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Opportunities and Barriers to the Application of Solar Heat For Industrial Processes Technologies to Turkish Industrial Parks: The Case of Kayseri Industrial Park[1]

Türkiye'deki Organize Sanayi Bölgelerinde Termal Güneş Enerjisi Uygulamalarına Yönelik Olanaklar ve Engeller: Kayseri Organize Sanayi Bölgesi Örneği

Sevgi Deniz Akdemir[2], Yelda Erden Topal[3]

ABSTRACT

Turkiye's industrial parks (IP) represent more than one-third of the country's exports and employ 2.1 million people, almost one-third of the country's total industrial employment. As an effective means of implementing macro policies, IPs are essential for inclusive and sustainable industrialisation by improving efficiency and lowering costs. Given Turkiye's vulnerability to climate change and natural disasters, investments in renewable energy (RE) are poised on the national climate change agenda for a steady and reliable energy supply. As an upper-middle-income country, Turkiye has a good start transitioning to RE mainly. Although one of the top 5 countries with total solar capacity, solar heat for industrial processes (SHIP) is one of the not-fully discovered areas for energy generation. With this background, this study examines drivers and barriers to adopting SHIP technologies. The method uses the lessons from prosumer experience in developing and applying SHIP technologies. For this purpose, the field research was conducted in two phases, and the two different data sets were collected by the methods of 'Semi-structured in-depth interviews with prosumers' and 'Survey on solar energy usage with members of IP'. The current barriers and drivers in decision-making for investment and installation of photovoltaics implications and their maintenance were identified. Then, a survey built on the lessons learned from the analysis of the interviews was made to determine why there is no improvement in the deployment of SHIP implications. Finally, essential barriers and sub-barriers are listed under the headings of 'legal, regulatory, procedural, economic, financial, Social, and technical'. The results of the data analysis show that 'insufficient government support, lack of financial support, inadequate capacity and expertise with modern technologies, and inefficient infrastructure' are identified as significant barriers to the diffusion of SHIP technologies in the IP context in Turkiye.

Key Words: Renewable Energy, Solar, Opportunities, Obstacles, Turkiye, Industrial Parks

ÖZ:

Türkiye'nin endüstriyel parkları (IP), ülke ihracatının üçte birinden fazlasını temsil etmekte ve toplam endüstriyel işgücünün neredeyse üçte birini (2,1 milyon kişi) istihdam etmektedir. Makro politika uygulamalarının etkili bir yolu olan IP politikası, verimliliği artırarak ve maliyetleri düşürerek kapsayıcı ve sürdürülebilir sanayileşme için temel bir araç olarak kabul edilmektedir. Türkiye'nin iklim değişikliğine ve doğal afetlere karşı savunmasızlığı göz önüne alındığında, istikrarlı ve güvenilir enerji arzı için yenilenebilir enerji yatırımlarının gerekliliği ulusal iklim değişikliği gündeminde yer almaktadır. Üst-orta gelir grubunda bir ülke olarak Türkiye, ağırlıklı olarak yenilenebilir enerjiye (YE) geçişte iyi bir başlangıç yapmıştır. Ülke, toplam güneş enerjisi kapasitesi ile dünyadaki ilk 5 ülkeden biri olmasına rağmen, endüstriyel süreçler için güneş

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ısısı (SHIP) 'enerji üretimi için tam olarak keşfedilmemiş alanlar'dan biridir. Buradan hareketle bu çalışma, SHIP teknolojilerinin benimsenmesinin önündeki engelleri ve destekleri incelemektedir. Amacımız, üreten-tüketici deneyimlerinden öğrenilen dersleri SHIP teknolojilerinin geliştirilmesi ve uygulanmasında kullanmaktır. Bu amaçla saha araştırması iki aşamalı bir yöntemle gerçekleştirilmiş ve 'Üreten-tüketici (prosumer) ile yarı yapılandırılmış derinlemesine görüşmeler' ve 'IP Üyeleri ile güneş enerjisi kullanımı anketi' yöntemleri kullanılarak iki farklı veri seti toplanmıştır. Fotovoltaik uygulamalarına yatırım ve kurulum için karar verme ve bakım ve sürdürülebilirlik süreçlerindeki mevcut engeller ve itici güçler belirlenmiştir. Ardından, SHIP Teknolojilerinin konuşlandırılmasında neden bir gelişme olmadığını belirlemek için görüşmelerin analizinden çıkarılan dersler üzerine inşa edilen bir anket yapılmıştır. Son olarak, temel engeller, 'yasal, düzenleyici, usule ilişkin, ekonomik, mali, sosyo-kültürel ve teknik' başlıklar altında listelenmiş ve sınıflandırılmıştır. Veri analizi sonuçları, 'yetersiz devlet desteği, mali destek eksikliği, modern teknolojilerle ilgili yetersiz kapasite ve uzmanlık ve verimsiz altyapı'nın Türkiye'de IP bağlamında SHIP teknolojilerinin yaygınlaşmasının önündeki önemli engeller olarak tanımlandığını göstermektedir.

Anahtar Kelimeler: Yenilenebilir Enerji, Güneş, Fırsatlar, Engeller, Türkiye, Endüstri Parkları

INTRODUCTION:

An industrial park (IP) is a region that includes the constituents to provide appropriate infrastructure and utility services for manufacturers, producers, and innovators, supporting industrial development. Industrial park structure is an agglomeration tool to enhance the business and manufacturing environment in a specialised production area. Being an effective macro policy for industrial development, IP policy is important for promoting industrial development by protecting unique creations and facilitating knowledge sharing. It encourages investment in research and development, innovation, and growth for small and medium-sized enterprises. IP policy is considered an effective macro policy for inclusive and sustainable industrialisation.

Due to Turkiye's strategic geographic position bridging production and consumption regions in its commercial hinterland, initiatives have been launched to establish the country as an energy hub. However, Turkiye is dependent on imported energy sources. Turkiye's 346 IPs are located across 81 cities, employing 2.1 million people, and makeup over a third of the country's exports and industrial employment. Investing in alternative energy is crucial for Turkey's climate resilience. IPs are vital to driving sustainable industrial development with a green and secure energy supply since these areas consume vast amounts of energy, including electricity and heat used in industrial processes.

Turkey has been transitioning to renewable energy (RE) since the 2000s. The priority now is to invest in RE technologies for sustainable and green energy. At the beginning of the RE sectoral development, incentives are the main motivations for investors in RE sources, and as technology development, production and implementation costs are becoming more advantageous day by day, and this enables the RE sector to develop faster and more continuously.

Due to the fact that Turkiye's solar radiation measures and geographical location in top 5 of the very best in the world, the solar-driven supply of heat needed in industrial production processes (so-called solar heat for industrial processes (SHIP) is an area of untapped potential for energy production in the industry (IEA, 2020). The development observed in increasing solar energy implementations called the 'solar energy revolution' has been mainly concentrated around photovoltaic systems (PV) integrations. On the other hand, there is no specific incentive mechanism for solar thermal (ST) energy systems in industry, and the government has no particular interest or incentive for the use of ST systems except for households living in rural areas. Additionally, no special license or permit is required for ST energy used for domestic water heating.

In 2015, Turkiye released an Energy Efficiency Strategy Paper, setting specific objectives for renewable energy-based energy generation. By 2023, the aim is to elevate the proportion of renewables in overall energy production to 30%. The surge in solar photovoltaic (PV) systems in Turkiye is evidence that innovations have motivated the adoption of these technologies and increased investments. However, our field research shows that Turkiye needs more market for SHIP applications, and this technology

faces multiple challenges. To support this claim derived from the field research, first of all, we need to see the overall picture of the energy sector in Turkiye. For this purpose, total energy consumption at the sectoral level is plotted between 1990 and 2019 in Turkiye Figure 1 to compare energy consumption figures in different sectors.

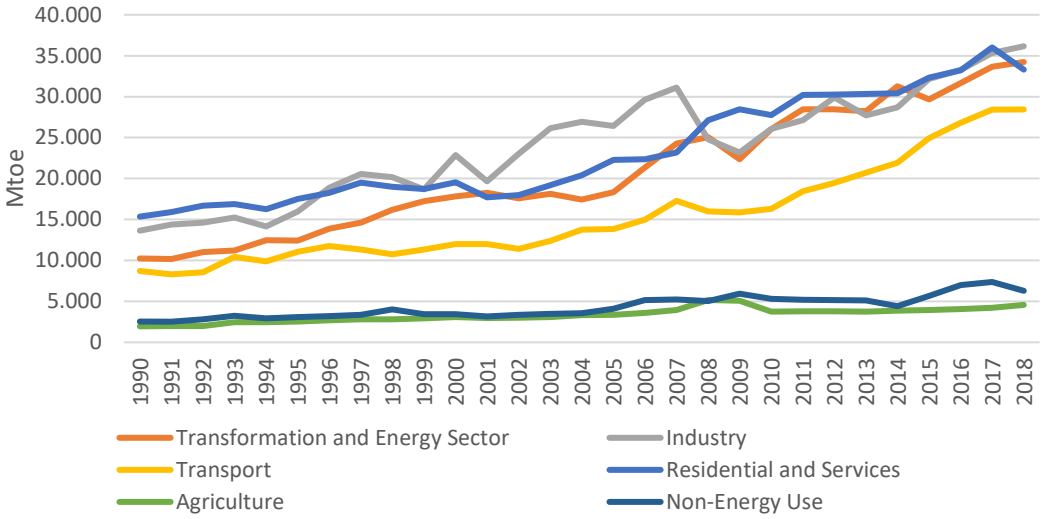

Figure 1. Sectoral Energy Figure in Turkiye (ETKB, 2018)

"Non-energy use" refers predominantly to petrochemical feedstock, and "Transformation and Energy Sector" includes energy sources consumption for the purpose of the energy generation (in other words, this is the energy conversion sector).In 2018, total energy consumption is mostly dominated by the total of energy conversation, needs in industrial production and residential use. According to the most recent official data published by the Ministy (ETKB), National Energy Equilibrium Table (kTEP)[4] in 2021, total energy consumption is 123,144k TEP (ETKB, 2022). According to the sectoral energy consumption distribution, industry consumes most of the energy (41,614k TEP), transport consumes the second highest (30,562k TEP), and residential use consumes the third highest (26,148k TEP) and these three main sectors consume approximately 80% of the total energy consumption in Turkiye (ETKB, 2022). Moreover, according to Turkiye's National Energy Plan 2022 (ETKB 2022.p.20), "the share of the industrial sector, which has the highest share in final energy consumption with 34.4% in 2020, rises to 38.7% by 2035, and the 40.1% share of the housing and services sector in the total decreases to 34.9% by 2035". Due to the role of industrial energy consumption in Turkiye's overall energy consumption, new actions are proposed to be taken[5]. For this purpose, we aim to identify supporting and blocking factors for solar heat applications and derive lessons learnt from PV applications to propose policy recommendations, regulations, and incentive perspectives for facilitating the successful commercialisation of RE technologies such as SHIP in industrial parks. In Turkiye, a country with vast solar energy potential and numerous industrial clusters, the adoption of industrial prosumers could serve as a viable solution for establishing low-carbon regions.

1. Methods and Materials:

This research unveils the results of a methodical evaluation of the barriers hindering the adoption of solar systems (PV and SHIP) in an IP and to identify opportunities (drivers) to overcome these barriers. For this purpose two field research practices were performed in the geographical region of Kayseri IP.

[4] https://enerji.gov.tr/eigm-raporlari -National Energy Equilibrium Tables (Ulusal Enerji Denge Tabloları)
[5] Türkiye_National_Energy_Plan.pdf (enerji.gov.tr)

Kayseri IP is specifically chosen after a comparison between the different provinces as it stands out as one of Turkiye's cities with abundant solar potential, boasting an average of 7.8 hours of daily insolation." There are 298 IPs in Turkiye, and Kayseri IP is in top ten IPs with its economic and industrial activities.

Kayseri IP is one of the most productive industrial zones in Turkiye. Moreover, as a primary reference point, when the field research was conducted, Kayseri IP had the highest Solar (PV) Power Plant Capacity in Turkiye and among Turkish IPs (Kayseri Investment Support Office, 2018) as seen in Figure 2 with an example of installed PV Power Plant in Kayseri IP. According to Kayseri Investment Support Office (2018), in 2018 (when we collected data), 12 different private companies had solar rooftop power plant applications, which means there were 12 different prosumers in the IP (Kayseri OIZ, 2020). The primary aim of our field research is to gather data PV systems industry and summarize the key insights/lessons learnt gained from the implementation of solar energy in the first stage. In simpler terms, we aim to pinpoint the factors that motivate the adoption of PV systems and identify the obstacles hindering the decision-making process in RE. Then in the second stage, we used the survey to learn the general approach of the companies to solar heat for industrial processes implications.

Figure 2. Kayseri Industrial Park ((Kayseri Industrial Park)

We used qualitative data collection and analysis methodology in our research and summarized and visualized the details of data collection process in Figure 3. We used two data collection methods in the field research of this paper: At first stage, Face to Face (Personal) Interview and at second stage (Online) Survey towards Solar Energy Usage" and we investigate the technical, social, regulatory and environmental aspects of RE implementations in Kayseri IP, and hence derived the analysis categories given in Section 4: Data Analysis. In face-to-face interviews, we asked open-ended questions. In the survey, we asked multiple-choice questions to the participants. The participants of the interviews and survey were *company owners* who installed PV power plants and/ or who had the potential to install SHIP applications on their own company areas (mainly rooftops), *electrical engineers* working in Kayseri IP companies and had the knowledge and experience on RE generation and *R&D Experts* of companies settled in Kayseri IP.

The first data source was the interviews. For this group, we had 12 potential participants since there were 12 private companies that had solar rooftop power plant applications (prosumers). We could

reach 6 out of these prosumers and had in-depth interviews with them at the first stage of data collection (face-to face interviews) between 10.12.2017 and 14.01.2018. As the authors of this paper, we made the interviews, by recording upon permission; then made transcription and the analysis of the collected data. The interview guide has 20 questions in total about the profile of the interview participant, his/her institution, current solar system, incentives and barriers, supporting and blocking mechanisms.

The second data source is the survey conducted on the sample of companies in Kayseri IP to find out the factors affecting SHIP applications. The survey was distributed to the companies that had the potential for SHIP implications since we benefitted from purposeful sampling to find out the information-rich cases (Patton, 2014). Industries such as food and beverage, textiles, paper, metal treatment, and machinery are the key application areas for ST systems (ETSAP & IRENA, 2015), and these sectors were given priority in the sampling. According to Kayseri IP website, there are 1,118 firms (the population for the survey). %7 of these firms belongs to food, 10% to textile, %4 to machinery and 2% to paper, and the remaining to other sectors[6] . These sectors are the most appropriate sectors for SHIP. Hence, first we first reach out to food companies, then textile, and machine segments, and the IP Directorate. That means, we reached out to approximately 300 companies first, then distributed the survey to the other sectors too. The number of return was 69, including one from the Directorate of the IP. The first part of the survey is the introduction. Same as the interview, the survey questions are categorised into four parts of (1) *Background information* of the Interviewee (II) The *Potential of SHIP* (III) Mindset of Companies on *RE* (IV) *RE* in Kayseri IP. The responses were then analysed to determine the percentage of respondents who agreed or supported a particular viewpoint.

Figure 3. Summary of the data collection process in field research.

2. Data Analysis: Main Barriers Derived from Interviews and Survey

2.1. Interview Results:

Interviews were made with current prosumers in Kayseri IP to determine the prosumers' motivations for using PV systems for energy needs and the experiences of these early adopters on solar energy. There were 12 prosumers in Kayseri IP and we talked to 6 of them. The companies are in the sectors of Steel wire and cable, construction materials

[6] Since we collected the data during the time period of 2018-2019; these numbers are numbers in this specific period. For the most recent data please check Kayseri IP website (https://www.kayseriosb.org/kayseri-osb-firmalar)

manufacturer, food, textile, metal production and mining. All of the interviewees are high level managers (4 CEOs, 1 CFO and 1 energy manager) as seen in Figure 4.

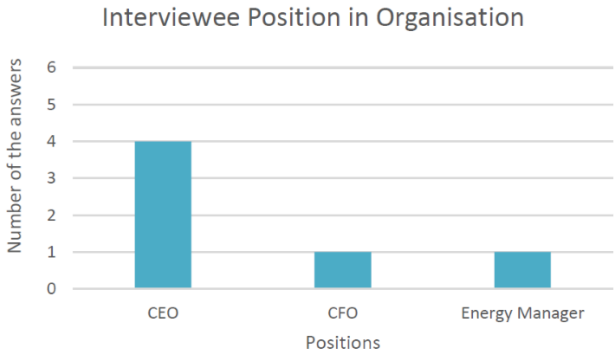

Figure 4. Inverviewee's position in the company

About the investment decision on solar systems, the main motivation to invest in RE system was the first question, they said that main motivation is learning by observation: they were affected by its neighbour companies' new RE system and decided to construct a PV system. All of the interviewee's installations were unlicensed (small-scale) rooftop PV systems up to 1 MW of each, supported by feed-in tariffs and used for self-consumption purposes as can be seen in the profile overview of the interviewees in Figure 5. All interviewees stated that they were feeding the grid with generated RE and consumed only the required level of electricity.

	Installed Systems	Capacities	Current Uses for RE
Company 1	Unlicensed Solar Rooftop	0,8 MW	Feed-in tariff + Self-consumption
Company 2	Unlicensed Solar Rooftop	1MW & 0,5MW	Feed-in tariff + Self-consumption
Company 3	Unlicensed Solar Rooftop	1MW	Feed-in tariff + Self-consumption
Company 4	Unlicensed Solar Rooftop	1MW & 0,5 MW	Feed-in tariff + Self-consumption
Company 5	Unlicensed Solar Rooftop	0,42 & 0,36 MW	Feed-in tariff + Self-consumption
Company 6	Unlicensed Solar Rooftop	0,8 MW	Feed-in tariff + Self-consumption

Figure 5. Profile overview of interviewee's companies and installed solar systems.

The financial support of the investment are bank loans (83% of the prosumers), private belongings (app. 0.2%), and local funds. The technical support for all solar energy instalment were totally provided by Engineering, Procurement and Construction (EPC) Companies. About the education support for the instalments, it was seen that there were no impactful and informative activity or supports to create skill sets, specifically for possible RE investors.

In following questions, we asked for the main motivations for PV instalments, and it was seen that Feed-in tariff was the most important driver for RE installation in Kayseri IP, then

production of self-electricity consumption and the suitable geographical location came as the main drivers as shown in Figure 6.

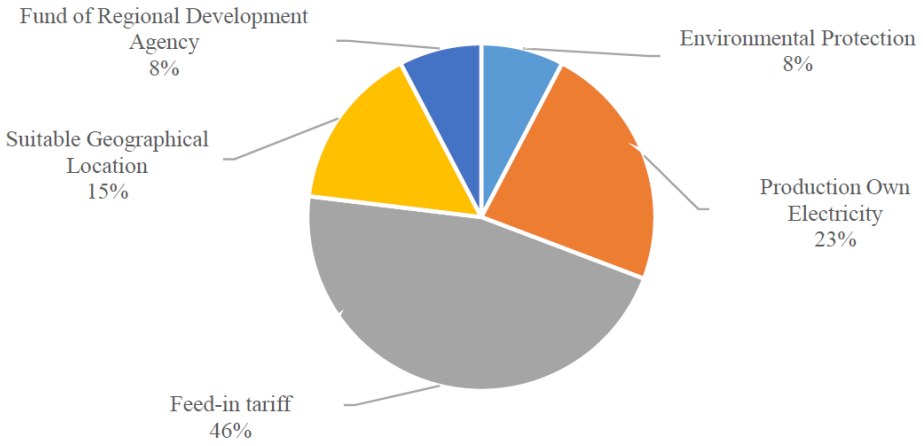

Figure 6. Driver of PV installations in Kayseri IP

When we asked the main barriers to RE investment in IP, we found out the main barriers and their statement frequency as shown in Figure 7. We saw that "Grid and Network problem" was the most severe obstacle for all interviewees. Then came the "frequent changes in regulations" and "low tariff rates" as the most frequently stated barriers in the RE installations. The prosumers thought that the solar energy implementations in Kayseri IP are a commercial product of RE electricity. Due to this reason, instability in the regulatory and policy framework are not wellcome by RE l investor.

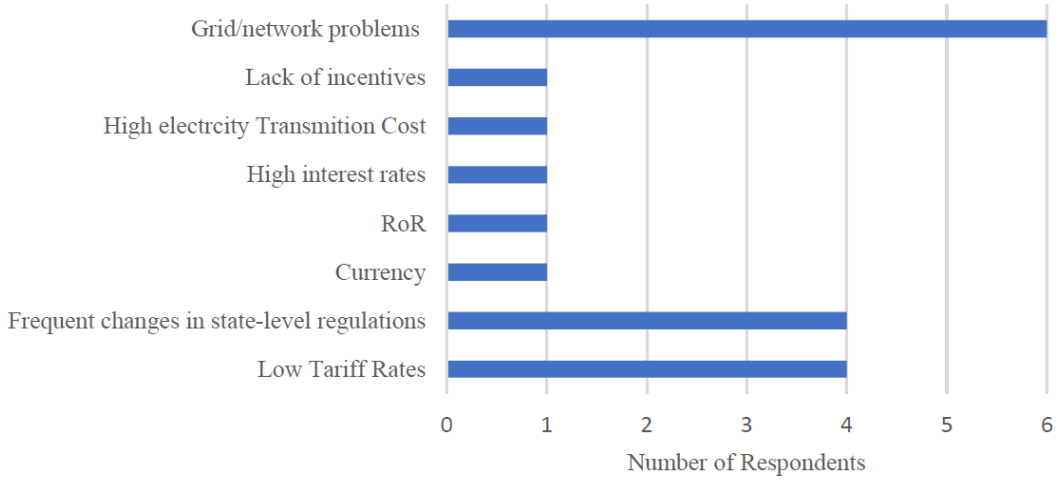

Figure 7. Obstacles on RE in Kayseri IP

In the last part of the interviews, we asked for suggestions from prosumers to increase in solar energy implementations in Kayseri IP. The most prevailing answer was on governmental incentives. Any type of supporting mechanism, mainly the financial support of incentives/ feed-in tariffs is said to be needed. As a last question to see the perception of PV prosumers on ST systems, we asked whether they would like to invest and/or use ST systems in their own plants, and it was found that they agree to use emerging technologies.

2.2. Survey Results

We conducted the survey with the experts from Kayseri IP companies in 2018-2019 in the sectors where SHIP applications are viable. Among 1,118 firms, 300 companies were reached out since they were in the sectors (such as textile, machinery, and food) suitable for SHIP implications. Among them, 69 were fully completed the survey. As seen in Figure 8, survey respondents were accountants (26%), owner-co-owner (23%), CEOs (19%) and R&D Managers (10%) who were highly top executives, decision-makers and specialists.

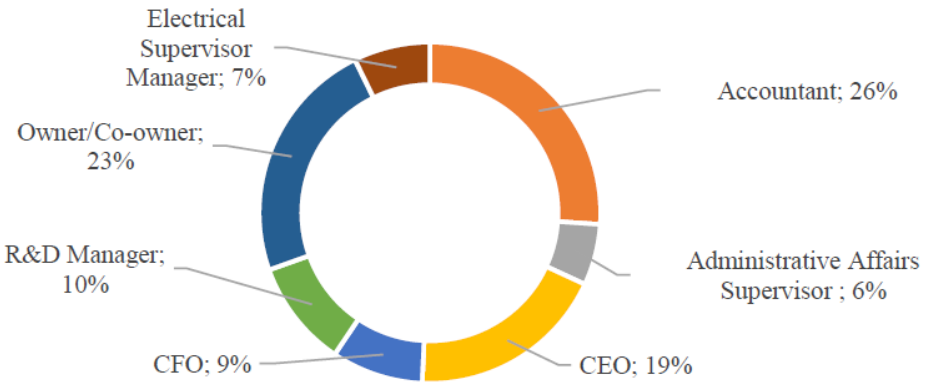

Figure 8. Survey Respondents' position in the company

In the first part we asked questions about the viability and acceptance of ST energy technologies in Kayseri IP. Among the survey participants, seventy-seven per cent of companies were using heat in their industrial processes, seven per cent were not using, and for 16% solar process heat was nor applicable. According to the Directorate (one of our survey participants), for the heating purposes IP the companies preferred electrical heating systems for space heating and industrial heat needs. Main driver is the advantageous tariff rates for using electricity for generating heat required in industrial process. According to Table 1, a very negligible part of the participants had ST energy systems despite the fact that more than 50% of participants were willing to use ST energy applications, they did not have knowledge on solar powered heating and cooling systems.

Table 1. Answer to the questions about Solar Thermal (ST) Applications

Question	Yes (%)	No (%)	Number of respondents
Knowledge Of "Solar Powered Heating and Cooling Systems"	13	62	69
Willingness to Use Solar Thermal Technology	81	17	69
Having a Solar Thermal Energy system	1,45	98,6	69

In the second part, we asked for the factors affecting SHIP investment for Kayseri IP companies, and we found that "life time" of the energy system was the most frequently stated parameter for SHIP

investments. Then, "initial investment cost", "internal rate of return" and "durability and reliability of RE" were the most frequently stated factors affecting SHIP Investment decision as shown in Figure 9.

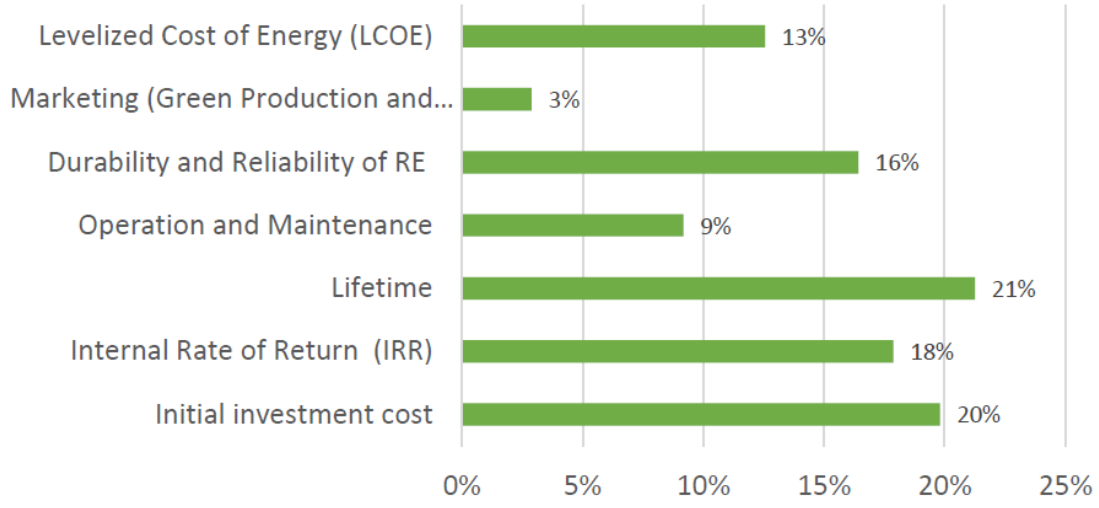

Figure 9. Factors affection SHIP Investment Decision

In the third part, we asked the about the essetial barriers for RE investment in the IP which is shown in Figure 10. "Insufficient initial Investment Incentives" was stated most frequently for RE investments. "Lack of bank loans" and also "Lack of equity" were the second and third most stated barriers to RE. As we see, the lack of financial resources in general was the main obstacle for RE investments in Kayseri IP. "Lack of equipment" and "lack of technical expert" were the other highly stated obstacles which could be generalized as technical barriers.

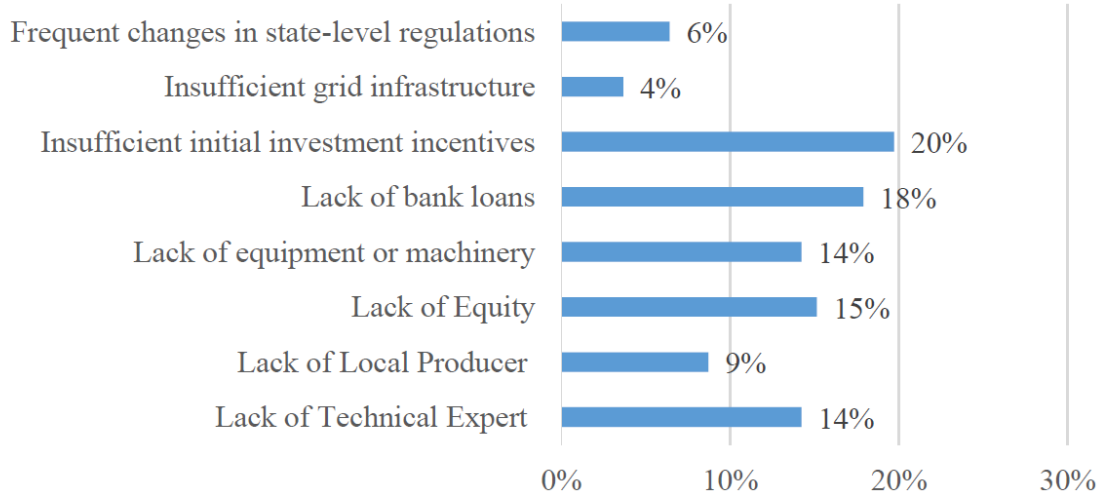

Figure 10. barriers to RE Investment in Kayseri IP

In the same part, we asked for the main drivers for RE investments in Kayseri IP. The results indicated "Incentives by Government" was stated as the most significant driver for RE investments. The fact that all the electricity generated in the power plant was certainly bought by the government ("guaranteed electricity purchase tariff") and "the inherent existence of RE investment experience in IP" were the other significant drivers as shown in Figure 11.

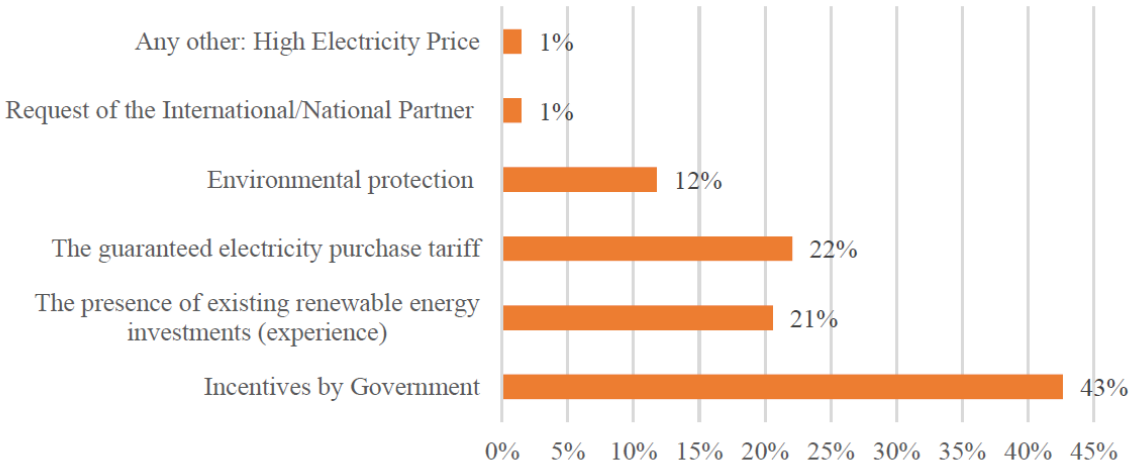

Figure 11. Main drivers of RE Investments in Kayseri IP

3. Main Findings: Opportunities and Barriers for using Solar Energy Technologies in Industrial Parks

The field research analysis of the data collected by stakeholder interviews and survey yielded valuable insights into the impact of consecutive utilization of solar thermal energy, patterns of RE innovation, individual preferences, and levels of knowledge. With the inferences and results derived from the field research of interviews and survey, as supported by the literature review on barriers and obstacles in solar (thermal) energy systems, the barriers were categorized under the suggested themes of "Legal, regulatory and procedural; economic and financial; Social and technical barriers" as given in the first column of Table 2. Legal barriers were mainly consolidated as "B1: Absence of technology specific initiatives" that hindered tailor made investments for specific energy generation systems (such as PV or CST- Concentrated ST), "B2: Future Policy framework" that created unstable and risky environment for any type of investment, "B3: Regional Policy Framework" that was seen as an obstacle for location specific conditions for RE investments (which are generally dependent on physical conditions). The most prominent economic & financial obstacle that was derived from the field research and literature review is the "B4: Lack of affordable financing options" such as bank credits, loans, feed in-tariff, in-kind contributions to investment to fund high cost RE investment in IPs. The other group of barriers were categorized under the main heading of Social barriers which were summarized as "B5: Absence of awareness for ST technologies and implications" and "B6: Lack of awareness programs conducted locally". Here in this group, the emphasis on "lack of awareness" underlined that the stakeholders in Kayseri IP had low level of information and experience on thermal energy technologies and their use in industrial processes and heating& cooling purposes, and moreover there was a lack of any informative / training event/ activities/ opportunities in the IP about CST, SHIP and solar heating& cooling implications. The last group of barriers was technical barriers and they were mainly on lack of human resources (B7: Absence of educated experts and organizations giving training) and infrastructural problems in the IP, national grid and energy transmission and distribution systems (B8: Lack of Adequate Energy Infrastructure)

Table 2. Definition and explanation for main barriers for IP SHIP adoption and the reference sources

	No	Barrier	Reference (of the academic works) and Field Research *(Interviews: I and Survey: S)*
Legal, Regulatory & Procedural	B1	Lack of initiatives tailored to specific technologies	Byrnes et al., 2013; del Río & Bleda, 2012; Polzin et al., 2015
	B2	Future Policy Framework	Wüstenhagen and Bilharz (2006), Kemp vd. (1998), Polzin et al. (2015)
	B3	Regional Policy Framework	Dewald and Truffer (2012), I&S
Economic & Financial	B4	Lack of Affordable Financing Options	Dijk et. al.(2003), I&S
Social	B5	Absence of awareness for ST energy	Cappel et al (2014), I&S
	B6	Lack of awareness programs conducted locally	Cappel et al (2014), I&S
Technical	B7	Absence of educated experts and organizations giving training	Munari Probst and Roecker (2011), I&S
	B8	Lack of Adequate Energy Infrastructure	Marinova ve Balaguer (2009)& I

3.1. Legal, Regulatory & Procedural

3.1.1. Lack of initiatives tailored to specific technologies:

The Turkiye's National Energy Plan released by the ETKB in 2022 (ETKB, 2022), plays a crucial role in transforming consumer preferences into a larger market share in the energy sector. Based on the field research of interviews and mainly survey, it is claimed that there is a need and interest on SHIP applications in Kayseri IP, as can be generalized as in Turkiye. For the current situation in Turkiye (whether recently in 2023 or during the research time period of this paper: 2018-2022), there did not exist a policy document specific and appropriate to increase ST energy technologies for the needs of industrial use. This fact underlined the importance of accelerating ST energy technologies' and SHIPs' implementations.

According to Turkiye's National Energy Plan (ETKB, 2022), Turkiye's energy targets are mainly on the power generation, mainly from RE sources of solar, wind, and hydro-electricity. In the case of solar, rooftop solar panel installations are regulated by important directives and regulations. These include the Electricity Facilities Regulation, the Renewable Energy Sources Support Mechanism, the Construction Works Regulation, and the Distribution Companies' Implementation Directives, Regulation on the Installation and Operation of Solar Power Plants. Moreover, Turkiye has advanced its efforts by introducing the new Unlicensed Electricity Market Regulation, aiming to boost the adoption of solar panels and expand Renewable Energy Development Areas (YEKA). ETKB Minister stated that approximately 700 companies' application for on-top PV applications at total amount of 432 MWs" (Kaya, 2019) and Kayseri Industrial Park is one of these IPs supporting rooftop solar implementations. Nevertheless, this is a one-sided interest, favouring certain solar

energy technologies, and while the legislation and incentives have ushered in a new era for photovoltaic (PV) and Concentrated Solar Thermal (CST) technologies, the overall situation remains unchanged and still for SHIP implications, it is not obvious to see the clear interest of industrial partners.

The presence of more targeted policies in ST technologies could significantly advance RE in local industrial zones. Turkiye hosts numerous industrial production sites, including energy-intensive sectors such as iron and steel, ceramics, cement, and glass manufacturing. These industries often rely heavily on thermal energy rather than electricity. Unlike the building and transportation sectors, the manufacturing sector is primarily driven by the pursuit of profitability, emphasizing energy efficiency improvements in heating and cooling systems. With increased awareness and the implementation of supportive policies, along with financing options that offer guarantees, we anticipate that investors would feel more inclined to invest in portfolios of solar thermal systems installed on industrial rooftops.

Additionally, the government's strategy regarding the link between thermal energy and its associated pricing is expected to drive the advancement of the ST energy market. Among the 69 survey responses obtained, 77% expressed a need for heat in their industrial processes. While data pertaining to space heating and cooling was not gathered or analysed, including such data would likely result in an increased percentage and would contribute to meeting the rising energy demand.

These insights hold significant importance for the Turkish Government's endeavours to address the diverse array of RE options available to industries. Although emission reduction targets have been set for industrial sectors, a definitive roadmap for decarbonizing their thermal energy requirements is still lacking. Consequently, there is a pressing need for a government policy focused on decarbonizing heating processes. To effectively promote the use of sustainable energy and lobby for policies conducive to its adoption in industrial settings, specialized programs tailored to specific technologies can be utilized. This approach allows producers to concentrate on energy production and consumption, thereby reducing their reliance on the grid. As per surveys and interviews, diversifying technology and resources can reduce dependence and promote a more diverse energy landscape.

When the researchers inquired, "Are you interested in adopting and utilizing ST systems?" they demonstrated openness to new technologies. Nevertheless, the prevailing response indicated a lack of knowledge about technology and insufficient governmental motivation and financial backing. In simpler terms, there is a need for certain incentives to stimulate the adoption of SHIP technologies in the country. It would be wise for the government to provide specific incentives for the installation of SHIP technologies, given their novelty. These incentives could include tax exemptions, grants, waived application fees, and incentives for using domestic products. Furthermore, there should be regulations and requirements to encourage the use of RE sources for heating needs and the installation of RE systems in both new and existing buildings. Additionally, support for diversifying energy sources within industrial parks should be provided, including RE sources, to reduce the reliance on fossil fuels and meet the energy demands of various companies within the industrial park. The integration of energy management into industrial park development and management is crucial. A promising approach to maximize productivity involves engaging, motivating, and facilitating enterprises through a local iterative method.

3.1.2 Future Policy Framework:

Supported by Wüstenhagen and Bilharz (2006), Kemp et.al. (1998), **the** interview reveals that

'Frequent alterations in state-level regulations' rank as one of the top impediments to increasing the adoption of RE generation for prosumers. Investors and potential investors share a perception that regulations undergo rapid changes, which can be a source of concern. Their experiences with personal projects may vary, but in the realm of RE investment, these policy shifts can lead to significant alterations in cost structures, profitability, and overall investments. Taking this step would yield substantial benefits, as it would provide a greater level of certainty, encouraging the initiation of more projects. A solid understanding of the regulations and their impact on the industry enables enterprises and their stakeholders to prepare effectively, minimize potential losses, and capitalize on opportunities for improved profitability.

Polzin et al. (2015) advocate for the implementation of technology-specific policies that take into account the existing business environment and technological landscape in order to formulate a well-rounded policy mix. Their research also highlights the importance of establishing a robust framework with an accurate approach and long-sighted strategic plans for the deployment of RE capacity and concurrent energy advancements. The potential risks stemming from regulatory uncertainty have a direct impact on the way investors assess risks and make investment decisions. Therefore, in the face of ongoing technological advancements, it is crucial to continuously update the measures taken, all while considering market conditions and technological developments (Polzin, Migendt, Täube, & von Flotow, 2015). Furthermore, there is a need to harmonize various support schemes and ensure the long-term viability of financing.

Mathiesen and Hansen (2017) made a projection that ST systems could contribute between 3% and 12% of global heat generation by the year 2050. The primary aim of this study is to assess the potential of integrating ST systems into energy systems and whether this integration aligns with Europe's energy objectives, or if there might be more favourable options. The research is based on the development of cases for specific countries, encompassing a comprehensive perspective that includes power, heat, and transportation, all within the context of the year 2050. The study concludes that implementing ST technology can enhance energy security, increase local energy production and reduce dependence on imported fuels. Moreover, it underscores the significant impact that policy frameworks can have on the proliferation of solar thermal energy technologies

The implementation of comprehensive policies and robust support mechanisms is vital for the long-term sustainability of ST as a means to decarbonize heat. These findings suggest that ST energy industries and technologies could be a favourable means of attaining climate-related goals (Mathiesen & Hansen, 2017). In summary, Turkiye's industrial sector presents a promising market for renewable energies, albeit it must address challenges stemming from its dispersed geographical layout and intense competitive pressures. In light of these new initiatives, there is a pressing requirement for long-term investment guarantees.

3.1.3. Local Policy Structure

Turkey aims to shift to clean energy while ensuring reliability. There exists a national legislative and regulatory framework for addressing climate change at local level. Recent efforts have seen all Turkish municipalities taking steps to confront climate-related challenges. However, these initiatives often function as isolated interventions within specific sectors, rather than comprising a systematic and structural approach. Furthermore, the linkage between the strategies to cope with climate change and vital localized regulation and management plans remains underdeveloped. Turkey's approach to local climate policy is confidently characterized as 'regional voluntarism.' This is due to the fact that regional programs are not yet fully established, which empowers

municipalities to take the lead in addressing climate issues if they choose to do so with a sense of ownership and accountability (Gedikli and Balaban, 2017).

The role of regions and cities is underlined in literature for facilitating the transition to sustainable energy. Different types of energy mainly used in daily city routines (ex. home use, transport…) such as gas, heat, electricity, and fuel, will undergo a shift in priority at the city level. Additionally, the geographical and natural features can be advantageous for the advancement of RE, as seen in the example of SHIP technology benefiting from abundant solar radiation in Kayseri.

Beyond technology-specific energy policies, as highlighted in Dewald and Truffer (2012), there is a pressing need for regional initiatives to support solar heat for industrial processes (SHIP). Many local governments have been driven by the imperative to reduce energy consumption and mitigate air pollution, leading them to expand their efforts in enhancing energy efficiency and adopting RE solutions in the domains of electricity, heating, and cooling. For instance, the municipality of Täby, located in the northern part of Stockholm, Sweden, has made a commitment to fulfil all the energy demands of local government activities and operations through renewable heat sources by 2020, while Stockholm's targets encompass the entire city. Cities like Curitiba in Brazil and the Msunduzi Municipality in South Africa are on track to achieve the 100% RE heating and cooling goal (REN21, 2019). Research findings and international case studies explain that governments can adopt more different methods of strategic planning that align better with climate action plans and implement effective measures. Local governments should take responsibility for executing climate action policies, including both mitigation and adaptation measures, with clearly defined stakeholders and budgetary allocations. Providing incentives and grants to cities can spur local initiatives.

In summary, it is crucial to prioritize decentralization and the active involvement of governments in shaping a national climate policy. City-wide and municipal targets can promote RE adoption for energy needs.

3.2. Economic & Financial

3.2.1. Lack of affordable financing options (Bank Credit-Loans)

The perennial challenge faced by innovations in the RE sector involves more access to loans for acquiring or investing in new technologies. Potential solutions include providing low-interest rate funding, tailored to specific requirements, by financial institutions. Considering consumer credit for purchases supporting private entrepreneurs in delivering RE products could be beneficial. The government's responsibility is to formulate advantageous policies for developing RE. Industries may drive market growth by choosing cost-effective RE systems with financing options available, independent of central government actions.

Investments in renewable energy are influenced by a variety of factors, including the amount of capital available at the outset, transaction costs, financial stability, and the availability of incentives and subsidies. In contrast to conventional energy sources, the initial capital cost of RE is relatively high, thereby elevating the expenditure associated with the consumption of RE. The significant obstacle posed by high investment costs to adopting sustainable solutions is underscored by many producers minimising their initial investment costs while maximising profitability (Luthra, Kumar, Garg, & Haleem, 2015). Additionally, investment is a barrier to RE, though its impact varies across technologies. PV prosumers believe that feed-in tariff mechanisms and bank loans encompass every financial investments. Similarly, these financial supports can be regarded as a valuable "lesson learned," guiding the initiatives undertaken by all market stakeholders to promote solar energy development in Turkiye for electricity generation and heating or cooling in industrial

process.

In the ST system, potential customers are discouraged by the high initial investment costs, which are elevated due to the more expensive imported technology. The survey substantiates this situation, indicating that the most crucial factors for investing in RE systems are the 'lifetime' and 'the initial investment cost.' The predominant barriers to deployment of RE are identified as 'Insufficient initial investment incentives', and the secondary barrier is the 'lack of bank loans.' Turkiye's national energy priorities (ETKB, 2022) involve setting specific credit expenditure goals for banks. Consequently, solar water heaters receive robust encouragement from several banks. Garanti BBVA is the sole Turkish bank providing direct investment credits in renewables, focusing on electricity generation and promoting funding for production areas (Ancelle et al., 2020). However, as observed in field work, support from financial institutions is not extended to the SHIP market or any other ST systems.

3.3. Social

3.3.1. Absence of awareness for ST technologies and implications:

In the field research comprising interviews and surveys, it was observed that CEOs play a central role in company vision and mission. Understanding current incentives and support is crucial for investing in RE. This suggests a significant correlation between CEOs' education level and innovation investment. Survey results show that companies require more knowledge about solar power systems. In Kayseri, numerous industries need to be informed about the existence of SHIP systems. This lack of awareness might lead to unfounded assumptions and an insufficient ability to identify and comprehend fundamental benefits and drawbacks in implementing or functioning these systems.

A significant impediment to the technological transition in the industry may stem from the low 'information flow and communication.' Resources for information are required to establish connections that facilitate the development of efficient and clean energy technologies. The prevailing consensus is that the adoption of RE technology is primarily hindered not by a deficiency in information/experience or expertise on the client's part nor by a lack of trust in accessing reliable information. Globally, numerous potential users of RE technology lack sufficient familiarity with its usage. There is inadequate support for developing this crucial aspect of new RE technology (United Nations, 2019).

The observable implementations and awareness of various ST power technologies might drive the utilisation of conventional energy sources in the industrial sector. Additionally, financial incentives should be coupled with public awareness campaigns and tariffs to endorse solar energy's potential. These measures can attract diverse investors, potential buyers, and technology providers. Furthermore, disseminating technology through various channels could serve as the foundation for adopting SHIP and CST. For instance, public-sector-owned facilities could incorporate various solar power technologies to serve as inspiration for the private sector. Porto, Portugal addressed energy insecurity by upgrading public buildings with energy-efficient measures and installing renewable heating and cooling technologies. This resulted in annual energy savings of 286 kilowatt-hours (kWh) per square meter (m^2) (Covenant of Mayors for Climate & Energy, 2019).

3.3.2. Lack of awareness programs conducted locally:

The construction of local capacity is also deemed necessary to heighten awareness and enhance expertise for installing and sustaining RE technology. Geographic locations greatly influence the efficiency of solar power systems. Local authorities and regional development agencies can organise capacity-building activities for industrial energy applications. It is crucial to nurture

innovative local skills, incorporating the adoption and implementation of technology tailored to local needs. Measures that can augment these capabilities encompass the encouragement of municipalities, universities, and research centres to engage in technology on solar power while concurrently undertaking actions to disseminate growth and demonstrate advancements on the industrial front. Despite national plans and regulations encouraging the promotion and subsidisation of SHIP technology, market growth can occur independently through ST research and development activities and the pioneering efforts of thriving entrepreneurial industries, exerting a significant influence on the development and exploitation of opportunities for SHIP in the industrial sector.

3.4. Technological

3.4.1. Absence of educated experts and organizations giving training :

A crucial aspect in planning low-carbon economic growth revolves around employment opportunities. Numerous governments prioritise RE development to diminish emissions, attain international climate targets, and reap broader socio-economic advantages. In the case of Turkiye, policies should be devised to foster employment in RE, accompanied by support and incentives in that direction. Each employment opportunity in the green sector contributes to realising a cleaner world envisioned for the future.

As of 2020, only two SHIP installations were discerned in Turkiye. Despite the near absence of SHIP markets, the providers of industrial-process solar heat in Turkiye are pretty limited. The Turkish market stands out among larger global markets as it operates voluntarily and unrestrictedly. Additionally, there is potential for further development in Turkiye's markets and capacities. The initial step involves the urgent need for certain and comprehensive official data to quantify these aspects.

To disseminate ST energy technologies, implementing projects involving installing new energy facilities and associated technical support can be performed. This necessitates the availability of skilled labour to support the deployment of solar technology, encompassing tasks such as system design, installation, and continual operating and managing.

Adequate guidance and technical support are essential for investors to prevent the effective exploitation of renewable/sustainable resources. Field research indicates that industries, as observed in the interview, often opt for learning and investing through imitation rather than formal training. Field research findings further substantiate this tendency. According to the discussions, whole existing PV prosumers were assisted by Engineering, Procurement, and Construction (EPC) Companies during the implementation phase. Preceding that, investors independently conducted inspections and decision-making without the benefit of guidance and professional cost-benefit calculations.

3.4.2. Lack of Adequate Energy Infrastructure:

An increasing focus is placed on the establishment of infrastructure to improve the RE utilisation in Kayseri IP. This encompasses the development of thermal district networks and infrastructure to charge electric vehicle (EV) to achieve elevated levels of RE usage in cities (REN21, 2019). The necessity of upgrading the existing grid to accommodate the growing share of decentralized and intermittent renewable power production has been underscored by the prosumer. Improvements to the national grid system are essential to facilitate the commissioning of more renewable power plants. Within this particular context, the term infrastructure encompasses transmission and distribution networks, along with any requisite equipment and services crucial to the operations of companies. Although the research makes no attempt to explore the details of PV/T or other grid-connected energy systems, interviews and surveys suggest that a lack of infrastructure could be a

challenge.

A noteworthy case is Germany, where power system operators have been able to successfully integrate over twenty-two per cent of fluctuating solar and wind energy production while ensuring international supply security. This achievement has been realised through integrating reliable grid infrastructure, strong interconnections with adjacent nations, enhanced flexibility in thermal power plants, and a creative strategy for constructing particular power grids. Germany is aiming to increase their RE sources by adopting smart grid technology, incorporating local electricity, heating, and transportation systems, promoting cross-border trade, and ensuring equilibrium between both demand and supply (SHURA Energy Transition Center and Agora Energiewende, 2018). Turkiye should give priority to investing in its grid infrastructure, operational transmission, and battery storage systems.

CONCLUSIONS AND RECOMMENDATIONS

Industrial parks (IPs) are dispersed throughout Turkiye and exhibit unique energy consumption patterns, necessitating tailor-made solutions for achieving low-carbon energy solutions. Additionally, the Turkish industrial sector is facing significant cost competitiveness pressures on an international level, which limits the potential for innovation (SHURA, 2018). These areas allow industries to collaborate and efficiently use resources. They also offer a valuable blueprint for promoting the adoption of RE within industrial production. The potential for reducing energy consumption and greenhouse gas emissions can be realized through the implementation of solar heating and cooling technologies. The significant number of PV prosumers serves as a motivation, creating strong word-of-mouth dissemination and communication among users. It's a well-established fact that companies place more trust in recommendations from investors than in other forms of advertising. Companies are more inclined to make purchases when they receive referrals from nearby businesses.

Kayseri IP is one of the most prominent industrial zones in Turkiye and hosts an important number of producers of energy-intensive industries. Aligned with the national clean energy targets, and having a vast potential of solar energy implications, Kayseri IP aims to reach a clean and economical energy supply benefitting from RE Sources. To this purpose, this article mainly examines the current conditions, existing opportunities and barriers for (i) meeting the thermal energy demand needed for energy-intensive industries benefitting from SHIP implications, (ii) establishing timely and required investments and infrastructural organization for dispersed SHIP applications and (iii) further investigation of new technologies and applications for efficient use of RE resources.

SHIP technology encounters several obstacles when applied and used in industrial production. These challenges encompass legal, regulatory, procedural aspects, climate-related, economic, financial, and social factors. These challenges were assessed in alignment with the perspectives of both residents and private sector representatives. Field research conducted by interviews and surveys were utilized to determine different factors affecting the integration of renewable and sustainable energy technologies in an industrial zone. Data analysis found that insufficient government support, limited financial backing, inadequate expertise and capacity, unfamiliarity with contemporary technologies, and inefficient infrastructure are prominent barriers impeding the adoption of SHIP technology.

The solar PV system adoption surge in Turkiye highlights how technological advancements have spurred excitement in deploying new technologies and infrastructure. As an initial step, government support mechanisms foster consumer awareness and energy generation. This study reveals that Turkiye needs to address the growing demand for SHIP markets within the country. The government can promote and expand the use of solar energy for thermal power generation within the existing policy framework. Tailored policies for specific technologies and regional considerations can be implemented to facilitate the growth of solar thermal energy in the industrial sector, necessitating the formulation of a long-term plan. Currently, investments in SHIP are voluntary and focus primarily on self-generation and consumption rather than financial gains. Furthermore, based on lessons learned from interviews, ensuring clarity and simplifying the application and regulatory processes can prevent potential investors from encountering confusion.

It is crucial to establish highly targeted financing and funding mechanisms to diminish the non-technological obstacles hindering the widespread adoption of solar process heat. These initiatives should facilitate many demonstration projects, potentially building critical mass within specific industries or geographical sectors. Encouraging the company's specific interest before and after introducing new technology requires effective investment promotion and post-implementation support to ensure successful IP investment promotion programs. Financial stakeholders, including government bodies and private organization, should incorporate innovative options into their investment strategies. Depending on the type of RE and the prospective buyers, industries need access to national RE incentives and supporting legal framework to motivate SHIP adoption.

Developing the skills and capabilities of individuals and institutions is paramount in ensuring the long-term viability of energy access policies and the seamless integration of technological, financial, and political initiatives. For SHIP, research data highlights the evident deficiency in capacity within this field. There is a substantial need to enhance capacity building in SHIP technology. This involves the design and implementation of training programs and capacity-building initiatives, as well as the execution of practical feasibility studies. These capacity development efforts should target various groups with differing access levels to educational programs, spanning technological, vocational, and institutional domains. As a result, these interventions help bridge the gap in technological and commercial expertise and knowledge.

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