPV systems. Furthermore, around 28% of the respondents were either executive/director (12 people, 13.3%) or manager/supervisor (13 people, 14.4%), which indicates that their knowledge would be better regarding this topic and hence once again validates the outcome of this study. Lastly, only 8 survey respondents are working as consultants or advisors (8.9%), which might indicate that companies are forming energy teams within instead of asking a consulting firm for their help.

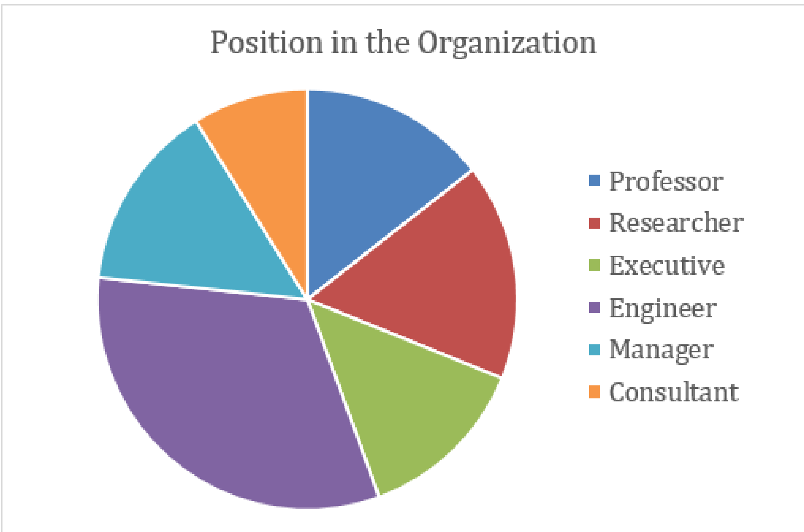

Figure 5.2. Positions of respondents in their organization.

5.2.2. Respondents' Organization Information

Figure 5.3 shows the distribution of respondents based on the type of organization they are working for. It is clear from the table that most of the respondents are working for contractor companies, with 29 people total and 32.2%, with only one of them working for a subcontractor. Contractor organization is followed by academia, which constitutes 27.8% of the respondents, with 25 people working for it. After the two main organizations of contractors and academia, clients and consultants are following with 10 people each. This table correlates with the previous table (Table 5.5) as in the previous table, it is stated that 8 people are working as consultants or advisors, while in this table, 10 people are working for consulting firms, which is reasonable. Lastly, after the previously mentioned 4 organization types, government, designer, and investor organizations come with 7, 6, and 3 people, respectively.

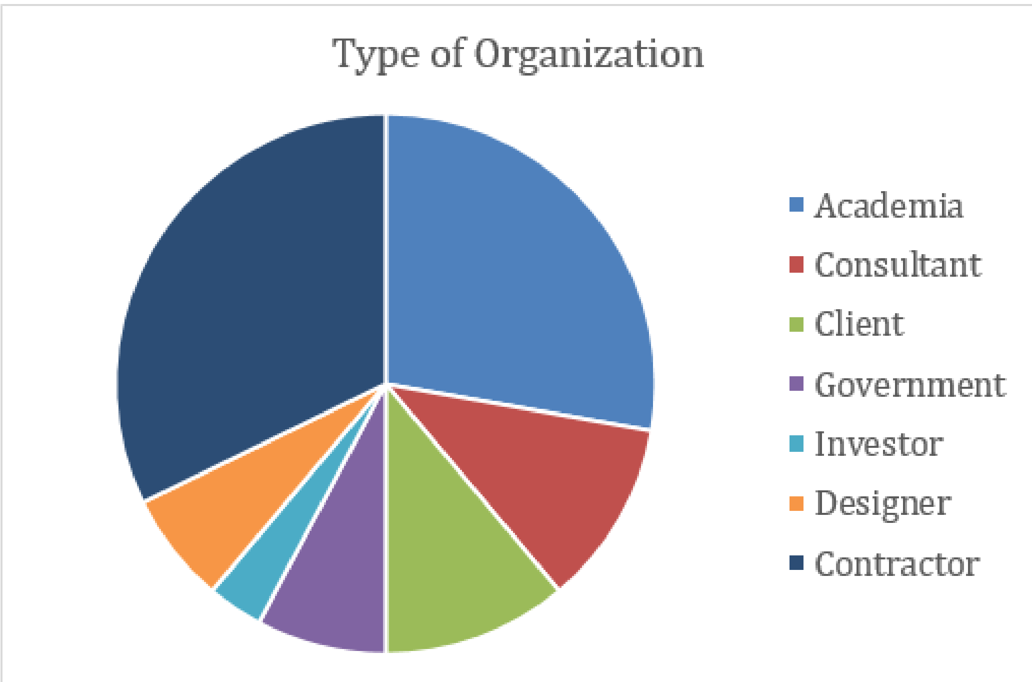

Figure 5.3. Type of organizations respondents are from.

5.3. Web Questionnaire Survey

Google Drive (drive.google.com) was used to conduct and manage the survey. Since Google Drive was used, data is stored online. The first response date is the 29th of October, 2024, while the last response is entered on the 23rd of November, 2024. Section 4.3 contained information on the target population, which populates the response group. Survey participants are asked to fill out the survey by either e-mailing it to them or sending a message through LinkedIn. To increase the response rate, participants who have not responded back are reminded to fill out the survey one week after the initial request. As stated in the above sections, 90 replies were gathered.

There are two sections to the survey. 4 main questions are asked in Part One to obtain participants' personal data, which can be seen in Section 4.3. The CSFs are explained in the second part of the survey, and after that, it is asked of the participants to rate the significance of all of the 17 CSFs using the following five-point Likert scale:

5 = "Extremely Significant", 4 = "Very Significant", 3 = "Significant", 2 = "Fairly Significant", and 1 = "Not Significant".

5.4. Analysis and Ranking

In order to compare CSFs' significant levels, the mean ranking method is utilized. In Section 3.2, CSFs and their short explanations, along with the corresponding sections of the articles where these CSFs are referenced, can be seen.

5.4.1. Reliability Test

Before beginning the analysis process, it is crucial to verify that the data are trustworthy and appropriate for analysis, which is known as testing the dependability of the obtained data. For this purpose, Cronbach's alpha is calculated. It is a measure of internal consistency that indicates how well a set of items measures a single latent construct. It ranges from 0 to 1, with higher values, especially over 0.7, suggesting that the items are reliably measuring the same underlying factor (Williams *et al.*, 2010). Cronbach's alpha reliability is calculated in SPSS software for the FPV systems' CSFs.

Cronbach's alpha came out as 0.892, which is above the limit. This shows that the test is credible, and the data collected shows internal consistency (Norusis, 2012). Hence, it is expected from the dataset to yield trustworthy results. Details of the reliability test are given in Section 4.5.3.

5.4.2. Critical Success Factors

This study's primary goal is to look into the CSFs for FPV systems in Türkiye. To test their significance, 17 CSFs were selected from the literature in this regard. It is evident from the mean value for each factor that they are all significant, with mean values ranging from 4.4 to 3.37. They are all important elements, according to a literature review along with expert opinions of 5 specialists, albeit their rankings vary.

Table 5.1 shows mean ranking for every CSF, while from Figure 5.4, mean ranking separated by the type of organizations in which the respondents are working can be seen. The CSF names have been shortened slightly to enhance the readability of the table. Moreover, the top ten most important vital success variables are first shown as in Table 5.5, with mean values ranging from 4.40 to 3.98, based on questionnaire survey replies.

Table 5.1. Mean, std deviation, and variances for CSFs.

CSFs	Mean	Std. Deviation	Variance
Site Selection for Maximizing Energy Potential	4.4	0.818	0.67
Resilient Structural Design and Robustness for Successful FPV Systems	4.3	0.942	0.887

Table 5.1 Mean, std deviation, and variances for CSFs. (cont.)

CSFs	Mean	Std. Deviation	Variance
Accessibility and Proximity of Infrastructure	4.24	0.891	0.794
Ensuring Energy Safety	4.21	0.93	0.865
Supportive Government Policies and Regulations	4.19	1.069	1.144
Panel optimization for Yield Enhancement	4.12	0.97	0.94
Successful Site Selection to Avoid Location-Based Extremes	4.06	1.01	1.019
Increased Interest for Renewable Energy	4.03	1.022	1.044
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	4	1.006	1.011
Innovative Approaches to Enhance Material Properties	3.98	1.038	1.078
Supporting Environmental Sustainability Objectives	3.96	1.09	1.189
Reducing Water Evaporation	3.96	1.038	1.077
Achieving Energy Independence	3.92	1.104	1.219
Mitigating Negative Environmental Impacts	3.92	1.052	1.106
Increased Usage of Remote Sensing Technologies	3.71	1.183	1.399
Stakeholder Collaboration and Engagement	3.69	1.118	1.25
Social Acceptance	3.37	1.175	1.381

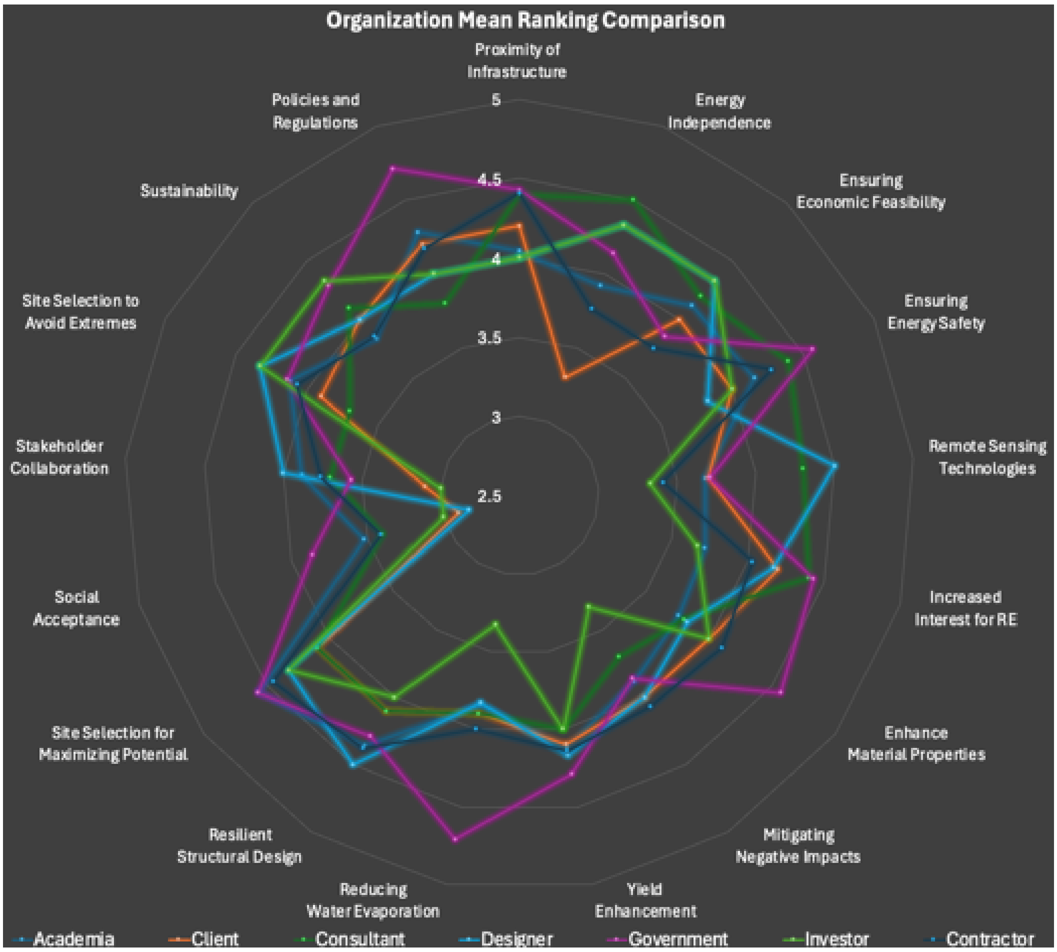

Figure 5.4. Mean ranking separated by the type of organizations.

Table 5.2. Top 10 CSFs.

CSF	Total	
	Mean	**Rank**
Site Selection for Maximizing Energy Potential	4.40	1
Resilient Structural Design and Robustness for Successful FPV Systems	4.30	2
Accessibility and Proximity of Infrastructure	4.24	3
Ensuring Energy Safety	4.21	4
Supportive Government Policies and Regulations	4.19	5
Panel optimization for Yield Enhancement	4.12	6
Successful Site Selection to Avoid Location-Based Extremes	4.06	7
Increased Interest for Renewable Energy	4.03	8

Table 5.2 Top 10 CSFs. (cont.)

CSF	**Total**	
	Mean	**Rank**
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	4.00	9
Innovative Approaches to Enhance Material Properties	3.98	10

The top nine CSFs, which all had mean values higher than 4, were ranked as follows: "Ensuring Energy Safety" (mean: 4.24), "Maximizing Energy Potential" (mean: 4.40), "Design and Robustness for Proximity of Infrastructure" (mean: 4.30), "Government Policies and Regulations for Yield Enhancement" (mean: 4.21), "Selection to Avoid Location-Based Extremes" (mean: 4.19), "Increased Interest for Renewable Energy" (mean: 4.12), "Feasibility through Cost Reduction and Competitiveness" (mean: 4.06), "Innovative Approaches to Enhance Material Properties" (mean: 4.03), and "Reducing Water Evaporation" (mean: 4.00).

The other factors with slightly lower but still notable significance (mean values ranging from 3.98 to 3.37) were as follows: "Reducing Water Evaporation" (mean: 3.98), "Supporting Environmental Sustainability Objectives" (mean: 3.96), "Achieving Energy Independence" (mean: 3.92), "Mitigating Negative Environmental Impacts" (mean: 3.92), "Increased Usage of Remote Sensing Technologies" (mean: 3.71), "Stakeholder Collaboration and Engagement" (mean: 3.69), and "Social Acceptance" (mean: 3.37). These CSFs contribute to understanding the comprehensive drivers behind FPV system adoption.

<u>5.4.2.1. Opinion Differences between Energy Sector Workers and Others.</u> Appendix C shows the result of t-test for people who either have worked or are still working in the energy sector and people who have not. Before continuing the table, it is important that while the test group for people who did not work in the energy sector consists of 17 people, the subject group of people who have worked in the energy sector consists of 73 people, meaning comparing those data can lead to some undesired result. The

distribution of these groups is illustrated in Figure 5.5. However, if observed with care, it is clear that the below table gives important insight regarding people's opinion about the most important elements for FPV systems in Türkiye. For the sake of simplicity, it is called that people who have worked in the energy sector test group 1 (TG1), and people who have not worked in the energy sector test group 2 (TG2).

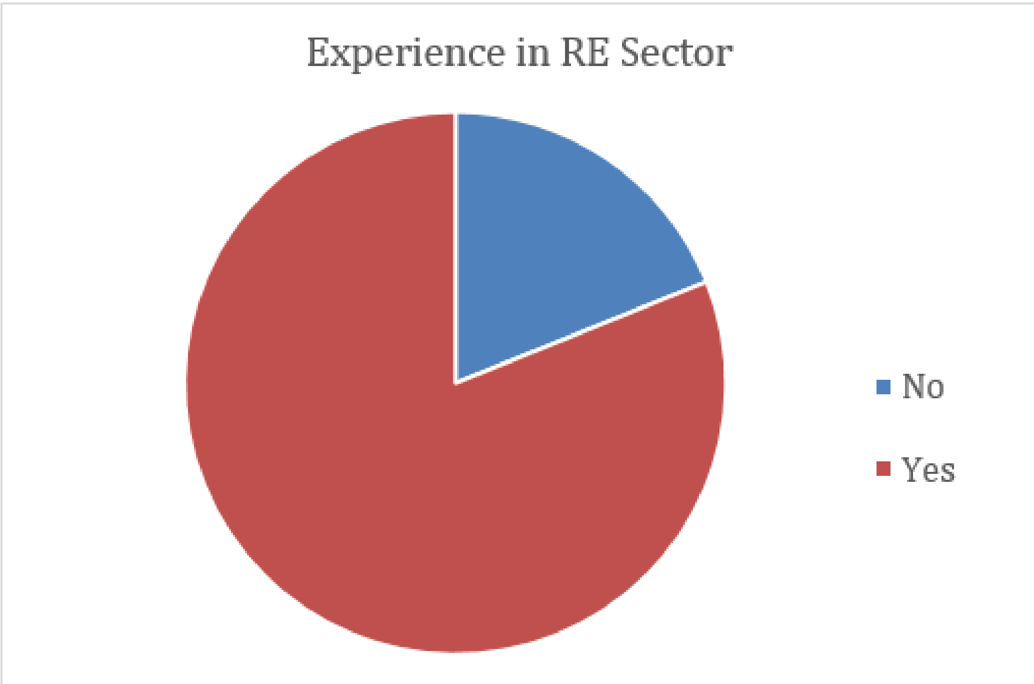

Figure 5.5. Does respondents have experience in the RE Sector.

From the mean ranking comparison, it is clear that although many of the CSFs' means are close to each other, there are still some important variances. For example, while TG1's mean for achieving energy independence, meaning continuous O&M processes, is lower (3.88, rank 14), TG2 ranked this CSF higher (4.12, rank 8). On the other hand, while TG1 ranked reducing water evaporation as an important CSF (4.03, rank 7), TG2 did not see this CSF as important as TG1, with a mean of 3.65 and ranking just 15th. Besides these 2 CSFs differing from each other, all the other CSFs are ranked within 2 spots difference compared to TG1 and TG2's ranking. Moreover, the results of the normality test indicated that the data were not distributed regularly. It was thought that the t-test, as a parametric test, is appropriate to ascertain whether there is a significant difference between the opinions of TG1 and TG2 regarding the importance of CSFs, notwithstanding this assumption violation and supported by evidence from earlier research, as previously mentioned. The table can be seen from Appendix C. It can be seen from the one-sided p that every p value is above 0.05, meaning the TG1 and TG2 did not create significant differences.

5.4.2.2. Opinion Differences between Six Organization Groups. The second assumption was not broken for ANOVA, as the homogeneity test indicates that the data are homogeneous. The results of an ANOVA test for significant differences in the responses of the "Academia, Client, Consultant, Designer, Government, and Investor" group on the 17 CSFs that were found (5% significance level) are displayed in Appendix C. The opinions of these five groups do not differ statistically significantly, according to the F value and significance level for each factor since $p > 0.05$ for all CSFs. Otherwise, to ascertain which groups have substantially different means, a post hoc test, also known as an a posteriori test, should have been conducted. A post hoc test (Tukey test, assuming equal variances, or Games-Howell test, assuming non-equal variances) is not used in this study because this is not the case. Nonetheless, the findings indicate that the groups' rankings of the criteria differ significantly. For example, while "reducing water evaporation" CSF ranked 14th with a mean of 3.83 out of 5 for designers, it is ranked 1st for government with a mean of 4.71; hence its F value is high.

5.4.2.3. Opinion Differences between Turkish and International Respondents. The results of the t-test comparing Turkish and international respondents for various CSFs are presented in Appendix C. The table evaluates the significance of differences in responses between the two groups, which comprise 72 Turkish respondents and 18 international respondents. The significance (p-value) for each CSF is provided, and none of the p-values fall below the threshold of 0.05, indicating that there are no statistically significant differences in the perceptions of the two groups across the analyzed CSFs.

However, certain CSFs are closer to the threshold of $p=0.05$, particularly Accessibility and Proximity of Infrastructure, which has a p-value of 0.06. This suggests that

Turkish respondents may place slightly greater importance on this factor compared to their international counterparts, as evidenced by the mean difference of -0.44. While not statistically significant, this difference could indicate a trend worth exploring further, particularly in the context of addressing infrastructure challenges in Türkiye for FPV systems.

Overall, the analysis highlights that Turkish and international respondents share broadly similar perspectives on the importance of CSFs for FPV systems. The absence of significant differences suggests a general alignment in priorities across both groups, underscoring the universal relevance of these success factors in the development of FPV systems. However, minor variations, such as in the perceived importance of accessibility and infrastructure, can still provide insights for tailoring strategies to meet regional needs.

5.5. Factor Analysis of FPV Systems in Türkiye

SPSS was used to do a factor analysis of the CSFs for FPV systems. The output files produced by the SPSS program included component matrices, rotating component matrices, correlation matrices, scree plots, eigenvalues and total variance explained, and component transformation matrices.

By identifying latent factors that explain the underlying relationships inside a collection of observed data, factor analysis is used to find and categorize related variables. Its goals are to simplify complicated data structures, lower the dimensionality of the data, and improve comprehension of the relationships between various variables.

5.5.1. CSFs for FPV Systems in Türkiye

With a significance level of less than 0.001, the Bartlett test of sphericity in this study produced a value of 693.955, suggesting that the correlation matrix is not an identity matrix and that the test statistic is suitably large. This implies that the variables have strong connections with one another, which qualifies them for factor analysis. Furthermore, this dataset's Kaiser-Meyer-Olkin (KMO) score was determined to be 0.826, falling within the "meritorious" range and demonstrating very strong sample adequacy. Overall, these findings demonstrate that the data is suitable for factor analysis because there is a high degree of sampling adequacy and adequate correlation between the variables.

To determine the data's degree of singularity, the determinant is computed. No factor should be removed if the determinant value is greater than 0.00001, which indicates that there is no singularity effect. Nevertheless, the determinant in this study is less than 0.00001, indicating that some of the variables for the main component analysis must be removed. There are 2 factors that should be excluded for a factor study to give realistic results. Firstly, "Accessibility and Proximity of Infrastructure" is excluded from the survey. The reason for this is that it has a high p-value in the correlation matrix, meaning that the observed data is likely under the null hypothesis. Since there are 17 cells for each CSF that have different p-values for this CSF with all other CSFs, there is not only one p-value to be considered. In this study, number of cells that have a p-value over 0.05 is observed. As you can see from the table below, "Accessibility and Proximity of Infrastructure" had 9 values that are over the limit. Since it is significant compared to other CSFs, it is decided that the "Accessibility and Proximity of Infrastructure" CSF is excluded from the study.

Table 5.3. P-Values.

CSF	**p>0.05**	**p<0.05**
Accessibility and Proximity of Infrastructure	9	7
Achieving Energy Independence	1	15
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	5	11
Ensuring Energy Safety	0	16
Increased Usage of Remote Sensing Technologies	3	13
Increased Interest for Renewable Energy	4	12

Table 5.3 P-Values. (cont.)

CSF	**p>0.05**	**p<0.05**
Innovative Approaches to Enhance Material Properties	1	15
Mitigating Negative Environmental Impacts	0	16
Panel optimization for Yield Enhancement	2	14
Reducing Water Evaporation	2	14
Resilient Structural Design and Robustness for Successful FPV Systems	1	15
Site Selection for Maximizing Energy Potential	2	14
Social Acceptance	4	12
Stakeholder Collaboration and Engagement	4	12
Successful Site Selection to Avoid Location-Based Extremes	1	15
Supporting Environmental Sustainability Objectives	0	16
Supportive Government Policies and Regulations	1	15

The communalities table, Table 5.4, shows the extent to which the extracted components account for the variation of each variable. Since they imply that the extracted components accurately reflect the variable, communalities larger than 0.5 are often regarded as acceptable. The majority of the variables in this table have communalities greater than 0.5, indicating that a sizable amount of the variance in these variables can be explained by the extracted components. Nonetheless, the communality value of one CSF, “Increased Usage of Remote Sensing Technologies” is 0.466, which is below the 0.5 cutoff. Since this value is not optimal, “Increased Usage of Remote Sensing Technologies” CSF is removed from the study.

Table 5.4. Communalities table.

Communalities	**Extraction**
Accessibility and Proximity of Infrastructure	0.578
Achieving Energy Independence	0.582
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.536

Table 5.4 Communalities table. (cont.)

Communalities	Extraction
Ensuring Energy Safety	0.684
Increased Usage of Remote Sensing Technologies	0.466
Increased Interest for Renewable Energy	0.595
Innovative Approaches to Enhance Material Properties	0.560
Mitigating Negative Environmental Impacts	0.580
Panel optimization for Yield Enhancement	0.591
Reducing Water Evaporation	0.549
Resilient Structural Design and Robustness for Successful FPV Systems	0.617
Site Selection for Maximizing Energy Potential	0.724
Social Acceptance	0.771
Stakeholder Collaboration and Engagement	0.806
Successful Site Selection to Avoid Location-Based Extremes	0.578
Supporting Environmental Sustainability Objectives	0.691
Supportive Government Policies and Regulations	0.610

After removing the previously mentioned 2 CSFs from the factor analysis, only 15 CSFs remain. The 15 variables' correlation matrix can be found in Appendix C. The matrix is now deemed suitable for analysis once these components have been removed. It is stated that the KMO statistic value of 0.828 (Appendix C) is appropriate for factor analysis.

Factor analysis is applied to those 15 CSFs. To determine the factor groups, Table 5.2 can be inspected. Three components were chosen for the analysis because they accurately capture the variability in the dataset. Together, these three elements account for a significant amount of the total variance, which is essential for comprehending the underlying patterns among the key CSFs. The chosen components account for roughly 60% of the cumulative variance, offering a strong basis for correctly assessing the connections between the CSFs and guaranteeing factor analysis success.

Table 5.5. Total variance explained.

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	6.314	42.092	42.092
2	1.364	9.093	51.185
3	1.288	8.586	59.770

Factors are grouped according to varimax rotation in Table 5.6. Every factor has a loading greater than 0.5 and solely belongs to one of the components. The following is an explanation of the three components based on the descriptions of the variables:

- Factor 1 is "Energy Optimization" (Internal Factor).
- Factor 2 is "Community Engagement" (External Factor).
- Factor 3 is "Economic Sustainability" (External Factor).

Table 5.6. Rotated component matrix for CSFs for FPV systems in Türkiye.

	Energy Optimization	Community Engagement	Economic Sustainability
Supportive Government Policies and Regulations	0.738		
Panel optimization for Yield Enhancement	0.727		
Supporting Environmental Sustainability Objectives	0.713		
Mitigating Negative Environmental Impacts	0.704		
Resilient Structural Design and Robustness for Successful FPV Systems	0.663		
Reducing Water Evaporation	0.641		
Successful Site Selection to Avoid Location-Based Extremes	0.636		

Table 5.6 Rotated component matrix for CSFs for FPV systems in Türkiye. (cont.)

	Energy Optimization	Community Engagement	Economic Sustainability
Innovative Approaches to Enhance Material Properties	0.617		
Increased Interest for Renewable Energy	0.555		
Stakeholder Collaboration and Engagement		0.828	
Social Acceptance		0.822	
Site Selection for Maximizing Energy Potential		0.542	
Ensuring Economic Feasibility through Cost Reduction and Competitiveness			0.746
Achieving Energy Independence			0.74
Ensuring Energy Safety			0.652

It can be concluded that Energy Optimization (mean 4.1) and community engagement (mean 4.0) are the most important factors for successful FPV systems after averaging the mean values of the variables to get a mean value for each group. These are followed by Economic Sustainability (mean 3.8).

5.5.1.1. Energy Optimization. Energy Optimization of FPV systems contributes 42.092% of the variances in the correlation matrix. This key component includes increased interest in RE, innovative approaches to enhance material properties, mitigating negative environmental impacts, panel optimization for yield enhancement, reducing water evaporation, resilient structural design and robustness for successful FPV systems, successful site selection to avoid location-based extremes, supporting environmental sustainability objectives, and supportive government policies and regulations.

Factor 1 consists of 9 CSFs. The loadings of all the sub-factors in Factor 1 are higher than 0.5, ranging from 0.738 to 0.555. Supportive government policies and regulations, panel optimization for yield enhancement, supporting environmental sustainability objectives, and mitigating negative environmental impact (loadings of 0.738, 0.727, 0.713, and 0.714, respectively) are the top 4 most significant aspects in this component. They are thought to be significant since their loadings are greater than 0.7.

Better integration of FPV technologies into the energy sector is made possible by the supportive framework that is provided by the alignment of government policies and regulations. Using sustainable goals and optimizing panels for optimal yield further guarantees that FPV installations are not only efficient but also eco-friendly. Government regulations, panel design, and environmental factors work together to make FPV systems robust and optimized for steady power output. The development of sophisticated floating panels, which minimize overheating and reflection losses to optimize energy yield, is one example. These developments create an effective, government-supported energy option that reduces environmental effects while complying with sustainability rules. Together, these actions improve FPV systems' performance and dependability, resulting in a more sustainable and efficient energy production environment.

Strategic site selection, structural stability, water management, material innovation, and interest in RE are also necessary for FPV systems to produce energy as efficiently as possible (mean, 3.76). In order to minimize potential environmental issues and guarantees that FPV installations are positioned for maximum efficiency and stability, it is imperative that sites be carefully chosen to prevent location-based extremes. Furthermore, FPV systems' robustness and longevity are greatly enhanced by resilient structural design, which makes it possible for them to tolerate harsh weather and environmental stresses.

Reducing water evaporation is critical to maintaining energy output since it keeps reservoirs at ideal levels and avoids energy losses from rising temperatures. By lowering wear and tear and boosting performance, creative methods to improve material qualities have a direct impact on the long-term effectiveness and dependability of FPV systems. The adoption of this cutting-edge technology has been fueled by growing interest in RE. The development and optimization of FPV systems has been hastened by a greater market need for greener energy sources, which has led to more efficient energy generation. Together, these elements guarantee that FPV systems are robust, effective, and able to generate power in the most efficient way possible.

5.5.1.2. Community Engagement. Community engagement contributes 9.093% of the variability in the correlation matrix. This category includes three elements: site selection for maximizing energy potential, social acceptance, and stakeholder collaboration and engagement. The success of FPV systems depends on community involvement since it guarantees that local communities participate in and gain from RE projects. The general acceptance and execution of FPV projects are linked to social acceptance, stakeholder cooperation, and site selection. Stakeholder participation and social acceptance have factor loadings of 0.828 and 0.822 for these CSFs, respectively, while site selection for maximizing energy potential has a lower loading of 0.542, suggesting a more indirect relationship with community engagement.

Due to the significance of community support and the participation of important stakeholders during the development process, FPV systems require both social acceptance (loading, 0.822) and stakeholder collaboration (loading, 0.828). Stakeholder collaboration helps align interests across many groups to prevent conflicts and improve outcomes, while social acceptability helps guarantee that the community views FPV systems as advantageous to their environment and well-being. Together, these elements can result in more seamless project execution and long-term success since FPV initiatives win over local stakeholders and steer clear of possible hiccups.

Although it is largely a technical factor, choosing a site to maximize energy potential can also be evaluated from the standpoint of community engagement. Gaining community support can be achieved by choosing a location that optimizes energy potential while taking the priorities and requirements of the stakeholders into consideration. Developers benefit the community both economically and environmentally when they select locations that maximize energy output while avoiding disturbance of nearby ecosystems or cultural sites. Energy Optimization combined with community-sensitive site selection promotes acceptability and strengthens the connection between community interests and energy aims.

<u>5.5.1.3. Economic Sustainability.</u> The third category, which is "Economic Sustainability", explains 8.586% of the variance. It includes CSFs of achieving energy independence, ensuring economic feasibility through cost reduction and competitiveness, and ensuring energy safety. They have respective factor loadings of 0.746, 0.74, and 0.652. This group concentrates on external factors that are important for FPV systems' long-term operation and expansion. Government organizations like DSİ in Türkiye place a strong focus on energy independence, operational maintenance for energy safety, and economic competitiveness, each of which is represented by a CSF.

One of the key components of guaranteeing the financial sustainability of FPV projects is establishing economic feasibility through cost reduction and competitiveness (loading, 0.746). Government organizations must maintain their competitiveness in the energy market while minimizing expenses. These projects are certain to be appealing to investors and capable of attaining long-term viability due to their emphasis on cost reduction and financial feasibility. Maintaining economic efficiency makes FPV systems a more viable option for supplying the nation's energy demands, which is crucial for reaching overall RE targets for a country, especially for Türkiye.

Achieving energy independence (loading, 0.74) is another crucial CSF. In order to provide a more stable and secure energy supply and lessen reliance on imported energy, energy independence is essential. By creating RE initiatives like FPV systems, government organizations are particularly concerned with improving national energy security. This increases the resilience of the nation's energy infrastructure by encouraging self-reliance in energy production and lessening the effects of volatile global energy prices.

The third CSF in this group, ensuring energy safety (loading, 0.652), highlights the significance of consistent and reliable energy generation, with special focus on operational maintenance. Government organizations like DSİ concentrate on reducing operating risks and making sure that FPV systems are resilient to possible threats or disruptions. This supports the resilience of the national power supply by ensuring the safety and dependability of energy infrastructure through appropriate maintenance procedures. Therefore, maintaining energy safety is essential to the operational and financial viability of government-backed RE projects.

6. DISCUSSION OF RESULTS

The previous chapter presents the key findings of the study on CSFs for FPV systems in Türkiye, based on a questionnaire survey. Statistical techniques such as mean ranking, t-test, and ANOVA, along with factor analysis, were utilized to identify significant factors and explore the underlying relationships between them.

This study's main goal is to look at the essential elements of an effective FPV system deployment. All of the highlighted criteria were thought to contribute to successful implementation based on the survey findings.

With a mean score of 4.40, "Site Selection for Maximizing Energy Potential" is placed as the first CSF overall, suggesting that it is the most important component of FPV system success in the eyes of respondents. This CSF was ranked highest by contractors (4.45, rank 1) and by academia (4.56, rank 1), highlighting its crucial significance in both research and real-world construction settings. Findings align with the real world, as most of the literature written about FPV systems is mainly focused on site selection. These organizations view site selection as a highest-priority subject since it is closely related to optimizing solar energy efficiency. However, consultants gave this CSF a lower ranking (4.10, rank 7), indicating that they might concentrate more on improving certain project elements rather than just choosing the best location to maximize energy yield. Because site selection directly affects energy output maximization, which is essential for the sustainability and performance of FPV systems, it is listed first.

With an aggregate mean score of 4.30, "Resilient Structural Design and Robustness for Successful FPV Systems" is ranked second, highlighting its significance in guaranteeing the long-term dependability and efficacy of FPV systems. The importance of resilient design in withstanding environmental difficulties and maintaining operational stability was highlighted by the designers as they rated this CSF highest

(4.50, rank 1), which was followed by academics (4.36, rank 2). On the other hand, the government gave this CSF a lower ranking (4.29, rank 8), which may indicate that they were more concerned with general policy or regulatory issues than with particular structural design flaws. Resilient structural design is ranked second because its robustness ensures the longevity and reliability of FPV systems, protecting them from environmental stresses and potential failures. If FPV systems lack resilience and robustness, they are at greater risk of structural failures during extreme events, such as the overturning of solar panels or fires caused by overheating. These failures can significantly reduce the lifespan of FPV systems and undermine their overall effectiveness, making it crucial for stakeholders to prioritize resilient designs to ensure operational stability and longevity.

With a mean score of 4.24, "Accessibility and Proximity of Infrastructure" is ranked third overall, showing its importance in assisting with the creation and functioning of FPV systems. Because they help to reduce logistical obstacles and guarantee the availability of energy resources, which have a direct impact on project schedules and total expenses, clients gave this CSF the highest rating (4.20, rank 1). Accessibility was also ranked highly by contractors (4.41, rank 2), who valued it for lowering labor costs and increasing installation and maintenance efficiency, which simplifies their work. On the other hand, designers gave this CSF a lower ranking (4.00, position 9), which would suggest that they were more concerned with adapting designs than with putting closeness to existing infrastructure first. In order to ensure the viability and profitability of FPV systems, accessibility and closeness are crucial because they drastically reduce installation and operating expenses. Numerous studies have emphasized the significance of accessibility and closeness, showing how integrating FPV systems with current infrastructure can significantly lower development and operating costs, enhancing the projects' overall viability and efficiency.

With a mean score of 4.21, "Ensuring Energy Safety" is ranked fourth overall, indicating how crucial it is to sustain dependable energy generation from FPV systems. This CSF had a high rating from consultants (4.40, rank 2), most likely as a result of their emphasis on detecting and reducing operational risks to guarantee successful project completion. Since energy safety fits with their regulatory supervision duties to guarantee a steady and secure energy supply, the government also gave this factor a high rating (4.57, rank 3). However, designers gave this CSF a lower rating (3.83, position 14), which would suggest that they place more value on system innovation and adaptability than on actively participating in operational safety issues. Energy safety is heavily focused on operation and maintenance strategies that help ensure continuous energy generation, highlighting the importance of resilient operational practices and robust safety measures. Numerous studies emphasize the significance of implementing structured O&M protocols to prevent potential failures and maintain effective energy output.

With a mean score of 4.19, "Supportive Government Policies and Regulations" are ranked fifth overall, emphasizing their critical significance in the implementation and effectiveness of FPV systems. They depend on government assistance to make the adoption of FPV systems financially feasible and to simplify regulations, which guarantees more seamless project implementation, resulting in clients giving this CSF the highest rating (4.20, rank 1). Additionally, the government gave this CSF a high rating (4.71, rank 1), highlighting their emphasis on creating incentives and a legislative framework to assist RE projects. However, consultants gave this CSF a much lower rating (3.80, rank 12), which can be a reflection of their preference for shallow regulations, since if so, they would be needed more. In order to promote investment, offer financial stability, and lower risks in FPV projects, supportive government policies are essential.

With a mean score of 4.12, "Panel Optimization for Yield Enhancement" is placed sixth overall, emphasizing its function in optimizing FPV systems' energy production. Because modifying panel designs immediately affects energy generation efficiency and improves financial returns on investments, clients gave this CSF a reasonably high rating (4.10, rank 4). Although they might give other economic considerations more weight, investors gave this element a rating of 4.00 (rank 6). They acknowledged the significance of effective panel design in guaranteeing profitability. Consultants, on the other hand, gave it a lower rating (4.00, rank 10), which might be a result of their emphasis on system-wide factors rather than merely panel-level improvements. The effectiveness and cost-efficiency of the entire system can be greatly impacted by changing environmental conditions, which makes panel modification essential for increasing energy yield.

With a mean score of 4.06, "Successful Site Selection to Avoid Location-Based Extremes" is ranked seventh overall, highlighting its significance in reducing the hazards associated with extreme environmental conditions. Lowering the danger of damage against extreme weather occurrences protects financial investment, assuring project profitability and lowering future repair costs, and thus, investors gave this CSF the highest rating (4.33, rank 1). Additionally, designers gave it a high rating (4.33, rank 1) since choosing the right location enables them to incorporate ideal design elements that are less likely to be weakened by environmental stressors, improving design dependability and lowering structural difficulties. Clients, on the other hand, gave this CSF a lower rating (3.90, rank 12), which may indicate that they are more concerned with short-term project execution than long-term risks. They may also give more weight to factors that have a direct impact on schedule and cost than environmental risk mitigation. In order to prevent environmental extremes and guarantee the long-term stability and economic viability of FPV systems, careful site selection is essential. With a mean score of 4.03, "Increased Interest for Renewable Energy" comes in eighth overall, underscoring the increased emphasis on sustainable energy options. Both clients and consultants gave this CSF high ratings (4.20, rank 1 for clients; 4.40, rank 2 for consultants). They believe that using RE is crucial to lowering reliance on NRE sources, lowering operating expenses, and satisfying market and regulatory sustainability standards. Because they are more advanced in their comprehension and development of RE concepts and view it as a well-established field rather than a fresh priority, academia gave this CSF a lower rating (3.72, rank 15). The growing interest in RE is significant because it reflects changes in society and politics that have a direct impact on the adoption of FPV and the energy landscape as a whole.

With a mean score of 4.00, “Ensuring Economic Feasibility through Cost Reduction and Competitiveness” comes in ninth overall, emphasizing the crucialness of making FPV systems financially feasible by cutting costs and boosting competitiveness. Because cost-effective solutions increase the likelihood of design adoption and successful implementation, designers gave this CSF a high rating (4.33, rank 3). Additionally, investors gave this element a high rating (4.33, rank 3), highlighting the necessity of robust financial returns and the significance of reducing high upfront monetary spends in order to increase profitability. Contractors, however, gave this CSF a lower rating (3.76, rank 13), presumably due to their emphasis on short-term project management and on-site execution as opposed to long-term financial considerations. In a growing, high-inflation nation like Türkiye, where economic viability is essential for attracting investment and controlling financial risk, it was anticipated that this CSF would have received a higher overall ranking.

“Innovative Approaches to Enhance Material Properties” has a mean value of 3.98, placing it 10th overall, indicating its importance in enhancing the robustness and efficiency of FPV systems. The requirement to guarantee the long-term stability and safety of RE infrastructure, which is essential for achieving national energy goals, is probably what led the government to give this CSF a high rating (4.57, rank 3). Also, contractors gave this CSF a moderate rating (4.10, rank 7) because better material quality immediately affects ease of installation and lowers maintenance frequency, making their responsibilities easier while increasing project durability. On the other hand, consultants gave this CSF a lower rating (3.80, rank 12), which would indicate that they are more interested in system-level improvements than material advancements. To improve FPV system performance and guarantee long-term sustainability, new material qualities like increased flexibility or corrosion resistance must be developed. In order to lower the cost and prolong the operational life of FPV installations, material innovations are crucial.

With a mean score of 3.96, “Reducing Water Evaporation” comes in at number eleven overall, which is lower than anticipated considering how well discussed this topic is in the academic literature. Since protecting water resources is a vital part of sustainable energy projects, particularly in areas where water scarcity is a major problem, the government gave this CSF the highest rating (4.71, rank 1). The fact that designers gave this CSF a lower rating (3.83, position 14) suggests that they are more concerned with technical and structural optimization than with environmental advantages like water conservation. Additionally, investors gave it a rather low rating (3.33, rank 13), indicating that they might not believe that lowering water evaporation would directly affect the profits from their investments. In order to protect precious water resources and produce RE, it is imperative to reduce water evaporation, especially in dry locations. Despite its significance, the lower ranking implies that some stakeholders might not be able to instantly see the direct advantages.

With a mean score of 3.96, “Supporting Environmental Sustainability Objectives” is placed 11th overall, ranking in the same range as “Reducing Water Evaporation”. Investors gave this CSF the highest rating (4.33, rank 1), since they understand that concentrating on environmental sustainability can increase brand value, draw in funding, and obtain government incentives, all of which improve the financial return on investment. Due to their primary focus on the project’s direct execution, where sustainability approaches may be viewed as adding complexity or additional expenses without apparent advantages to construction efficiency, contractors gave this CSF a lower rating (3.86, position 12). Lastly, academia likewise gave this CSF a comparable rating (3.84, position 12), due to the fact that their research frequently focuses on certain technological or scientific issues, while environmental sustainability is viewed as an indirect effect rather than the main emphasis of their study. Its ranking is lower than anticipated, despite the fact that promoting environmental sustainability is crucial for raising public acceptability and coordinating with international climate measures. The practical challenges of directly connecting sustainability objectives with immediate operational advantages may be reflected in this.

With a mean score of 3.92, “Mitigating Negative Environmental Impacts” is placed 13th overall, demonstrating stakeholders’ differing opinions about how important it is to minimize environmental impact throughout FPV implementation. Contractors gave this CSF a comparatively higher rating (4.10, rank 7), acknowledging that reducing adverse environmental effects can facilitate project approvals and cut down on delays brought on by public or regulatory opposition. Investors gave it a lower rating (3.33, rank 13), perhaps because they thought there would be no immediate financial gains from activities aimed at reducing environmental effects. Additionally, consultants gave this CSF a lower rating (3.70, rank 14), which can be a reflection of their emphasis on efficiency and operational enhancements as opposed to environmental risk reduction. Despite receiving a lower ranking than anticipated, minimizing adverse environmental effects is still essential for long-term project viability and regulatory compliance. This helps achieve environmental goals and wider societal acceptance.

With a mean score of 3.92, "Achieving Energy Independence" is rated 13th overall, indicating the differing opinions of stakeholders regarding the significance of energy self-sufficiency. However, consultants ranked this CSF as the most critical one (4.50, rank 1). The reason why consultants gave this CSF the highest rating is probably because attaining energy independence is crucial for their advising duties and fits in nicely with strategy goals for long-term stability and resilience. Moreover, investors also gave this CSF a high rating (4.33, rank 1) because energy independence can increase control over energy prices, lower exposure to market volatility, and improve return predictability. Clients, on the other hand, gave this CSF a much lower rating (3.30, rank 15), presumably as a result of their immediate attention being drawn to the project's implementation costs and viability rather than the more comprehensive strategic objective of energy independence. Particularly in unstable geopolitical environments, achieving energy independence is essential to guaranteeing the stability and dependability of the energy supply.

With a mean score of 3.71, "Increased Usage of Remote Sensing Technologies" is placed 15th overall, indicating that its significance varies throughout stakeholders. Since using RS data is essential for efficient design, especially when determining appropriate sites and modifying designs based on environmental considerations, designers gave this CSF the highest rating (4.50, rank 1). A vital tool for guaranteeing the performance of FPV systems, RS enables designers to maximize site selection and enhance the precision of design parameters. Furthermore, academia gave this CSF a lower rating (3.68, rank 16) since they can be more concerned with doing fundamental research and less with the real-world use of RS technology in particular projects. Similarly, contractors rated this CSF low (3.41, rank 16), possibly indicating that they do not see direct operational benefits from the use of RS data, as their focus is more on project execution and on-ground construction tasks. RS technologies play a crucial role in enhancing FPV systems' efficiency, from site analysis to maintenance monitoring.

With a mean score of 3.69, "Stakeholder Collaboration and Engagement" is ranked 16th overall, indicating low levels of desire among stakeholders to actively engage in FPV initiatives. Designers gave this CSF a moderate rating (4.00, rank 9) because they understand how crucial it is to coordinate their design work with feedback from other stakeholders in order to guarantee project viability and successfully meet site-specific demands. This CSF received a lower rating from the government (3.57, rank 17), which might be a result of a tendency to concentrate on creating policy frameworks rather than actively participating in cooperative project execution processes. Lastly, this CSF received the lowest score from investors (3.00, rank 16), suggesting that they would rather play a more passive role unless there are financial concerns involved and that they are more concerned with generating financial rewards than encouraging collaborative engagement. The desire or reluctance of stakeholders to participate in FPV projects is also shown by these scores. However, meeting the various project needs and guaranteeing a successful conclusion need efficient cooperation and engagement from all parties. The research highlights the importance of this kind of cooperation in overcoming obstacles and improving FPV projects' long-term success.

With an average score of 3.37, "Social Acceptance" is by far the lowest of all the CSFs and is rated 17th overall. As demonstrated by its continuously low evaluations from the majority of stakeholder groups, including academia (3.52), clients (2.90), consultants (3.40), and designers (2.83), the survey's main conclusions include the undervaluation of social acceptance. In comparison to other CSFs, these results imply that social approval is mainly disregarded. The large difference between its score and the next lowest-rated CSF indicates that social acceptance is not getting enough attention, even if it may still have had the lowest ranking. However, societal acceptance received a better score from the government (3.86, position 13), probably acknowledging its significance in securing community support and guaranteeing regulatory compliance, both of which are essential for the effective implementation of RE projects. Social acceptance is essential for increasing public support, lowering resistance, and guaranteeing the successful deployment of FPV systems.

Factor analysis was conducted to reveal the underlying relationships among the CSFs, leading to the identification of three components: "Energy Optimization", "Community Engagement" and "Economic Sustainability". This categorization highlights how factors contribute to FPV implementation in distinct but interconnected ways, thus providing a comprehensive understanding of the key areas that need attention for the successful integration of FPV systems in Türkiye.

In conclusion, the results highlight the intricacy of FPV projects, necessitating a multidimensional strategy that strikes a balance between stakeholder, economic, and environmental concerns. Türkiye can maximize the potential of its FPV systems and support international RE targets by addressing three crucial success element groupings.

However, these results not only help guide the implementation of FPV in Türkiye, but they also offer a framework that may be modified for comparable projects in other nations, especially those with substantial water resources and expensive land.

7. SUMMARY AND CONCLUSIONS

This study focuses on identifying the most crucial CSFs necessary for the effective implementation of FPV systems, especially in Türkiye. The findings are based on responses gathered from various stakeholders, such as designers, investors, contractors, consultants, and government officials, through a structured questionnaire survey.

In the first step, a literature review is conducted. It starts with explaining the importance of energy generation. Then, it deep dives into the energy sector, mentioning NRE sources and their harmful effects on the environment. NRE resources are resources that cannot be regenerated throughout a person's lifetime. Those types of resources include coal, oil, nuclear, and natural gas. These resources are extracted and burned, which releases toxic chemicals into the air and water, increases greenhouse gas emissions, and accelerates climate change. After that, RE resources are mentioned. They are natural sources of energy that can be replenished naturally over time. These resources provide significant environmental benefits, including reducing greenhouse gas emissions, minimizing air pollution, and contributing to a more sustainable and resilient energy system. RE sources include, but are not limited to, wind, tidal, hydro, biomass, and solar power. For solar energy, it can be separated into two as LPV and FPV. Because LPV systems are placed on land surfaces and take up a lot of space, they may cause conflict between operations that also require land use, especially in places that are heavily populated or agriculturally significant. Conversely, FPV systems are installed on bodies of water, like lakes, oceans, or reservoirs, which helps preserve land resources and provides further advantages like lowering water evaporation and increasing panel efficiency because of the water's cooling effects. Although each method has its benefits, FPV offers a novel way to address the problems associated with land availability and seeks to boost energy production by efficiently utilizing water surfaces.

With a focus on wind, hydroelectric, and solar energy, Türkiye has been aggressively exploring RE sources to lessen its need for NRE resources. Currently, the most widely used RE source in the nation, hydropower contributes significantly to Türkiye's energy mix. The capacity of FPV systems to take advantage of existing water bodies, especially dams, to lower land use costs and increase energy efficiency has drawn attention recently. In order to improve the capacity of RE, notable projects are either finished or about to finish. Those projects include the FPV system on Keban Dam and the upcoming FPV installation on the Atatürk Dam. Given its high GHI levels, which guarantee optimal solar energy generation, and its high land costs in densely populated areas, which make FPV an appealing substitute compared to other RE sources.

In the 2nd step, after the literature review, CSFs are found by expert analysis and a survey of the literature, which includes books, theses, journal articles, conference proceedings, news, and web articles. A thorough list of 48 CSFs was first created, and then by grouping them based on their common traits and similarities, the list was reduced to 17 factors.

In the 3rd step, a questionnaire survey was created as the main means of gathering data for the following stage. The survey was divided into two primary sections: the first part gathered organizational and general demographic data, and the second part used a five-point Likert scale to assess each CSF's significance. Experts and professionals in the energy industry, including those in academia, solar panel manufacturers, and organizations involved in digital energy solutions and related research and development, were sent the survey via email and the LinkedIn network. Members of governmental and non-governmental organizations, such as DSİ, GEADER, TCA, GENSED, and GÜNAM, were also asked to fill the survey. There were 90 responses in total, with a respectable response rate.

In the fifth step, the gathered data was examined using a variety of statistical techniques in SPSS, such as factor analysis, mean ranking, t-test, ANOVA, and other descriptive statistics. Respondent groups were divided into 7 sections based on the type of organization that they are working for. Based on the opinions of the respondents, the analysis's most important crucial success elements were determined for total and for each type of organization. Then, using factor analysis, based on their common traits, the variables were then used to classify them into three primary groups using factor analysis: Economic Sustainability, Community Engagement, and Energy Optimization.

The study findings indicated that almost 60% of the respondents have been involved with FPV systems for less than a decade, suggesting the adoption of FPV systems into Türkiye's energy sector is expected to increase even further. FPV systems are primarily utilized by government bodies, large energy companies, and investors in both feasibility and implementation phases. This study aims to shape the perception of Turkish energy stakeholders towards FPV systems by encouraging innovation adoption. The results also highlight key benefits of FPV technology, such as increased energy yield and enhanced company reputation. This research provides Turkish energy companies with essential CSFs for successfully integrating FPV systems into their projects to maximize these benefits. Project managers can utilize these insights to prioritize important elements like stakeholder participation and structural design to ensure successful implementation, while policymakers can use them to streamline legislation and offer incentives.

According to the findings of the statistical analysis, the most important success factors for FPV systems in Türkiye are the following: site selection for optimizing energy potential (mean 4.40, rank 1), robust and resilient structural design (mean 4.30, rank 2), and accessibility and proximity of infrastructure (mean 4.24, rank 3). These elements are thought to be essential for FPV projects to be implemented successfully. However, societal acceptance (mean 3.37, rank 17) and stakeholder collaboration and engagement (mean 3.69, rank 16) are regarded as the least significant characteristics, underscoring the sector's existing disregard for public perception and community involvement.

Similar findings are observed in the literature regarding the evaluation of critical factors for FPV system implementation. The two recent studies reviewed in the study, "Site Selection of Floating Photovoltaic Systems on Hydropower Reservoirs" (Haspolat *et al.*, 2024) and “Fuzzy Einstein-based Decision-making Model for the Evaluation of Site Selection Criteria of Floating Photovoltaic Systems” (Melek *et al.*, 2024), also used a ranking approach for key criteria affecting FPV site selection. The study using a fuzzy sine trigonometric decision-making model found that factors such as proximity to the energy grid, high GHI, and accessibility to water bodies are critical in determining the feasibility of FPV sites. Similarly, the fuzzy Einstein-based decision-making model highlighted criteria like energy generation potential and environmental safety as top considerations. This study’s mean ranking of CSFs, such as site selection for maximizing energy potential, resilient structural design, and supportive government policies, aligns well with these key criteria identified in the literature, emphasizing that site selection and energy efficiency are universally recognized as crucial for FPV system success. A more comprehensive framework for FPV success is provided by this research, which offers a thorough examination of additional aspects, including stakeholder participation and structural resilience, whereas prior studies have mostly concentrated on site selection. Moreover, while the literature highlights environmental and grid proximity aspects, this study further explores factors like community engagement and structural resilience, providing a more comprehensive overview of FPV implementation in the context of Türkiye.

Based on the findings of the studies by Haspolat *et al.* (2024), this research on FPV systems reveals some similarities and differences in prioritizing site selection criteria. The studies conducted by Haspolat *et al.* (2024) used a multi-criteria decision-making model to evaluate suitable sites for FPV installations, focusing on criteria such as technical, economic, environmental, and social aspects. In particular, they highlighted the importance of factors like GHI and ecological impacts. Findings of this study similarly indicate that factors related to energy potential, resilience of the structural design, and government support are critical for successful FPV deployment. Both studies emphasize that site-specific characteristics, including GHI and proximity to infrastructure, are essential for maximizing energy output and ensuring feasibility. These similarities underscore the alignment between this research and the literature, particularly regarding the emphasis on optimizing site characteristics for effective FPV implementation. Moreover, while the literature highlights environmental and grid proximity aspects, this study further explores factors like community engagement and structural resilience, providing a more comprehensive overview of FPV implementation in the context of Türkiye.

According to the p-values over 0.05 in the one-way ANOVA results, there is no discernible difference in the opinions of academia, clients, consultants, designers, the government, investors, and contractors about the importance of the CSFs for FPV implementation. Finding a group of three underlying components using factor analysis was a crucial component of this investigation. The most important elements for the effective deployment of FPV systems were found to be "Energy Optimization" (mean 4.06) and "Economic Sustainability" (mean 4.04), with "Community Engagement" (mean 3.82) coming in third. This demonstrates that the effective implementation of FPV technology in the energy industry, as well as the optimization of energy output, are greatly influenced by economic stability and political backing. Additionally, the involvement of the community in site selection and project engagement plays an important role in ensuring successful implementation. Therefore, companies' willingness to support and adjust to RE technologies is crucial to the effective deployment of FPV systems in Türkiye's energy industry. Leaders and senior managers should not only focus on the operational aspects of the technology but also emphasize inspiring and empowering their people. This could be accomplished by encouraging an innovative culture among all employees. In addition to encouraging participation in training programs, conferences, seminars, and webinars that advance awareness of RE technologies, leaders should set clear goals that are in line with the usage of FPV systems. Team members will be able to comprehend and successfully deploy FPV systems thanks to these exercises, which will increase energy and cost efficiency. Comprehensive training programs for local engineers and technicians should be implemented in order to guarantee the successful deployment of FPV systems. In order to develop a competent staff that promotes long-term project sustainability, this training can concentrate on the particular difficulties associated with FPV installation and maintenance.

The effectiveness of FPV systems can be increased by focusing on three main CSFs. Firstly, supportive government policies and regulations play a crucial role. Streamlined project approvals and financial incentives can ease the adoption process, while compliance with environmental standards helps minimize ecological disruptions. Additionally, optimizing panel layout for yield enhancement ensures efficient energy generation, minimizing potential losses. The use of advanced materials to withstand environmental conditions further enhances durability and reduces maintenance. Lastly, collaboration with stakeholders, especially local communities, is essential for gaining support and mitigating conflicts during project implementation.

FPV planning that incorporates cost-benefit analysis can give stakeholders useful information for setting investment priorities. Finding high-return projects can be aided by examining elements such as initial installation costs, operating effectiveness, and long-term economic rewards. Furthermore, by including social and environmental costs in these studies, FPV systems will be guaranteed to be in line with sustainability and financial objectives. These assessments can help investors and policymakers make better decisions regarding the feasibility of projects.

The success of FPV systems also relies on enhancing the material properties to withstand the dynamic conditions of water bodies, thus ensuring consistent energy generation and longevity. Stakeholder collaboration fosters community acceptance, which is vital for the project's smooth development. Selecting appropriate sites with high GHI values optimizes energy production, allowing for better integration into existing energy systems. By ensuring these CSFs are well addressed, the overall success and sustainability of FPV projects can be significantly improved.

The three main factor groups, Energy Optimization, community engagement, and Economic Sustainability, can be instrumental in enhancing FPV success. Energy Optimization focuses on aspects such as material properties and panel optimization to improve energy yield and durability. Community Engagement emphasizes the importance of involving stakeholders to foster local acceptance, reducing potential resistance. Economic Sustainability encompasses regulatory and economic support that makes FPV projects feasible and aligned with national energy goals. Utilizing these groups holistically ensures that FPV projects are technologically sound, economically feasible, and socially accepted, leading to increased success in energy production.

7.1. Road Map for Future FPV Implementations

This study offers a road map for the effective deployment of FPV systems while taking stakeholder, financial, and environmental factors into account. This road map can be seen in Figure 7.1. The following sections provide detailed explanations for each phase in the road map. The road map is for every stakeholder, and roles of each stakeholder are assigned where necessary to ensure clarity and effective implementation throughout the process.

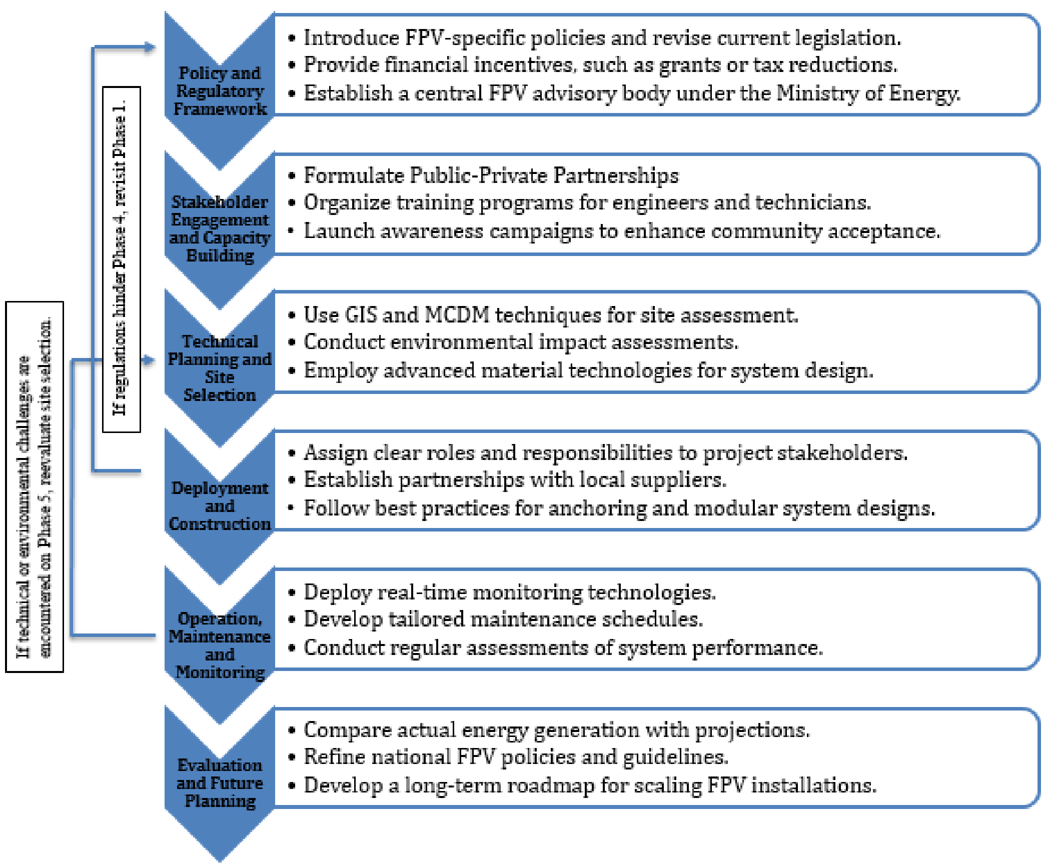

Figure 7.1. Road map for effective FPV deployment.

7.1.1. Phase 1: Policy and Regulatory Framework

A strong policy and regulatory framework are the cornerstones of an effective FPV deployment. It is essential to implement FPV-specific regulations that consider the needs of water-based facilities. Clear legal and procedural rules should be created to accelerate project approvals, and existing legislation must be updated to fit emerging technologies. Policymakers, such as the Ministry of Energy, should draft these FPV-specific regulations, while legislators ensure their alignment with Türkiye's broader renewable energy goals. To motivate private sector investment, financial incentives, including grants, tax breaks, and subsidized loans, should be made available. Government agencies like TÜBİTAK and DSİ should oversee these incentives, ensuring proper allocation to eligible projects.

In Türkiye, in order to make sure that FPV systems complement Türkiye's larger RE objectives, a cohesive national policy is required. The Ministry of Energy should create a special FPV advisory body to supervise the application of policies, facilitate stakeholder coordination, and resolve regulatory obstacles. This advisory body should consist of energy policymakers, industry experts, and academic representatives to ensure comprehensive input. Additionally, this organization would be essential in incorporating global best practices into regional frameworks. The advisory body should collaborate with international organizations to adapt best practices effectively.

Current laws in Türkiye restrict the use of FPV to dam reservoirs, which limits the technology's full potential. It is crucial to broaden the legal definition to cover additional bodies of water, such as lakes and reservoirs close to cities. The Ministry of Energy, in collaboration with DSİ, should lead these legislative updates. TÜBİTAK can assist by funding studies to assess the feasibility of non-dam FPV installations. Coherence with Türkiye's goals for RE will be ensured by coordinating these policies with the National Energy and Climate Plan.

7.1.2. Phase 2: Stakeholder Engagement and Capacity Building

For FPV projects to be successful, capacity building and stakeholder participation are essential. PPPs, or public-private partnerships, can be formed for cooperation, risk sharing, and resource pooling. Private sector entities and government bodies, such as municipalities, should form PPPs to share risks and resources effectively. Early stakeholder engagement facilitates target alignment, problem solving, and the development of a sense of shared ownership. Acceptance by the community is especially crucial; focused awareness campaigns should address common misconceptions and possible resistance while highlighting the economic and environmental advantages of FPV systems. Municipalities should lead these awareness campaigns, with support from local media and DSİ.

It is necessary to implement capacity-building initiatives for engineers, technicians, and legislators that are specific to FPV needs. In addition to operational elements like real-time monitoring, these programs must concentrate on technical elements like FPV system maintenance, mooring, and anchoring. Academic institutions should design and deliver these training programs in collaboration with industry stakeholders like equipment manufacturers. These programs should be up-to-date and useful through collaborations with academic institutions and business leaders. By providing experts with the necessary training, Türkiye can develop a workforce that can manage the difficulties presented by FPV systems.

It is essential that local stakeholders are involved in Türkiye in order to overcome opposition and promote cooperation. These initiatives can be led by municipalities in areas that have already shown interest in FPV projects, such as Ankara and Muğla. Municipalities should organize technical workshops, while DSİ provides logistical support and ensures coordination among stakeholders. Technical workshops and training sessions can be held at universities. Furthermore, local populations can be informed about FPV's potential to improve energy security while protecting land resources through public awareness initiatives run by DSİ and backed by TÜBİTAK.

7.1.3. Phase 3: Technical Planning and Site Selection

The foundation of an FPV project's success depends on technical planning and location selection. To assess possible locations, advanced tools such as GIS and MCDM methodologies must be used. DSİ, in collaboration with academic institutions, should take the lead in conducting GIS-based site assessments and MCDM studies. It is necessary to consider elements like GHI, water stability, grid closeness, and environmental impact. A ÇED report ought to be required in order to guarantee sustainability and lessen possible ecological disturbances. Environmental agencies and DSİ should oversee the preparation and approval of ÇED reports.

To improve system robustness, this phase also calls upon the application of cutting-edge material technologies. Selecting materials that can endure extreme weather conditions such as water corrosion, temperature swings, and high winds is essential. Material suppliers and research institutions should collaborate to identify and produce suitable materials. The longevity of FPV systems will be guaranteed by working with specialists in material research and utilizing new technologies. To handle site-specific difficulties, either comprehensive technical plans should be created, including designs for anchoring and mooring, or a site that does not possess those difficulties should be selected. FPV system designers and consultants should focus on creating site-specific technical plans to address these challenges.

Pilot FPV projects in Türkiye have highlighted the critical importance of careful site selection, particularly in the case of Büyükçekmece Dam, which overturned due to high wind loads. It is essential to carefully assess site-related difficulties while also extending FPV approaches to additional possible locations, like the Atatürk and Karakaya dams.

DSİ, in collaboration with academic and municipal stakeholders, should identify and evaluate these potential locations. To find new sites that are appropriate for FPV systems, DSİ should work with academic institutions and municipal governments. To maximize FPV's influence on the country's electricity system, GIS-based studies that have already been carried out in Türkiye could be extended to encompass smaller reservoirs and urban water bodies.

7.1.4. Phase 4: Implementation and Construction

Technical plans are converted into workable steps during the implementation phase. Delays are reduced and accountability is ensured when project stakeholders are given clear roles and duties. For a project to go smoothly, contractors, suppliers, and regulators must coordinate. Project managers should ensure clear communication and delineation of responsibilities among contractors, suppliers, and regulators to maintain a streamlined process. Utilizing prefabricated and modular building techniques can guarantee scalability, cut expenses, and expedite the process. Contractors and suppliers should adopt these techniques to enhance efficiency and reduce project timelines.

Partnerships with local suppliers should be promoted in order to boost the local economy and lessen the reliance on imported goods. Municipalities and project developers should prioritize working with regional producers to secure essential materials such as floats and anchors. Systems for anchoring and mooring should be built to withstand site-specific factors, including strong currents and varying water levels. Engineering firms and material suppliers should collaborate on the design and development of robust anchoring and mooring systems tailored to specific sites. During construction, routine progress monitoring guarantees that any new issues are dealt with right away. Construction teams, under the oversight of project managers, should implement regular progress reviews to identify and address emerging challenges.

The Regulatory Refinement Loop serves as a feedback mechanism to address unforeseen challenges that may arise during the implementation and construction phase. This loop directs stakeholders to review and modify the current policy framework in the event that legal or procedural challenges arise, such as delays brought on by unclear legislation or unforeseen environmental compliance difficulties. It guarantees that the regulations controlling FPV systems are adaptable and sensitive to actual situations. The FPV advisory body established in Phase 1 should oversee this refinement process, ensuring that input from contractors, developers, and regulators is incorporated to update policies. In addition to facilitating more efficient project execution, this loop fortifies the regulatory environment to support future FPV projects by permitting modifications based on real-world insights obtained during construction. This loop is especially important in Turkey because the laws that are in place are only applicable to dam reservoirs and could need to be expanded to cover a wider range of project circumstances.

For Türkiye, the DSİ is essential for enabling FPV building, especially at dam locations. DSİ should coordinate with local municipalities and project developers to identify feasible dam sites and streamline approval processes. Costs can be considerably decreased by working with regional producers to provide essential parts like floats and anchors. Local manufacturers should be engaged in the production of these components to reduce dependence on imports and strengthen the domestic supply chain. In areas with abundant water resources, such as Southeast Anatolia, municipalities might serve as intermediaries, guaranteeing that building complies with regional standards. Municipalities should collaborate with construction firms and DSİ to ensure compliance with regional and national standards during the building phase. Innovative construction methods that are adapted to the geographical and environmental requirements of Türkiye can receive financial support from TÜBİTAK. TÜBİTAK should provide grants and subsidies to encourage the adoption of these innovative methods, ensuring that construction techniques are aligned with Türkiye's environmental and energy goals.

7.1.5. Phase 5: Operation, Maintenance, and Monitoring

FPV systems' lifespans need to be continuously monitored to guarantee peak performance and handle any possible problems. Private operators and technology suppliers should implement real-time monitoring technology, such as sensors and software for tracking energy output. It is necessary to create customized maintenance plans that address site-specific issues such as biofouling, temperature fluctuations, and salt level of water. Maintenance teams, in collaboration with system designers, should develop these customized plans to address site-specific challenges effectively. Long-term dependability and efficiency will be guaranteed by routine system inspections. Private operators should schedule and conduct these inspections regularly, ensuring adherence to the defined maintenance protocols.

Proactive maintenance lowers long-term expenses and downtime. Maintenance crews should be trained in FPV-specific issues and equipped with cutting-edge tools to proactively address potential failures. System reliability can be further increased by working with technology suppliers to include predictive maintenance technologies. Technology suppliers, in coordination with maintenance crews, should integrate predictive analytics tools to detect and resolve issues before they impact system performance. Stakeholders who share performance data have more possibilities to exchange information and develop continuously. Private operators, municipalities, and research institutions should collaborate to establish platforms for sharing operational data and best practices.

The Site Optimization Loop is essential for resolving operational issues that emerge following the activation of an FPV system. This loop makes it easier to go back to technical planning and site selection if problems like decreased energy output, environmental stress, or structural breakdowns are discovered during the monitoring phase. The FPV advisory body, along with private operators and municipalities, should evaluate data from operational challenges and ensure modifications are made to technical planning and site selection methodologies as needed. Stakeholders can enhance system performance and reliability by reassessing elements such as anchoring systems, material durability, and site-specific environmental conditions. Research institutions and engineering firms should lead the analysis of these site-specific elements, ensuring that future installations benefit from the lessons learned during operations. This loop makes sure that lessons learned during operation are implemented to improve planning and design procedures for both present and future installations in Turkey, where environmental factors like strong winds and varying water levels differ between dam sites.

In Türkiye, FPV systems can be efficiently managed by utilizing local hydropower maintenance skills. Hydropower operators, trained in maintaining water-based systems, should extend their expertise to FPV installations to streamline operations. Private operators and municipalities should work together to create thorough maintenance procedures. Municipalities should provide logistical and administrative support, while private operators should oversee the execution of maintenance activities. Operational efficiency can be further improved by utilizing domestic monitoring technology, which is funded by TÜBİTAK. TÜBİTAK should provide financial support for the development and deployment of domestic monitoring systems, ensuring their integration into ongoing FPV operations. Future FPV installations across the nation can benefit from maintenance procedures that are guided by the lessons learned from current efforts on Keban Dam. Insights from Keban Dam's operations should be documented by the FPV advisory body and shared widely to inform the maintenance strategies for upcoming FPV projects.

7.1.6. Phase 6: Evaluation and Future Planning

To observe the success of FPV projects, evaluation is crucial. By comparing projected and actual energy generation, one can learn more about the system's performance and identify areas for development. Private operators, in collaboration with municipalities and research institutions, should collect and analyze energy generation data to identify performance gaps and opportunities for improvement.

Economic, environmental, and social effects should all be included in thorough assessments. Research institutions and universities should conduct these comprehensive assessments to ensure that all aspects of FPV system performance are considered. Policies and guidelines for upcoming projects might be improved with the help of the insights gathered during this phase. The Ministry of Energy should incorporate these insights into updated policies and guidelines to ensure alignment with FPV advancements.

Creating long-term plans for FPV system scaling is part of future planning. The Ministry of Energy, in coordination with DSİ and TÜBİTAK, should take the lead in formulating strategies for scaling up FPV systems across new waterbodies or dams. Sustainable growth depends on finding new waterbodies or dams, including FPV into national energy plans, and encouraging international cooperation. International collaboration can be facilitated by the FPV advisory body, which should engage with global experts, funding agencies, and technology developers to share best practices and secure resources. Creating a consolidated database of FPV performance indicators will help with ongoing development and well-informed decision-making. TÜBİTAK, along with The Southeastern Anatolia Project (GAP), should spearhead the development of this database and ensure its accessibility to key stakeholders.

The outcomes of FPV installations on Keban Dam and other comparable locations in Türkiye should influence changes to national policy. DSİ should compile detailed reports on Keban Dam and other pilot projects to inform policymakers about their findings. With an emphasis on dams in Southeast Anatolia, the Ministry of Energy and DSİ should prioritize this region for future FPV development due to its abundant water resources. TÜBİTAK and The Southeastern Anatolia Project (GAP), especially in Southeast Anatolia, can take the lead in establishing a consolidated information center that will encourage cooperation between government, business, and academics. This center should be managed collaboratively by GAP, TÜBİTAK, and local universities to ensure effective knowledge exchange. This strategy guarantees Türkiye's continued leadership in FPV innovation.

Türkiye can fully utilize FPV technology and support international RE targets by addressing the stated CSFs with the help of the road map explained above.

7.2. Recommendations for FPV Adaptation in Türkiye

The scope and advantages of FPV systems are currently limited in Türkiye because they are mostly installed on dam reservoirs. Extending FPV initiatives to maritime areas may offer significant additional benefits. Large-scale FPV installations are possible in coastal regions due to Türkiye's sea slope steeply deepening, making its coastal waters quickly descend into greater depths and allowing floating structures to be easily anchored to the seabed without venturing far from the shore. Additionally, the natural cooling influence of the water may increase the solar panel's efficiency, leading to higher energy output. In addition to utilizing underutilized marine space, coastal FPV projects offer a chance to supplement other coastal RE projects, like offshore wind, for hybrid energy production. Offshore wind farms and coastal FPV systems can be combined to provide hybrid RE projects that use the advantages of both technologies for increased energy production. This kind of integration offers resilience against changing energy demands in addition to optimizing the use of coastal spaces. To choose appropriate coastal areas for FPV, policymakers should take environmental and regulatory evaluations into account. This will allow Türkiye to diversify its RE infrastructure and lessen its reliance on a small number of dam surfaces.

Moreover, although Türkiye has previously begun combining FPV systems with its current HPPs, grid connectivity and space allocation are frequently issues for these combinations. The potential for FPV systems to produce energy is severely limited because they typically only take up a small percentage of dam surfaces, often less than 1%. The best utilization of the hybrid configuration is hindered by restrictions as well as communication problems between FPV and the current HPP grids. Government officials should encourage an integrated strategy that designs FPV and HPP systems together rather than treating FPV as an add-on to HPP systems in order to overcome these obstacles.

Future HPP projects must be built with specialized infrastructure that meets the unique requirements of FPV systems, guaranteeing effective energy transfer and resource sharing, such as grid links. This combination strategy will minimize grid connectivity problems, make the most of available dam surfaces, and open the door for more all-encompassing RE plans that optimize the potential of hybrid RE systems.

Furthermore, a number of parties, including local communities, private investors, and government agencies, must be involved for FPV systems to be implemented successfully in Türkiye. The low investments made for FPV projects relative to other forms of RE are a major obstacle, frequently brought on by uncertainty surrounding legislation and grid access. The government should provide financial tools, including tax exclusions, low-interest loans, and grants that lower investors' financial risk, in order to encourage public-private partnerships and promote the adoption of FPV. Additionally, encouraging private sector investments can be achieved by streamlining permit procedures and establishing clear criteria for environmental assessments. By taking these actions, government organizations and private investors will work together to reduce the financial risks connected to large-scale FPV installations. Stakeholder confidence will also rise with the establishment of a legal framework that guarantees FPV projects are incorporated into Türkiye's RE policy. Stakeholder partnerships, such as those between energy developers, environmental groups, and local water authorities, can improve system integration and site selection while fostering community acceptability. Through stakeholder incentives, FPV projects can receive adequate financial and infrastructural support, fostering adoption.

Lastly, site selection for FPV systems is the primary emphasis of R&D and academic study in Türkiye, which is insufficient for wider success. Improvements in FPV materials, anchoring systems, integration procedures, and grid connectivity should all be the focus of future research. The effectiveness of FPV systems could be completely transformed by emerging technologies like IoT-enabled monitoring systems and AI-driven predictive maintenance. In order to improve real-time performance tracking and save operating expenses, future research should concentrate on combining these technologies. It will be easier to overcome real-world obstacles and increase the effectiveness of FPV system adoption if R&D is expanded beyond site selection.

FPV implementation could be greatly improved by emerging technologies. For example, by examining huge datasets on social, economic, and environmental aspects, machine learning and AI can optimize site selection. Similar to this, developments in materials science can increase the longevity and efficiency of panels in watery settings. The expansion of FPV systems in Türkiye and abroad can be further supported by promoting R&D partnerships between academics and industry, which can hasten the acceptance of these breakthroughs.

7.3. Study Limitations and Recommendations for Future Research

There are a number of limitations to this study that should be discussed. Firstly, the sample was primarily composed of Turkish respondents, which severely restricts how broadly the results can be applied. Stakeholders in the energy sector in Türkiye may have different views and experiences from those in other nations, especially those with differing market conditions or regulatory frameworks. Future research should use a larger and more varied sample, with participants from various nations and regions, to improve the findings' global applicability and offer a more thorough understanding of the CSFs for FPV systems. The effect of climatic and geographic fluctuation on FPV system performance should also be investigated in future studies. For example, the effects of temperature variations, wind speeds, and sea salinity on panel longevity and efficiency may offer important information for improving FPV designs.

The factor analysis methodology employed in this investigation is another drawback. Smaller coefficients (less than 0.5) were suppressed during the factor analysis in order to remove multiple factor loadings and streamline the factor structure that resulted. Although this made the factor grouping easier to understand and analyze, it might have unintentionally left out significant correlations that would have shed more light on the connections between the CSFs. Suppressing coefficients may have diminished the analysis's depth and had an effect on the nuanced comprehension of the ways in which different components interact in the context of FPV implementation.

Additionally, because of their p-values above 0.05 and communalities falling below 0.5, two CSFs, "Increased Usage of Remote Sensing Technologies" and "Accessibility and Proximity of Infrastructure", were eliminated from the factor analysis. Although statistically warranted, their elimination might have compromised the analysis's thoroughness. Their omission may have resulted in an insufficient depiction of all pertinent aspects, and these CSFs may still be crucial to the overall success of FPV systems' implementation. In order to attain higher statistical reliability, future research should think about how to incorporate such variables by perhaps improving the survey design or growing the dataset.

The results of this study could be applied globally for future suggestions, accounting for national differences in economic, environmental, and regulatory circumstances. Furthermore, the creation of further CSFs and factor groups may offer even more thorough understandings of the application of FPV. A more detailed analysis of particular factors would be possible with such an approach, which could result in improved tactics for the effective adoption of FPV. The integration of FPV systems with other RE sources, including offshore wind and wave energy, may also be the subject of future research. Examining the viability and economics of such hybrid systems may open up possibilities for improved grid stability and energy output. Last but not least, modifying this framework to fit the needs of other nations and adding CSFs that are suited to their unique situations may improve the research's relevance and impact and make it a useful manual for international FPV deployment plans.

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APPENDIX A: ARTICLES CONSIDERED IN THIS STUDY

This section provides a comprehensive list of all articles reviewed and utilized as references to determine 17 CSFs.

Table A.1. Articles considered for 17 CSFs.

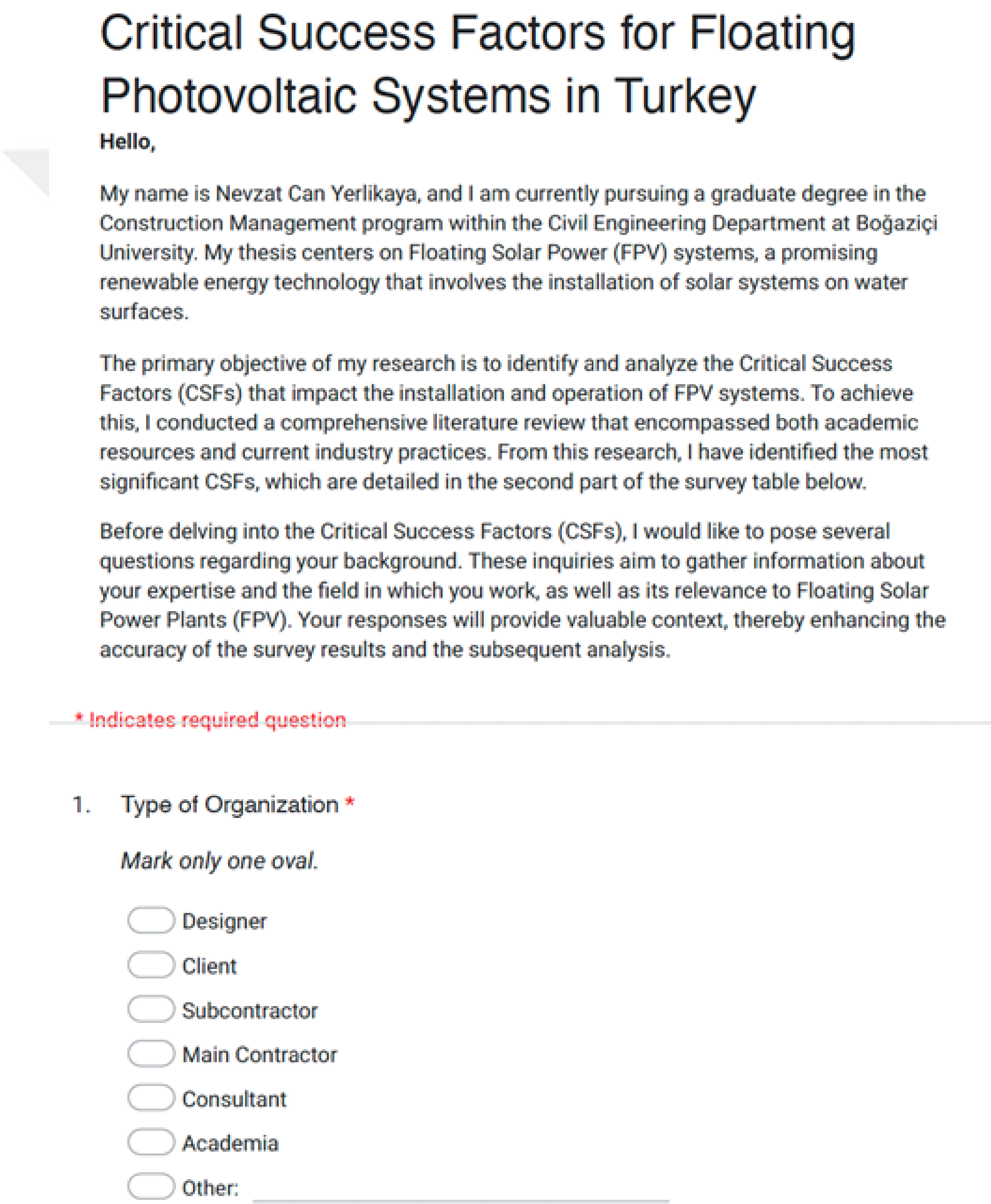
List of Literature Sources		
Number	**TR/Int**	**Reference**
1	Int	Al-Smairan *et al.* (2024)
2	TR	Ali *et al.* (2024)
3	TR	Ates *et al.* (2020)
4	TR	Ateş (2022)
5	TR	Aydin *et al.* (2013)
6	Int	Bajc and Kostadinović (2023)
7	Int	Ramanan *et al.* (2024)
8	TR	Caceoğlu *et al.* (2022)
9	TR	Durmaz and Üçgül (2023)
10	TR	Deveci *et al.* (2022)
11	Int	Djalab *et al.* (2024)
12	Int	Du *et al.* (2024)
13	Int	Elminshawy *et al.* (2024a)
14	Int	Elminshawy *et al.* (2024b)
15	Int	Frehner *et al.* (2024)
16	Int	Garrod *et al.* (2024)
17	TR	Gunes and Balog (2024)
18	TR	Haspolat *et al.* (2024)
19	Int	Irshad *et al.* (2024)
20	Int	Jung *et al.* (2024)

Table A.1 Articles considered for 17 CSFs. (cont.)

List of Literature Sources		
Number	**TR/Int**	**Reference**
21	TR	Karipoğlu *et al.* (2024)
22	Int	Kassem *et al.* (2021)
23	TR	Kaymak and Şahin (2021a)
24	TR	Kaymak and Şahin (2021b)
25	TR	Koca (2024)
26	Int	Koondhar *et al.* (2024)
27	TR	Korkmaz and Sahin (2023)
28	TR	Korkmaz *et al.* (2023)
29	TR	Kulat *et al.* (2023)
30	Int	Li *et al.* (2024)
31	TR	Melek *et al.* (2024)
32	Int	Nagababu *et al.* (2024)
33	Int	Nobre *et al.* (2024)
34	Int	Ranjbaran *et al.* (2019)
35	Int	Rosa-Clot (2020)
36	Int	Saeed *et al.* (2024)
37	Int	Shi *et al.* (2023)
38	TR	Temiz and Javani (2020)
39	TR	Yilmaz *et al.* (2023)
40	TR	Yılmaz *et al.* (2023)

APPENDIX B: GOOGLE SURVEY

This section includes the detailed structure and questions of the Google Survey used to collect data from participants regarding CSFs.



Critical Success Factors for Floating Photovoltaic Systems in Turkey

Hello,

My name is Nevzat Can Yerlikaya, and I am currently pursuing a graduate degree in the Construction Management program within the Civil Engineering Department at Boğaziçi University. My thesis centers on Floating Solar Power (FPV) systems, a promising renewable energy technology that involves the installation of solar systems on water surfaces.

The primary objective of my research is to identify and analyze the Critical Success Factors (CSFs) that impact the installation and operation of FPV systems. To achieve this, I conducted a comprehensive literature review that encompassed both academic resources and current industry practices. From this research, I have identified the most significant CSFs, which are detailed in the second part of the survey table below.

Before delving into the Critical Success Factors (CSFs), I would like to pose several questions regarding your background. These inquiries aim to gather information about your expertise and the field in which you work, as well as its relevance to Floating Solar Power Plants (FPV). Your responses will provide valuable context, thereby enhancing the accuracy of the survey results and the subsequent analysis.

* Indicates required question

1. Type of Organization *

Mark only one oval.

- Designer
- Client
- Subcontractor
- Main Contractor
- Consultant
- Academia
- Other: ____________

Figure B.1. Google survey-1.

2. Position in the Organization *

Mark only one oval.

- ◯ Executive/Director
- ◯ Manager/Supervisor
- ◯ Engineer/Technical Specialist
- ◯ Researcher/Analyst
- ◯ Consultant/Advisor
- ◯ Professor
- ◯ Other: ____________________

3. Experience in the Industry *

Mark only one oval.

- ◯ 0 - 5 years
- ◯ 5 - 10 years
- ◯ 10 - 15 years
- ◯ 15 - 20 years
- ◯ +20 years

4. Previously worked or currently working in the renewable energy sector? *

Mark only one oval.

- ◯ Yes
- ◯ No

Part 2: Critical Success Factors for FPV Systems

Before proceeding with the second part of this survey, an extensive literature review was conducted to identify the Critical Success Factors (CSFs) for Floating Photovoltaic (FPV) systems. The findings from this review are summarized in the table below, which lists the key CSFs along with their references from various studies in the literature. These factors have been highlighted as essential for the successful implementation and operation of FPV systems.

Figure B.2. Google survey-2.

Table 1: Critical Success Factors

Variable	Definition	Sources
Accessibility and Proximity of Infrastructure	Ensuring that necessary infrastructure, such as power supply lines and gridlines, is readily available and close to FPV sites.	(Ali et al., 2024)(Ates et al., 2020)(Ateş, 2022)(Caceoğlu et al., 2022)(Garrod et al., 2024)(Haspolat et al., 2024)(Karipoğlu et al., 2024)(Kaymak & Şahin, 2021)(Korkmaz et al., 2023)(Kulat et al., 2023)(Melek et al., 2024)(Ranjbaran et al., 2019)(Rosa-Clot, 2020)
Achieving Energy Independence	Developing FPV systems that contribute to self-sufficiency in energy production, reducing reliance on external sources.	(Garrod et al., 2024)(Irshad et al., 2024)(Kulat et al., 2023)(Temiz & Javani, 2020)
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	Implementing strategies to lower expenses and enhance market position, ultimately validating the financial viability of a project or business initiative.	(Al-Smairan et al., 2024)(Ateş, 2022)(Aydin et al., 2013)(Bajc & Kostadinović, 2023)(Djalab et al., 2024)(Du et al., 2024)(Elminshawy et al., 2024)(Gunes & Balog, 2024)(Irshad et al., 2024)(Jung et al., 2024)(Kassem et al., 2021)(Kaymak & Şahin, 2021)(Kaymak & Şahin, 2021)(Koca, 2024)(Koondhar et al., 2024)(Korkmaz & Sahin, 2023)(Melek et al., 2024)(Ranjbaran et al., 2019)(Saeed et al., 2024)(Temiz & Javani, 2020)(Yılmaz et al., 2023)
Ensuring Energy Safety	Strategies and systems in place to maintain uninterrupted energy generation from FPV systems.	(Djalab et al., 2024)(Haspolat et al., 2024)(Kaymak & Şahin, 2021)(Koondhar et al., 2024)(Melek et al., 2024)(Nagababu et al., 2024)(Ranjbaran et al., 2019)(Yılmaz et al., 2023)
Increased Usage of Remote Sensing Technologies	Application of tools such as GIS and spatial data analysis to collect, process, and interpret information about the Earth's surface	(Al-Smairan et al., 2024)(Ali et al., 2024)(Ates et al., 2020)(Ateş, 2022)(Aydin et al., 2013)(Deveci et al., 2022)(Djalab et al., 2024)(Elminshawy et al., 2024)(Karipoğlu et al., 2024)(Korkmaz & Sahin, 2023)(Yılmaz et al., 2023)(Yılmaz et al., 2023)
Increasing Interest for Renewable Energy	Growing market need for sustainable energy solutions, especially for hybrid systems, drives the adoption of FPV.	(Ateş, 2022)(Cesur Durmaz & Üçgül, 2023)(Frehner et al., 2024)(Frehner et al., 2024)(Garrod et al., 2024)(Irshad et al., 2024)(Koca, 2024)
Innovative Approaches to Enhance Material Properties	Improved quality and longevity of materials to ensure consistent performance of FPV systems over time.	(Cesur Durmaz & Üçgül, 2023)(Frehner et al., 2024)(Kaymak & Şahin, 2021)(Kaymak & Şahin, 2021)(Li et al., 2024)(Koondhar et al., 2024)(Korkmaz et al., 2023)(Li et al., 2024)(Ranjbaran et al., 2019)(Rosa-Clot, 2020)(Saeed et al., 2024)(Shi et al., 2023)
Mitigating Negative Environmental Impacts	Actions taken to lessen adverse effects on ecosystems and communities from FPV installations.	(Ates et al., 2020)(Caceoğlu et al., 2022)(Cesur Durmaz & Üçgül, 2023)(Elminshawy et al., 2024)(Elminshawy et al., 2024)(Haspolat et al., 2024)(Karipoğlu et al., 2024)(Kassem et al., 2021)(Koondhar et al., 2024)(Kulat et al., 2023)(Melek et al., 2024)(Nobre et al., 2024)(Ranjbaran et al., 2019)(Shi et al., 2023)(Yılmaz et al., 2023)
Panel optimization for Yield Enhancement	Refinement of design features to improve the energy output and overall performance of FPV systems.	(C.J. et al., 2024)(Elminshawy et al., 2024)(Gunes & Balog, 2024)(Jung et al., 2024)(Kassem et al., 2021)(Koca, 2024)(Kulat et al., 2023)
Reducing Water Evaporation	Implementing strategies to minimize water loss from reservoirs, enhancing water conservation.	(Ates et al., 2020)(Ateş, 2022)(C.J. et al., 2024)(Du et al., 2024)(Elminshawy et al., 2024)(Garrod et al., 2024)(Irshad et al., 2024)(Jung et al., 2024)(Kaymak & Şahin, 2021)(Koca, 2024)(Koondhar et al., 2024)(Kulat et al., 2023)(Ranjbaran et al., 2019)(Rosa-Clot, 2020)(Temiz & Javani, 2020)
Resilient Structural Design and Robustness for Successful FPV Systems	Strong and adaptable designs that ensure FPV systems can withstand environmental challenges.	(Kaymak & Şahin, 2021)(Kaymak & Şahin, 2021)(Korkmaz et al., 2023)(Shi et al., 2023)
Site Selection for Maximizing Energy Potential	Identifying optimal locations for FPV systems to harness the maximum available energy resources	(Al-Smairan et al., 2024)(Ates et al., 2020)(Cesur Durmaz & Üçgül, 2023)(Du et al., 2024)(Elminshawy et al., 2024)(Frehner et al., 2024)(Haspolat et al., 2024)(Karipoğlu et al., 2024)(Kassem et al., 2021)(Koca, 2024)(Koondhar et al., 2024)(Ranjbaran et al., 2019)(Yılmaz et al., 2023)(Yılmaz et al., 2023)
Social Acceptance	The degree to which local communities support FPV projects that aligns with local values and needs.	(Ali et al., 2024)(Djalab et al., 2024)(Du et al., 2024)(Haspolat et al., 2024)(Karipoğlu et al., 2024)(Kaymak & Şahin, 2021)(Korkmaz et al., 2023)(Melek et al., 2024)(Nagababu et al., 2024)(Nobre et al., 2024)
Stakeholder Collaboration and Engagement	Involving various parties, including government, industry, and communities, in the planning and implementation of FPV projects.	(Bajc & Kostadinović, 2023)(Deveci et al., 2022)(Djalab et al., 2024)(Frehner et al., 2024)(Irshad et al., 2024)(Karipoğlu et al., 2024)
Succesfull Site Selection to Withstand Location-Based Extremes	Identifying sites that can effectively resist extreme environmental conditions or do not have those extremes.	(Ali et al., 2024)(Aydin et al., 2013)(Bajc & Kostadinović, 2023)(C.J. et al., 2024)(Caceoğlu et al., 2022)(Deveci et al., 2022)(Djalab et al., 2024)(Elminshawy et al., 2024)(Haspolat et al., 2024)(Korkmaz & Sahin, 2023)(Korkmaz et al., 2023)(Nobre et al., 2024)(Saeed et al., 2024)(Yılmaz et al., 2023)(Yılmaz et al., 2023)(Yılmaz et al., 2023)(Yılmaz et al., 2023)(Saeed et al., 2024)(Korkmaz et al., 2023)(Korkmaz & Sahin, 2023)(Korkmaz & Sahin, 2023)
Supporting Environmental Sustainability Objectives	Aligning FPV systems with goals that promote ecological balance and resource conservation.	(Al-Smairan et al., 2024)(Ateş, 2022)(Aydin et al., 2013)(Bajc & Kostadinović, 2023)(Cesur Durmaz & Üçgül, 2023)(Djalab et al., 2024)(Frehner et al., 2024)(Garrod et al., 2024)(Gunes & Balog, 2024)(Koondhar et al., 2024)(Korkmaz & Sahin, 2023)(Li et al., 2024)(Li et al., 2024)(Nagababu et al., 2024)(Rosa-Clot, 2020)(Saeed et al., 2024)(Temiz & Javani, 2020)(Temiz & Javani, 2020)
Supportive Government Policies and Regulations	Favorable laws and guidelines that facilitate the development and implementation of FPV systems.	(Ali et al., 2024)(Ateş, 2022)(Bajc & Kostadinović, 2023)(Cesur Durmaz & Üçgül, 2023)(Frehner et al., 2024)(Jung et al., 2024)(Kaymak & Şahin, 2021)(Kulat et al., 2023)(Melek et al., 2024)(Nobre et al., 2024)(Ranjbaran et al., 2019)(Temiz & Javani, 2020)

Importance Rating for CSFs

In this part of the survey, you are asked to evaluate the importance of each CSF by assigning a rating on a 1 to 5 scale. This method is based on a Likert scale, a widely used approach in surveys to gauge the level of agreement or importance on a particular subject.

Your ratings will provide valuable insights into which CSFs are perceived as most crucial by industry professionals and will contribute to the analysis of FPV success factors. Thank you for your thoughtful responses.

Scale: 1- not significant; 2- fairly significant; 3- significant; 4- very significant; 5- extremely

Figure B.3. Google survey-3.

5. *

Accessibility and Proximity of Infrastructure

Ensuring that necessary infrastructure, such as power supply lines and gridlines, is readily available and close to FPV sites.

1	2	3	4	5
☆	☆	☆	☆	☆

6. *

Achieving Energy Independence

Developing FPV systems that contribute to self-sufficiency in energy production, reducing reliance on external sources.

1	2	3	4	5
☆	☆	☆	☆	☆

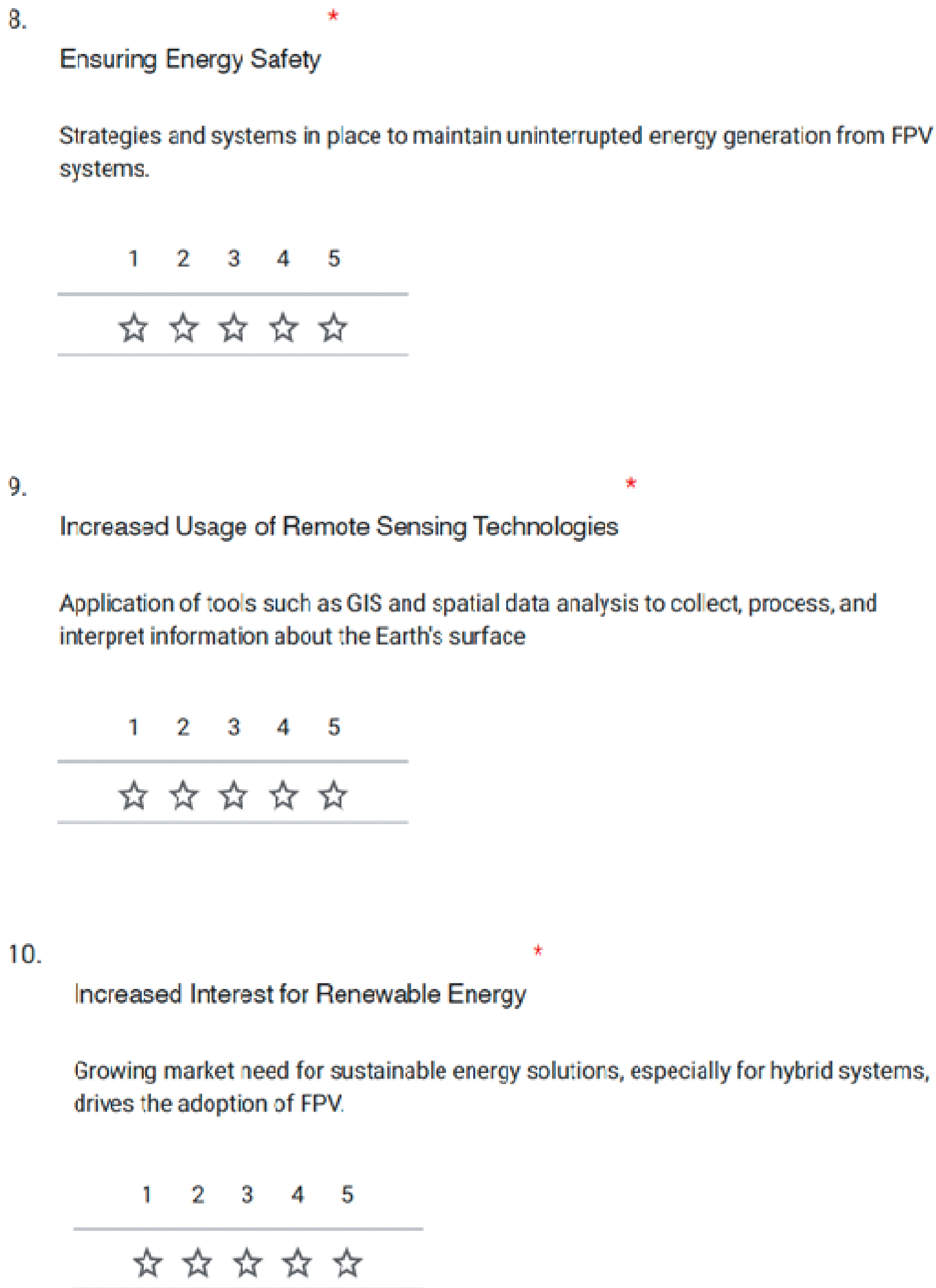
7. *

Ensuring Economic Feasibility through Cost Reduction and Competitiveness

Implementing strategies to lower expenses and enhance market position, ultimately validating the financial viability of a project or business initiative.

1	2	3	4	5
☆	☆	☆	☆	☆

Figure B.4. Google survey-4.



8. *

Ensuring Energy Safety

Strategies and systems in place to maintain uninterrupted energy generation from FPV systems.

1 2 3 4 5

☆ ☆ ☆ ☆ ☆

9. *

Increased Usage of Remote Sensing Technologies

Application of tools such as GIS and spatial data analysis to collect, process, and interpret information about the Earth's surface

1 2 3 4 5

☆ ☆ ☆ ☆ ☆

10. *

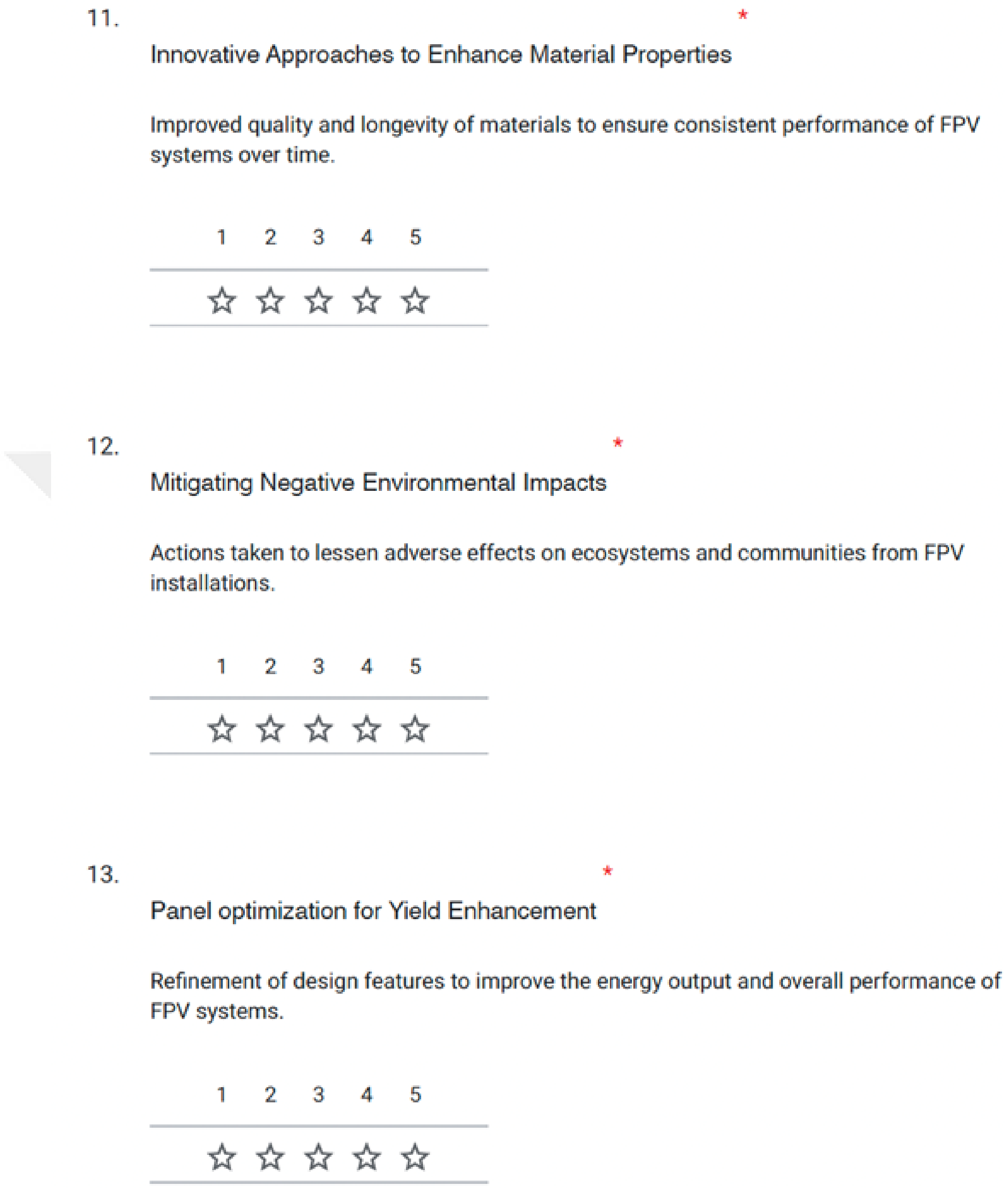
Increased Interest for Renewable Energy

Growing market need for sustainable energy solutions, especially for hybrid systems, drives the adoption of FPV.

1 2 3 4 5

☆ ☆ ☆ ☆ ☆

Figure B.5. Google survey-5.



11. *

Innovative Approaches to Enhance Material Properties

Improved quality and longevity of materials to ensure consistent performance of FPV systems over time.

1	2	3	4	5
☆	☆	☆	☆	☆

12. *

Mitigating Negative Environmental Impacts

Actions taken to lessen adverse effects on ecosystems and communities from FPV installations.

1	2	3	4	5
☆	☆	☆	☆	☆

13. *

Panel optimization for Yield Enhancement

Refinement of design features to improve the energy output and overall performance of FPV systems.

1	2	3	4	5
☆	☆	☆	☆	☆

Figure B.6. Google survey-6.

14. *

Reducing Water Evaporation

Implementing strategies to minimize water loss from reservoirs, enhancing water conservation.

1	2	3	4	5
☆	☆	☆	☆	☆

15. *

Resilient Structural Design and Robustness for Successful FPV Systems

Strong and adaptable designs that ensure FPV systems can withstand environmental challenges.

1	2	3	4	5
☆	☆	☆	☆	☆

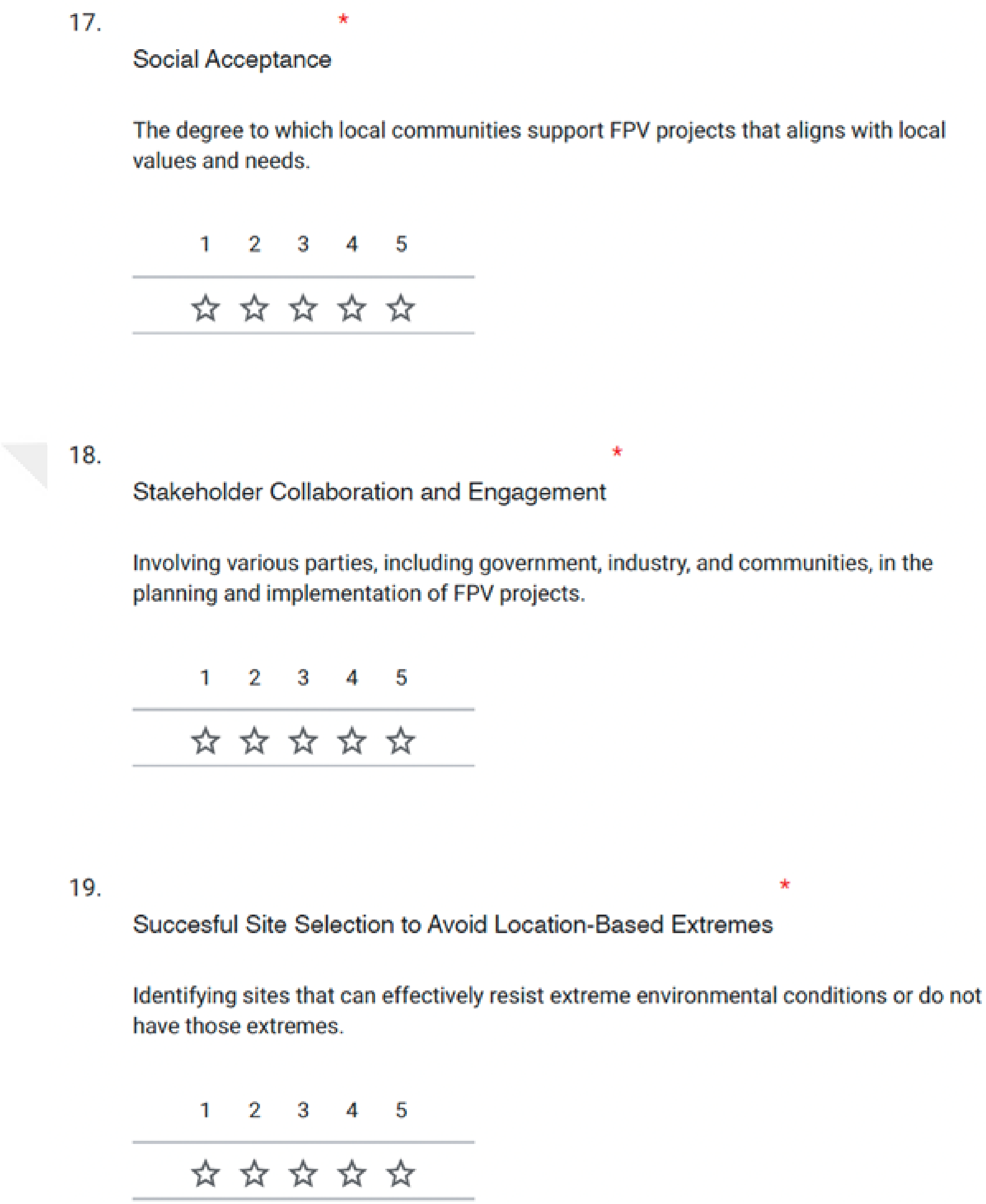
16. *

Site Selection for Maximizing Energy Potential

Identifying optimal locations for FPV systems to harness the maximum available energy resources

1	2	3	4	5
☆	☆	☆	☆	☆

Figure B.7. Google survey-7.



17. *

Social Acceptance

The degree to which local communities support FPV projects that aligns with local values and needs.

1 2 3 4 5

18. *

Stakeholder Collaboration and Engagement

Involving various parties, including government, industry, and communities, in the planning and implementation of FPV projects.

1 2 3 4 5

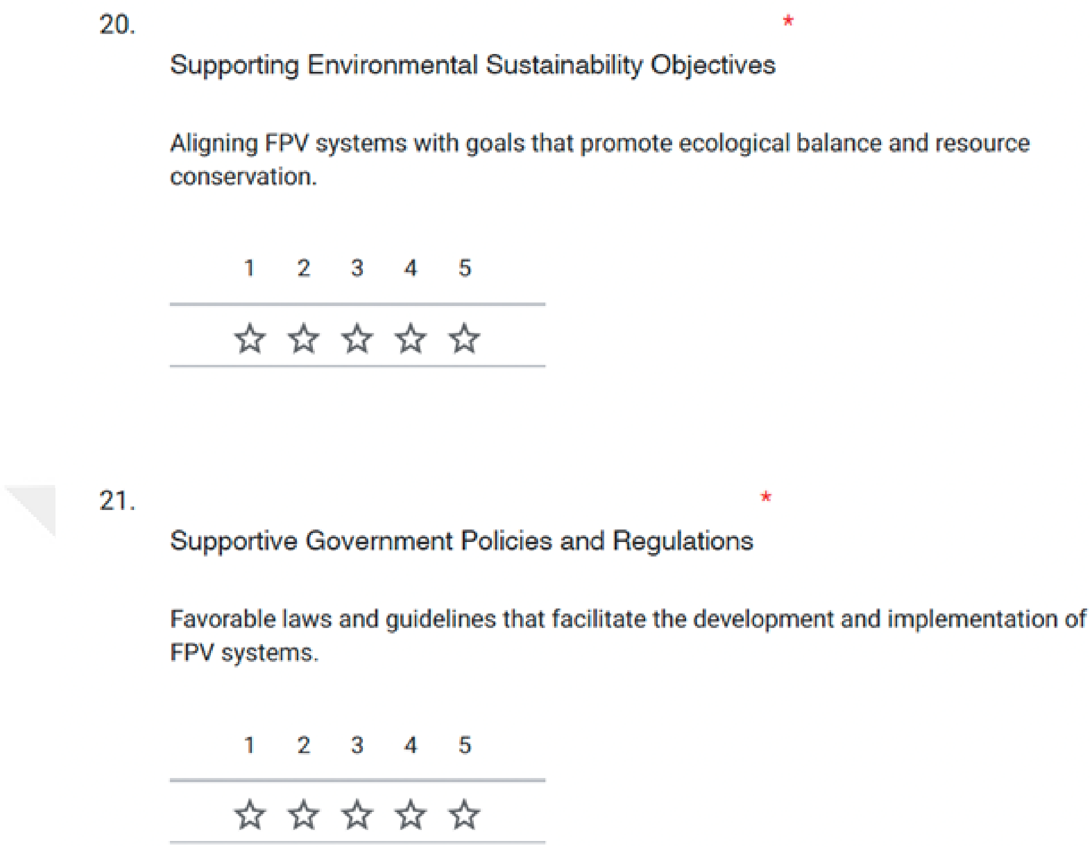
19. *

Succesful Site Selection to Avoid Location-Based Extremes

Identifying sites that can effectively resist extreme environmental conditions or do not have those extremes.

1 2 3 4 5

Figure B.8. Google survey-8.



20. *

Supporting Environmental Sustainability Objectives

Aligning FPV systems with goals that promote ecological balance and resource conservation.

1	2	3	4	5
☆	☆	☆	☆	☆

21. *

Supportive Government Policies and Regulations

Favorable laws and guidelines that facilitate the development and implementation of FPV systems.

1	2	3	4	5
☆	☆	☆	☆	☆

Figure B.9. Google survey-9.

APPENDIX C: QUANTITATIVE RESULTS

This section presents the results of T-tests conducted to evaluate differences in participant opinions regarding the identified CSFs. Additionally, it includes the correlation matrix, which highlights the relationships and interdependencies between various CSFs as identified through the statistical analysis.

Table C.1. T-test: Energy sector vs. non-energy sector.

CSF	Levene's Test for Equality of Variances			df
	F	Sig.	t	
Accessibility and Proximity of Infrastructure	1.52	0.22	(0.56)	0.09
	-	(0.66)	30.68	0.26
Achieving Energy Independence	0.01	0.94	(0.81)	0.09
	-	(0.81)	23.93	0.21
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.79	0.38	(0.27)	0.09
	-	(0.29)	26.80	0.39
Ensuring Energy Safety	2.21	0.14	(0.70)	0.09
	-	(0.85)	32.23	0.20
Increased Usage of Remote Sensing Technologies	2.99	0.09	1.16	0.09
	-	1.00	20.91	0.16
Increased Interest for Renewable Energy	0.10	0.76	(0.11)	0.09
	-	(0.12)	25.39	0.45
Innovative Approaches to Enhance Material Properties	0.09	0.76	0.42	0.09
	-	0.46	26.82	0.33

Table C.1 T-test: Energy sector vs. non-energy sector. (cont.)

CSF	Levene's Test for Equality of Variances			df
	F	Sig.	t	
Mitigating Negative Environmental Impacts	0.11	0.74	(0.08)	0.09
	-	(0.08)	22.53	0.47
Panel optimization for Yield Enhancement	0.16	0.70	(0.26)	0.09
	-	(0.26)	24.56	0.40
Reducing Water Evaporation	0.01	0.91	1.37	0.09
	-	1.41	24.80	0.09
Resilient Structural Design and Robustness for Successful FPV Systems	0.23	0.63	0.31	0.09
	-	0.31	23.53	0.38
Site Selection for Maximizing Energy Potential	2.77	0.10	1.054.	0.09
	-	(1.29)	32.04	0.10
Social Acceptance	2.46	0.12	0.05	0.09
	-	0.05	21.45	0.48
Stakeholder Collaboration and Engagement	0.49	0.49	(0.07)	0.09
	-	(0.08)	27.22	0.47
Successful Site Selection to Avoid Location-Based Extremes	0.10	0.75	(0.55)	0.09
	-	(0.52)	22.89	0.30
Supporting Environmental Sustainability Objectives	0.98	0.33	0.31	0.09
	-	0.27	21.43	0.39
Supportive Government Policies and Regulations	0.83	0.36	(0.20)	0.09
	-	(0.23)	28.44	0.41

Table C.1 T-test: Energy sector vs. non-energy sector. (cont.)

CSF	t-test for Equality of Means			
	Significance		Mean Difference	Std. Error Difference
	One-Sided p	Two-Sided p		
Accessibility and Proximity of Infrastructure	0.29	0.58	(0.13)	0.24
	0.51	(0.13)	0.20	(0.55)
Achieving Energy Independence	0.21	0.42	(0.24)	0.30
	0.43	(0.24)	0.30	(0.86)
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.40	0.79	(0.07)	0.27
	0.77	(0.07)	0.25	(0.59)
Ensuring Energy Safety	0.24	0.49	(0.18)	0.25
	0.40	(0.18)	0.21	(0.59)
Increased Usage of Remote Sensing Technologies	0.12	0.25	0.37	0.32
	0.33	0.37	0.37	(0.40)
Increased Interest for Renewable Energy	0.46	0.91	(0.03)	0.28
	0.91	(0.03)	0.26	(0.58)
Innovative Approaches to Enhance Material Properties	0.34	0.68	0.12	0.28
	0.65	0.12	0.26	(0.41)
Mitigating Negative Environmental Impacts	0.47	0.94	(0.02)	0.29
	0.94	(0.02)	0.30	(0.65)
Panel optimization for Yield Enhancement	0.40	0.80	(0.07)	0.26
	0.80	(0.07)	0.26	(0.60)
Reducing Water Evaporation	0.09	0.18	0.38	0.28
	0.17	0.38	0.27	(0.18)
Resilient Structural Design and Robustness for Successful FPV Systems	0.38	0.76	0.08	0.26
	0.76	0.08	0.26	(0.46)

Table C.1 T-test: Energy sector vs. non-energy sector. (cont.)

CSF	t-test for Equality of Means			
	Significance		Mean Difference	Std. Error Difference
	One-Sided p	Two-Sided p		
Site Selection for Maximizing Energy Potential	0.15	0.30	(0.23)	0.22
	0.21	(0.23)	0.18	(0.60)
Social Acceptance	0.48	0.96	0.02	0.32
	0.96	0.02	0.36	(0.73)
Stakeholder Collaboration and Engagement	0.47	0.95	(0.02)	0.30
	0.94	(0.02)	0.27	(0.58)
Successful Site Selection to Avoid Location-Based Extremes	0.29	0.59	(0.15)	0.27
	0.61	(0.15)	0.29	(0.74)
Supporting Environmental Sustainability Objectives	0.38	0.76	0.09	0.30
	0.79	0.09	0.33	(0.60)
Supportive Government Policies and Regulations	0.42	0.84	(0.06)	0.29
	0.82	(0.06)	0.26	(0.58)
CSF	95% Confidence Interval of the Difference			
	Lower	Upper		
Accessibility and Proximity of Infrastructure	(0.61)	0.35		
	0.28	-		
Achieving Energy Independence	(0.83)	0.35		
	0.38	-		
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	(0.61)	0.47		
	0.44	-		

Table C.1 T-test: Energy sector vs. non-energy sector. (cont.)

CSF	95% Confidence Interval of the Difference			
	Lower	Upper		
	(0.67)	0.32		
Ensuring Energy Safety	0.24	-		
Increased Usage of Remote	(0.26)	1.00		
Sensing Technologies	1.13	-		
Increased Interest for Renewable	(0.58)	0.52		
Energy	0.51	-		
Innovative Approaches to Enhance Material	(0.44)	0.68		
Properties	0.65	-		
Mitigating Negative Environmental	(0.59)	0.54		
Impacts	0.60	-		
Panel optimization for	(0.59)	0.46		
Yield Enhancement	0.46	-		
Reducing Water	(0.17)	0.93		
Evaporation	0.94	-		
Resilient Structural Design and Robustness for Successful FPV	(0.43)	0.59		
Systems	0.62	-		
Site Selection for Maximizing	(0.67)	0.21		
Energy Potential	0.14	-		
	(0.62)	0.65		
Social Acceptance	0.76	-		
Stakeholder Collaboration	(0.62)	0.58		
and Engagement	0.54	-		
Successful Site Selection to Avoid Location-Based	(0.69)	0.39		
Extremes	0.44	-		

Table C.1 T-test: Energy sector vs. non-energy sector. (cont.)

CSF	95% Confidence Interval of the Difference			
	Lower	Upper		
Supporting Environmental Sustainability Objectives	(0.50)	0.68		
	0.78	-		
Supportive Government Policies and Regulations	(0.63)	0.52		
	0.46	-		

Table C.2. T-test: Turkish vs. international respondents.

CSF	Levene's Test for Equality of Variances		t	df
	F	Sig.		
Accessibility and Proximity of Infrastructure	0.98	0.33	(1.92)	88.00
Achieving Energy Independence	0.59	0.45	(0.14)	88.00
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.18	0.68	0.78	88.00
Ensuring Energy Safety	2.43	0.12	0.06	88.00

Table C.2 T-test: Turkish vs. international respondents. (cont.)

CSF	Levene's Test for Equality of Variances		t	df
	F	Sig.		
Increased Usage of Remote Sensing Technologies	1.06	0.31	(1.76)	88.00
Increased Interest for Renewable Energy	0.32	0.57	(1.45)	88.00
Innovative Approaches to Enhance Material Properties	0.27	0.61	(1.17)	88.00
Mitigating Negative Environmental Impacts	-	1.00	(1.41)	88.00
Panel optimization for Yield Enhancement	0.41	0.52	(0.05)	88.00
Reducing Water Evaporation	0.04	0.85	(0.81)	88.00
Resilient Structural Design and Robustness for Successful FPV Systems	0.80	0.37	0.45	88.00

Table C.2 T-test: Turkish vs. international respondents. (cont.)

CSF	Levene's Test for Equality of Variances		t	df
	F	Sig.		
Site Selection for Maximizing Energy Potential	0.02	0.88	0.256.	88.00
Social Acceptance	2.30	0.13	(0.13)	88.00
Stakeholder Collaboration and Engagement	0.22	0.64	0.14	88.00
Succesful Site Selection to Avoid Location-Based Extremes	0.32	0.57	(0.26)	88.00
Supporting Environmental Sustainability Objectives	0.34	0.56	(0.77)	88.00
Supportive Government Policies and Regulations	0.33	0.57	(0.10)	88.00
CSF	t-test for Equality of Means			
	Significance	Mean Difference	Std. Error Difference	
Accessibility and Proximity of Infrastructure	0.06	(0.44)	0.23	

Table C.2 T-test: Turkish vs. international respondents. (cont.)

CSF	t-test for Equality of Means			
	Significance	Mean Difference	Std. Error Difference	
Achieving Energy Independence	0.89	(0.04)	0.29	
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.44	0.21	0.27	
Ensuring Energy Safety	0.96	0.01	0.25	
Increased Usage of Remote Sensing Technologies	0.08	(0.54)	0.31	
Increased Interest for Renewable Energy	0.15	(0.39)	0.27	
Innovative Approaches to Enhance Material Properties	0.25	(0.32)	0.27	
Mitigating Negative Environmental Impacts	0.16	(0.39)	0.28	
Panel optimization for Yield Enhancement	0.96	(0.01)	0.26	

Table C.2 T-test: Turkish vs. international respondents. (cont.)

CSF	t-test for Equality of Means			
	Significance	Mean Difference	Std. Error Difference	
Reducing Water Evaporation	0.42	(0.22)	0.27	
Resilient Structural Design and Robustness for Successful FPV Systems	0.66	0.11	0.25	
Site Selection for Maximizing Energy Potential	0.80	0.06	0.22	
Social Acceptance	0.89	(0.04)	0.31	
Stakeholder Collaboration and Engagement	0.89	0.04	0.30	
Succesful Site Selection to Avoid Location-Based Extremes	0.80	(0.07)	0.27	
Supporting Environmental Sustainability Objectives	0.44	(0.22)	0.29	

Table C.2 T-test: Turkish vs. international respondents. (cont.)

CSF	t-test for Equality of Means			
	Significance	Mean Difference	Std. Error Difference	
Supportive Government Policies and Regulations	0.92	(0.03)	0.28	
CSF	95% Confidence Interval of the Difference			
	Lower	Upper		
Accessibility and Proximity of Infrastructure	(0.90)	0.02		
Achieving Energy Independence	(0.62)	0.54		
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	(0.32)	0.74		
Ensuring Energy Safety	(0.48)	0.50		
Increased Usage of Remote Sensing Technologies	(1.15)	0.07		
Increased Interest for Renewable Energy	(0.92)	0.14		

Table C.2 T-test: Turkish vs. international respondents. (cont.)

CSF	95% Confidence Interval of the Difference			
	Lower	Upper		
Innovative Approaches to Enhance Material Properties	(0.86)	0.22		
Mitigating Negative Environmental Impacts	(0.94)	0.16		
Panel optimization for Yield Enhancement	(0.52)	0.50		
Reducing Water Evaporation	(0.77)	0.32		
Resilient Structural Design and Robustness for Successful FPV Systems	(0.38)	0.61		
Site Selection for Maximizing Energy Potential	(0.38)	0.49		
Social Acceptance	(0.66)	0.58		
Stakeholder Collaboration and Engagement	(0.55)	0.63		

Table C.2 T-test: Turkish vs. international respondents. (cont.)

CSF	95% Confidence Interval of the Difference			
	Lower	Upper		
Succesful Site Selection to Avoid Location-Based Extremes	(0.60)	0.46		
Supporting Environmental Sustainability Objectives	(0.80)	0.35		
Supportive Government Policies and Regulations	(0.59)	0.54		

Table C.3. Correlation Matrix.

Correlation Matrix	Achieving Energy Independence	Ensuring Economic Feasibility through Cost Reduction and Competitiveness	Ensuring Energy Safety	Increased Interest for Renewable Energy	Innovative Approaches to Enhance Material Properties
Achieving Energy Independence	1.000	0.375	0.454	0.192	0.391
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.375	1.000	0.348	0.252	0.161

Table C.3 Correlation Matrix. (cont.)

Correlation Matrix	Achieving Energy Independence	Ensuring Economic Feasibility through Cost Reduction and Competitiveness	Ensuring Energy Safety	Increased Interest for Renewable Energy	Innovative Approaches to Enhance Material Properties
Ensuring Energy Safety	0.454	0.348	1.000	0.264	0.528
Increased Interest for Renewable Energy	0.192	0.252	0.264	1.000	0.499
Innovative Approaches to Enhance Material Properties	0.391	0.161	0.528	0.499	1.000
Mitigating Negative Environmental Impacts	0.237	0.202	0.224	0.368	0.420
Panel optimization for Yield Enhancement	0.313	0.323	0.220	0.200	0.349
Reducing Water Evaporation	0.193	-0.022	0.313	0.298	0.479
Resilient Structural Design and Robustness for Successful FPV Systems	0.325	0.249	0.453	0.270	0.559

Table C.3 Correlation Matrix. (cont.)

Correlation Matrix	Achieving Energy Independence	Ensuring Economic Feasibility through Cost Reduction and Competitiveness	Ensuring Energy Safety	Increased Interest for Renewable Energy	Innovative Approaches to Enhance Material Properties
Site Selection for Maximizing Energy Potential	0.246	0.150	0.552	0.091	0.434
Social Acceptance	0.187	0.095	0.298	0.149	0.301
Stakeholder Collaboration and Engagement	0.208	0.250	0.410	0.157	0.313
Successful Site Selection to Avoid Location-Based Extremes	0.357	0.210	0.406	0.216	0.580
Supporting Environmental Sustainability Objectives	0.277	0.236	0.364	0.496	0.475
Supportive Government Policies and Regulations	0.127	0.272	0.287	0.406	0.490

Table C.3 Correlation Matrix. (cont.)

Correlation Matrix	Mitigating Negative Environmental Impacts	Panel Optimization for Yield Enhancement	Reducing Water Evaporation	Resilient Structural Design and Robustness for Successful FPV Systems	Site Selection for Maximizing Energy Potential
Achieving Energy Independence	0.237	0.313	0.193	0.325	0.246
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.202	0.323	-0.022	0.249	0.150
Ensuring Energy Safety	0.224	0.220	0.313	0.453	0.552
Increased Interest for Renewable Energy	0.368	0.200	0.298	0.270	0.091
Innovative Approaches to Enhance Material Properties	0.420	0.349	0.479	0.559	0.434
Mitigating Negative Environmental Impacts	1.000	0.439	0.429	0.568	0.520
Panel optimization for Yield Enhancement	0.439	1.000	0.463	0.513	0.405

Table C.3 Correlation Matrix. (cont.)

Correlation Matrix	Mitigating Negative Environmental Impacts	Panel Optimization for Yield Enhancement	Reducing Water Evaporation	Resilient Structural Design and Robustness for Successful FPV Systems	Site Selection for Maximizing Energy Potential
Reducing Water Evaporation	0.429	0.463	1.000	0.462	0.326
Resilient Structural Design and Robustness for Successful FPV Systems	0.568	0.513	0.462	1.000	0.557
Site Selection for Maximizing Energy Potential	0.520	0.405	0.326	0.557	1.000
Social Acceptance	0.387	0.236	0.474	0.346	0.442
Stakeholder Collaboration and Engagement	0.323	0.098	0.259	0.399	0.383
Successful Site Selection to Avoid Location-Based Extremes	0.512	0.510	0.378	0.573	0.585

Table C.3 Correlation Matrix. (cont.)

Correlation Matrix	Mitigating Negative Environmental Impacts	Panel Optimization for Yield Enhancement	Reducing Water Evaporation	Resilient Structural Design and Robustness for Successful FPV Systems	Site Selection for Maximizing Energy Potential
Supporting Environmental Sustainability Objectives	0.595	0.505	0.525	0.517	0.574
Supportive Government Policies and Regulations	0.483	0.508	0.382	0.590	0.478
Correlation Matrix	Social Acceptance	Stakeholder Collaboration and Engagement	Successful Site Selection to Avoid Location-Based Extremes	Supporting Environmental Sustainability Objectives	Supportive Government Policies and Regulations
Achieving Energy Independence	0.187	0.208	0.357	0.277	0.127
Ensuring Economic Feasibility through Cost Reduction and Competitiveness	0.095	0.250	0.210	0.236	0.272
Ensuring Energy Safety	0.298	0.410	0.406	0.364	0.287

Table C.3 Correlation Matrix. (cont.)

Correlation Matrix	Social Acceptance	Stakeholder Collaboration and Engagement	Successful Site Selection to Avoid Location-Based Extremes	Supporting Environmental Sustainability Objectives	Supportive Government Policies and Regulations
Increased Interest for Renewable Energy	0.149	0.157	0.216	0.496	0.406
Innovative Approaches to Enhance Material Properties	0.301	0.313	0.580	0.475	0.490
Mitigating Negative Environmental Impacts	0.387	0.323	0.512	0.595	0.483
Panel optimization for Yield Enhancement	0.236	0.098	0.510	0.505	0.508
Reducing Water Evaporation	0.474	0.259	0.378	0.525	0.382
Resilient Structural Design and Robustness for Successful FPV Systems	0.346	0.399	0.573	0.517	0.590

Table C.3 Correlation Matrix. (cont.)

Correlation Matrix	Social Acceptance	Stakeholder Collaboration and Engagement	Successful Site Selection to Avoid Location-Based Extremes	Supporting Environmental Sustainability Objectives	Supportive Government Policies and Regulations
Site Selection for Maximizing Energy Potential	0.442	0.383	0.585	0.574	0.478
Social Acceptance	1.000	0.635	0.276	0.539	0.382
Stakeholder Collaboration and Engagement	0.635	1.000	0.294	0.385	0.266
Successful Site Selection to Avoid Location-Based Extremes	0.276	0.294	1.000	0.523	0.458
Supporting Environmental Sustainability Objectives	0.539	0.385	0.523	1.000	0.537
Supportive Government Policies and Regulations	0.382	0.266	0.458	0.537	1.000

Table C.4. Sampling adequacy and sphericity tests.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.828
Bartlett's Test of Sphericity	Approx. Chi-Square	646.574
	df	105
	Sig.	<0.001