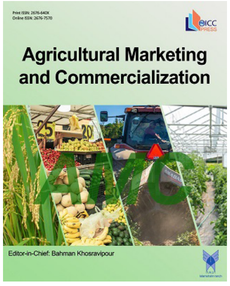

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Original Article

Feasibility of Solar Utilization in Vegetables Greenhouse of Pishva County

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Abstract:

The aim of this research was to assess the feasibility of solar energy utilization in greenhouses of Pishva County. The present research was applied in nature with a descriptive-survey methodology. Data were collected through a researcher-designed questionnaire with 53 items in 7 dimensions (attitude, knowledge and awareness, environment, technical and infrastructure, policy-making, economic, cultural-social). The validity of the questionnaire was confirmed using factor analysis with a KMO index of 0.791 and a significant Bartlett's test (sig=0.000), and its reliability was appropriately evaluated using Cronbach's alpha coefficient of 0.806. The statistical population consisted of 1,759 greenhouse farmers, and the sample size was determined to be 386 persons using simple random sampling. Data were analyzed using SPSS version 22 software, and descriptive statistical indicators (mean, standard deviation, frequency) and inferential tests (chi-square and Kendall's tau-b) were employed. Findings showed that respondents' overall attitude toward solar energy was at a moderate level (mean=3.08 out of 5), while belief in the impact of solar energy on greenhouse prosperity (mean=4.34) and reducing environmental threats (mean=4.24) was positively evaluated. However, managers' and farmers' attitudes toward practical use of this energy were lower than expected (mean=2.45 to 2.77). Assessment of farmers' knowledge and awareness revealed that their knowledge regarding solar technologies was low (mean=2.0 out of 5), and there was an urgent need for training and access to information sources such as virtual platforms (mean=4.2). Additionally, economic barriers (high initial and maintenance system costs), technical and infrastructural obstacles (lack of consultants and implementation standards), and cultural-social factors (lack of trust in renewable energies) were among the most important limiting factors for solar energy utilization in greenhouses. Finally, the research results demonstrate that solar energy use in Pishva County greenhouses is technically and environmentally justified; however, its successful implementation requires addressing economic barriers, increasing awareness and training of farmers, and improving institutional coordination. This research can serve as a foundation for future policymaking in sustainable agriculture and renewable energy utilization.

Keywords: Environment, solar energy, renewable energy, greenhouse, feasibility study, technical infrastructure, solar energy feasibility assessment

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INTRODUCTION

Energy is recognized worldwide as the engine of economic development, and today the main problem of most societies is its production and consumption (Broesamle et al., 2001). On the other hand, with population growth worldwide, energy demand has increased and energy resources are being depleted at an accelerating rate (IPCC, 2007). In the 1990s, the world witnessed significant changes in energy policies. Today's industrialized countries are making doubled efforts to gradually replace fossil fuels with renewable energies such as solar energy; because of their special advantages such as environmental non-pollution, abundance, cost-effectiveness, inexhaustibility, and independence, they are always accessible (Ahmadi et al., 2013). Fossil fuels are the primary cause of greenhouse gas emissions and global warming (Ani, 2015). Sustainable energy means providing energy equitably to all people while protecting the environment for future generations. The use of renewable energies is a way to achieve these goals (Freitas et al., 2015). Solar energy is one of the cheapest, cleanest, and most sustainable renewable energy sources. If only 0.1% of solar energy reaching Earth is converted to electricity with 10% efficiency, 3000 gigawatts of energy would be produced, approximately four times the energy generated annually worldwide (Sukumaran & Sudhakar, 2017). The use of renewable energies (wind and solar power plants) in meeting the energy needs of homes and industrial centers is one of the most practical and cost-effective methods of using renewable energies in today's world and is therefore among the most developed methods. Countries are pursuing large investments in this direction (Selvaraj & Victor, 2021). Solar systems are new technologies used in both power plants and non-power-generating facilities and can be used for providing heating and cooling, electricity generation, and more (Kiray, 2021).

On the other hand, greenhouses today supply a significant portion of vegetables and produce in most countries worldwide. As a horticultural center for increasing crop productivity, greenhouse promotion is increasing globally. Greenhouse cultivation, as an effective and popular method for growing agricultural crops, can increase production up to ten times more than traditional field cultivation. Greenhouse cultivation offers advantages such as out-of-season production, ability to produce different crops based on market needs, high efficiency and consequently high income generation, higher employment compared to traditional farming, ability to produce healthy and organic crops, use of modern technologies, automatic monitoring and control of plant growth environment, use of insect-proof, drip-resistant, and dust-proof plastic covers resistant to sunlight, and more. These factors have led to good development of this type of cultivation. One important aspect of this type of cultivation is the high potential for using new energies such as solar energy (Sukumaran & Sudhakar, 2017). In fact, among the different processes in greenhouses to obtain products, heating and cooling greenhouses is one of the energy-intensive operations. Greenhouse cultivation requires significant energy for heating and lighting, which is currently supplied based on fossil fuels. The increased use of fossil fuels to meet the energy required for greenhouse heating has many undesirable effects on the environment. In this context, solar energy as an inexhaustible, clean, and accessible resource can be a suitable alternative to conventional fuels used in greenhouses with good storage capacity (Mohammadi et al., 2021). Solar energy is used in many advanced countries as an inexpensive and cost-effective accessible energy; using this energy for plant cultivation in greenhouses increases energy efficiency and reduces costs. Given the current predicted shortages of fossil fuels, carbon taxes, and increased awareness of environmental impacts, the use of renewable energies for heating greenhouse products has become a priority (Grisey et al., 2019). However, traditional greenhouse facilities face significant challenges, and in contrast, solar energy-based greenhouses have the ability to reduce fuel consumption and replace it with solar energy, which has recently been used in various developed and developing countries.

However, there are barriers and challenges to utilizing solar energy in greenhouses. Greenhouse operators' lack of awareness of the importance and benefits of using solar energy in greenhouses, the absence of a comprehensive and documented program with specific quantitative criteria, insufficient credit availability for greenhouse operators to transition energy processes, lack of qualified consultants and contractors in the field of solar energy utilization in greenhouses, and other issues; lack of cooperation from executive managers, greenhouse operators' distrust of new energies, lack of farmers' awareness and knowledge; absence of experience and information, transportation costs, and technical factors can be cited as problems hindering solar energy utilization in greenhouses(Ahmadi et al., 2013).

In this research, the main issue is based on the growing need for sustainable energy resources and reducing dependence on fossil fuels in the agricultural sector and greenhouses. Using solar energy as a clean and renewable resource can meet a significant portion of the heating and electrical needs of greenhouses and livestock/poultry housing units. Given limited energy resources and rising fuel costs, finding economical and technical solutions for optimal solar energy exploitation, especially in arid and semi-arid regions of the country, is necessary and forms the rationale for this research.

The importance and necessity of this research stems from the fact that effective use of solar energy can not only reduce energy costs but also mitigate the negative environmental impacts of fossil fuels and create conditions for sustainable agriculture development. Despite previous research, there is still a research gap in precisely estimating the capability of solar systems in different agricultural environments, identifying implementation and economic obstacles, and designing optimal operating models. Understanding these limitations and conducting technical and economic assessments of solar systems can help managers and policymakers in the agricultural sector make better decisions.

The consequences of conducting this research include providing a scientific framework for designing and implementing solar systems in greenhouses and livestock/poultry housing units, reducing fossil fuel consumption, and increasing energy efficiency. On the other hand, failure to conduct this research could lead to continued dependence on unsustainable energy sources, increasing production costs, and reducing agricultural system efficiency. Therefore, this research, aiming to fill the existing gap and provide practical solutions for optimal solar energy utilization, is of significant importance and necessity.

LITERATURE REVIEW

Numerous studies have examined the technical and economic feasibility of using solar energy in agricultural and greenhouse environments. Jalali et al. (2023) showed that installing a limited portion of solar collectors provides only a small percentage of the heating load of poultry houses, and increasing collector area will improve system capability (Jalali et al., 2023). Hosseini Fashmi et al. (2018) also showed that using photovoltaic and combined photovoltaic-thermal systems in greenhouses increases electricity production, particularly in cities like Kerman (Hosseini F. et al., 2018). Abbasi (2015) also demonstrated through designing an active solar greenhouse that the payback period of solar systems with flat-plate and vacuum tube collectors is possible after 5 to 14 years, respectively (Abasi, 2015).

On the other hand, other studies have focused on barriers to solar energy application. Ahmadi et al. (2013) identified six factors including human, managerial, educational, economic, environmental, and promotional as primary obstacles (Ahmadi et al., 2013). Alimoradian and Ebrahimpour (2013) considered lack of managers' awareness, absence of educational needs assessment, and lack of researcher participation as the most important limitations in greenhouses (Alimoradian & Ebrahimpour, 2013). Additionally, Shahi et al. (2013) showed that initial investment in solar energy storage systems is significant and includes collectors and storage tanks with specific volumes, which are necessary to reduce fuel consumption in greenhouses (Shahi et al., 2013).

RESEARCH METHODOLOGY

The current research was applied in nature and designed with the goal of improving and optimizing tools, methods, and programs to enhance human welfare and comfort. The research method is descriptive-survey; it addresses a known phenomenon with unknown dimensions and uses surveys and questionnaire distribution in the statistical population to investigate the current situation. Research information was collected through library studies and field surveys. The information gathering tool was a researcher-designed

Table 1. Theoretical Framework and Operational Framework of the Research

Author(s)/Year	Research Title	Extracted Ideas
Domestic Studies		
(Jalali et al., 2023)	Technical and Economic Feasibility Assessment of Solar Energy Use for Meeting Poultry House Heating Load	Economic justification, equipment and available facilities
(Hosseini F. et al., 2018)	Feasibility Assessment of Energy Production in Greenhouses Using Different Solar Technologies	Solar radiation intensity, equipment and facilities
(Abasi, 2015)	Designing an Active Solar Greenhouse Under Yazd Climatic Conditions	Economic factors, capital payback period
(Ahmadi et al., 2013)	Factor Analysis of Barriers to Solar Energy Application in Rural Environments	Human, managerial, educational, economic, environmental, and promotional factors
(Alimoradian & Ebrahimpour, 2013)	Barriers to Solar Energy Application from Greenhouse Operators' Perspective in Tehran and Alborz Provinces	Manager awareness, educational needs assessment for farmers
(Shahi et al., 2013)	Thermoeconomic Evaluation of Solar Energy Storage Systems in Greenhouses to Reduce Fuel Consumption	Capital payback period, fuel consumption reduction
International Studies		
(Mostafa et al., 2023)	Solar Energy in Africa - A General Overview, with Focus on Egypt	Egypt's suitable climate
(Salman et al., 2020)	Study of Possibility of Using Solar Panels on Plastic Greenhouse Roof for Electricity Generation in Iraqi Climate	Warm climatic conditions, water consumption reduction
(Grisey et al., 2019)	Feasibility Study on Using Solar Energy for Heating, Cooling, and Dehumidification of Tomato Greenhouses in France	Energy consumption reduction
(Kıyan et al., 2013)	Modeling and Simulation of Hybrid Solar Heating System for Greenhouse Applications Using Matlab/Simulink	Environmental factors (solar radiation intensity and geographic location)

questionnaire in 7 dimensions (attitude, knowledge, environment, technical, policy-making, economic, cultural-social) consisting of 53 items. The questionnaire's validity was confirmed in terms of content and through factor analysis, with a KMO index of 0.791 and Bartlett's test (sig=0.000), and the questionnaire's reliability was assessed at an appropriate level using Cronbach's alpha coefficient of 0.806. The statistical population consisted of 1,759 greenhouse farmers in Pishva County, and the sample size was determined to be 386 persons based on Morgan's table using simple random sampling. Data were collected through questionnaires via personal visits and entered into SPSS version 22 software. In the descriptive statistics section, indicators such as mean, standard deviation, frequency, and percentage were used, and in the inferential statistics section, chi-square and Kendall's tau-b tests were employed for hypothesis testing. The research had one dependent variable, namely solar energy application in greenhouses, and 7 independent variables (attitude, knowledge, environmental awareness, technical and infrastructural, policy-making, economic, cultural-social), examining the relationships between these variables.

RESEARCH FINDINGS

Attitude Toward Environmental Impacts of Solar Energy

According to the findings, respondents' attitude toward the environmental impacts of solar energy use in greenhouses varies among different educational groups. Specifically, 92.9% of individuals with university education believed that utilizing solar energy in greenhouses could significantly affect environmental and energy sectors. This ratio was 56.6% among individuals with non-university education. Respondents' attitude toward the environmental impacts of solar energy use in greenhouses showed no statistically significant difference among other demographic variables.

Respondents' Attitude Toward the Impact of Cultural and Social Issues on Solar Energy Use in Greenhouses

According to findings, attitudes toward the impact of cultural and social issues of greenhouse farmers on solar energy use in greenhouses differ between men and women. Specifically, men (57.9%) more than women (32.4%) believed that cultural and social issues of greenhouse farmers significantly affect solar energy use in greenhouses. Respondents' attitude toward the impact of cultural and social issues did not show statistically significant differences among other demographic variables.

Examining the Relationship Between Attitude Toward Solar Energy Utilization and Knowledge and Awareness

According to findings, there is a significant relationship between respondents' attitude toward solar energy utilization in greenhouses and their knowledge, awareness, and environmental perspective. Specifically, 72.4% of those with low knowledge and awareness about solar energy application in greenhouses believed that solar energy plays a small role in greenhouse industry prosperity. In contrast, 25.4% of those with high knowledge and awareness about solar energy application in greenhouses expressed a more positive attitude toward solar energy use in greenhouses. Additionally, 29.5% of those aware of the environmental

Table 2. Attitude Toward Environmental Impacts of Solar Energy by Education Level

Attitude Toward Environmental Impacts of Solar Energy	Non-University (%)	University (%)
Low	24.2	3.0
Moderate	19.1	4.0
High	56.6	92.9
Total	100.0	100.0
Test Type	Chi-Square	
Test Value	42.491	
Significance Level (Sig)	0.001	
Correlation Coefficient	0.346	

Table 3. Respondents' Attitude Toward the Impact of Cultural and Social Issues by Gender

Impact of Cultural and Social Issues	Male (%)	Female (%)
Low	21.2	40.5
Moderate	20.9	27.0
High	57.9	32.4
Total	100.0	100.0
Test Type	Chi-Square	
Test Value	9.914	
Significance Level (Sig)	0.007	
Correlation Coefficient	0.160	

impacts of solar energy had a more positive attitude toward solar energy utilization in greenhouses.

Examining the Relationship Between Attitude and Economic and Social Indicators

According to results, 67% of those stating economic obstacles in implementing solar energy in greenhouses did not have a particularly positive attitude toward solar energy utilization in greenhouses.

76.4% of those stating that solar energy planners have limited understanding of farmers' cultural and social issues or that Pishva farmers lack sufficient culture of renewable energy acceptance had a more negative attitude toward solar energy utilization in greenhouses.

Relationship Between Policy-Making and Management Variables and Technical Infrastructure

According to results, 60.1% of those considering the country's technical and infrastructure capacity high in greenhouse areas stated that proper policy-making and management could significantly affect improving solar energy implementation in greenhouses. Additionally, 80.3% of those with high knowledge and awareness regarding solar energy use in greenhouses stated that proper policy-making and management could significantly improve solar energy implementation in greenhouses.

Relationship Between Technical and Infrastructure Variables and Knowledge and Awareness

According to the following results, there is a significant relationship between technical and infrastructure variables and respondents' knowledge and awareness. Specifically, 50.7% of those with high knowledge and awareness about greenhouses and solar energy believed that the country has considerable technical and infrastructure capacity in the greenhouse sector. Furthermore, 44.3% of those aware of the impacts and consequences of solar energy use in greenhouses said that the greenhouse's structural suitability for implementing related systems significantly increases the farmer's willingness to adopt solar energy.

RESULTS AND DISCUSSION

Attitude Analysis

Greenhouse farmers and officials of Pishva County have a positive attitude toward solar energy utilization in greenhouses. The average score of respondents' overall attitude regarding solar energy utilization in greenhouses on a scale of 1 to 5 was 3.08 and is at a moderate level. Although most respondents believe that meeting energy needs through traditional methods threatens the future of agriculture or believe that solar energy application plays an important role in the greenhouse industry, the attitude of Pishva County managers and experts as policymakers and decision-makers, as well as greenhouse farmers as

Table 5. Relationship Between Attitude and Economic and Social Issues

Attitude	Economic Issues			Social Issues		
	Low (%)	Moderate (%)	High (%)	Low (%)	Moderate (%)	High (%)
Low	67.0	34.3	4.3	76.4	83.1	6.5
Moderate	17.0	44.8	46.8	5.6	1.2	65.4
High	16.0	20.9	48.9	18.0	15.7	28.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Test Type	Kendall's Tau-b			Kendall's Tau-b		
Significance Level (Sig)	0.001			0.000		
Correlation Coefficient	0.334			0.492		

Table 4. Relationship Between Attitude, Knowledge and Awareness, and Environmental Perspective

Attitude	Knowledge and Awareness			Environmental and Energy Awareness		
	Low (%)	Moderate (%)	High (%)	Low (%)	Moderate (%)	High (%)
Low	72.4	67.0	18.4	49.2	37.7	32.9
Moderate	1.7	17.0	56.1	44.6	34.0	37.6
High	25.9	16.0	25.4	6.2	28.3	29.5
Total	100.0	100.0	100.0	100.0	100.0	100.0
Test Type	Kendall's Tau-b			Kendall's Tau-b		
Significance Level (Sig)	0.001			0.001		
Correlation Coefficient	0.341			0.152		

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Table 6. Relationship Between Policy-Making/Management and Technical Infrastructure and Knowledge

Policy-Making and Management	Technical and Infrastructure Issues			Knowledge and Awareness		
	Low (%)	Moderate (%)	High (%)	Low (%)	Moderate (%)	High (%)
Low	26.1	20.0	19.6	12.1	16.0	14.0
Moderate	73.9	50.0	20.2	10.0	6.0	5.7
High	0.0	30.0	60.1	77.9	78.0	80.3
Total	100.0	100.0	100.0	100.0	100.0	100.0
Test Type	Kendall's Tau-b			Kendall's Tau-b		
Significance Level (Sig)	0.001			0.000		
Correlation Coefficient	0.428			0.283		

Table 7. Relationship Between Technical Infrastructure and Knowledge/Awareness

Technical and Infrastructure	Environmental and Energy Issues			Knowledge and Awareness		
	Low (%)	Moderate (%)	High (%)	Low (%)	Moderate (%)	High (%)
Low	40.0	18.9	11.8	88.3	43.0	25.0
Moderate	27.7	38.2	43.9	10.0	27.0	24.3
High	32.3	42.8	44.3	1.7	30.0	50.7
Total	100.0	100.0	100.0	100.0	100.0	100.0
Test Type	Kendall's Tau-b			Kendall's Tau-b		
Significance Level (Sig)	0.015			0.005		
Correlation Coefficient	0.128			0.169		

the target population, are not particularly positive toward solar energy use in greenhouses. Specifically, the average score of Pishva County managers and experts regarding solar energy use in greenhouses was 2.77, and the average score of Pishva County greenhouse farmers regarding solar energy use in their greenhouses was 2.45. Therefore, hypothesis 1 of the research is not confirmed.

Knowledge and Awareness Gaps

Greenhouse farmers and officials of Pishva County lack the necessary knowledge and awareness regarding solar energy utilization in greenhouses of the county. Although most respondents agree with creating virtual platforms and advertising through these channels in the county for training and gaining more information about solar energy in greenhouses, and believe that forming active associations in the field of solar energy application would significantly impact spreading this topic, Pishva County farmers have very low knowledge and training for solar energy use in their greenhouses. Specifically, the average score of agricultural extension managers regarding solar energy potential in greenhouses and the average score of farmers' knowledge and training for solar energy use in their greenhouses was 2.1. Additionally, the average score of Pishva farmers' access to training opportunities and courses was 2.0, and the average score of extension staff's motivation in providing services toward solar energy utilization was 2.0, assessed as below the moderate level of 3. Therefore, hypothesis 2 of the research is confirmed.

Environmental Awareness

Results showed that in the environmental and energy dimension, the average score of most items was above the moderate level of 3, and most respondents believed that using solar energy and utilizing it in greenhouses could have significant impacts on environmental conditions. The average score of 4.24 indicates that solar energy has more than moderate impact on improving environmental conditions, including reducing greenhouse gases, reducing air pollution, and preserving natural resources. Therefore, hypothesis 3 of the research is confirmed.

Technical and Infrastructure Potential

Results showed that among items related to the technical and infrastructure component, most respondents believed that farmers' lack of access to technical knowledge significantly hinders solar energy implementation in greenhouses. The average score for this factor was 4.40.

Additionally, respondents believed that establishing organizational implementation standards in the country or province would significantly encourage increased solar energy use in Pishva County greenhouses. The average score of 3.55 indicates that technical and infrastructure potential for solar energy exists in the country for utilization in Pishva County greenhouses. Therefore, hypothesis 4 of the research is confirmed.

Policy-Making Adequacy

Results showed that among items related to the policy-making and management component, most respondents believed that lack of cooperation between government and private organizations significantly hinders solar energy implementation in greenhouses. However, improving support services such as insurance for tools used for implementing solar energy in greenhouses would significantly affect their willingness to take action. Additionally, government and private social media could significantly contribute to gaining information and modern technologies in this direction. The overall average score for the policy-making and management area was 3.25 and assessed at a moderate level. Although the score obtained is above the moderate level of 3, field observations suggest that policy-making and management by officials for solar energy utilization in Pishva County greenhouses is inadequate.

Economic Barriers

Results showed that high initial costs of solar energy use significantly negatively affect motivation to implement it in greenhouses, with an average score of 4.6 for this item. Additionally, concerns about initial costs, maintenance, repairs of solar systems, and price changes in total costs if they decide to use this energy are significant (average score of 4.4). High costs of installing and maintaining solar systems (mean=4.6) and banks' unwillingness to provide loans (mean=2.5) are major challenges. In the technical and infrastructure dimension, shortage of technical consultants (mean=2.52) and implementation standards (mean=3.99) are among these challenges.

Cultural and Social Obstacles

Results showed that among items related to the cultural and social area, Pishva County greenhouse farmers have minimal culture of accepting renewable energy. Solar energy planners have limited understanding of farmers' cultural and social issues (average score for this section was 2.51, below the moderate level of 3). Farmers in this area have minimal trust in solar energy and the results of its utilization in their greenhouses. Cultural resistance to accepting new technologies (mean=2.51) is among the obstacles to the management and cultural dimensions of solar energy implementation in Pishva County greenhouses.

CONCLUSIONS

Solar energy, as one of the best renewable resources, plays a key role in providing sustainable energy for greenhouses. Given fossil fuel limitations, environmental pollution, and rising energy costs, the use of solar systems (active/passive) for heating, cooling, and electricity generation in greenhouses is necessary. This technology not only reduces operational costs but also helps protect the environment by reducing dependence on fossil fuels. Studies show that solar energy can deliver up to 60 million BTU per hour to Earth and is a suitable alternative to fossil fuels.

However, the success of these systems requires financial support, farmer training, and infrastructure development. Therefore, given the importance of the topic, this research was conducted with the aim of assessing the feasibility of solar energy use in greenhouse units of Pishva County. The research method used was survey-based, and data were collected through a questionnaire with a 5-point Likert scale. The statistical population consisted of 386 greenhouse farmers, managers, and agricultural extension professionals.

Key findings showed that attitude toward solar energy was assessed at a moderate level (mean=3.08 out of 5). Belief in the impact of solar energy on greenhouse prosperity (mean=4.34) and reducing environmental threats (mean=4.24) was positively evaluated. However, managers' and farmers' attitudes toward practical use of this energy were lower than expected (mean=2.45 to 2.77).

Assessment of farmers' knowledge and awareness showed that farmers had minimal knowledge (mean=2.0 out of 5) of solar technologies, and there was an urgent need for training and access to information sources such as virtual platforms (mean=4.2).

Assessment of solar energy's impact on reducing costs showed that solar energy is effective in reducing fossil fuel costs, consistent with previous research. Respondents believed solar energy could reduce operational costs. However, high initial costs (mean=4.6) and lack of government financial support (mean=2.5) were the main obstacles. Assessment and measurement of the relationship between cooling/heating systems and cost-saving shows that theoretically, these systems can reduce costs by replacing fossil fuels. In practice, weak infrastructure and lack of specialized personnel (mean=4.4) have limited this possibility.

In the field of solar energy implementation in greenhouses by farmers, there are multiple challenges including economic, technical, infrastructure, and management dimensions. Technical and structural challenges are among the problems of solar energy use in greenhouses. To prepare suitable environmental conditions inside greenhouses, selecting greenhouse type and cover have fundamental importance in efficiency and productivity. Results of management and technical dimensions also show lack of cooperation among related organizations (mean=1.88).

In the final summary, it must be said that using solar energy in Pishva greenhouses is technically and environmentally justified; however, its successful implementation requires addressing economic barriers, increasing awareness, and improving institutional coordination. If these conditions are met, fuel costs can be reduced, productivity increased, and environmental sustainability achieved. This research

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can serve as a foundation for future policymaking in sustainable agriculture and renewable energy utilization.

Author's contribution
All authors contributed to the intellectual content, manuscript editing and read and approved the final manuscript.

Availability of data and materials
The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Conflict of interest
The authors declare that they have no conflict of interests.

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