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RAISING AWARENESS AMONG RURAL RESIDENTS ABOUT THE USES AND BENEFITS OF SOLAR ENERGY IN LIGHT OF ACHIEVING THE SUSTAINABLE DEVELOPMENT GOALS A STUDY OF SELECTED VILLAGES IN ASWAN GOVERNORATE

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ABSTRACT

This research discusses rural residents' awareness of solar energy uses and its economic, social, and environmental benefits, the concept of sustainable development, and the extent to which solar energy use achieves its goals. It also examines the significance of the relationship between certain studied characteristics of the respondents and their level of awareness of solar energy uses and benefits, as well as the multiple and regression correlations between these characteristics and their awareness of solar energy uses and benefits. Furthermore, it explores the differences in rural residents' awareness of solar energy uses and benefits when categorized based on the three villages studied. The study included 347 participants. Data were collected using frequencies, percentages, arithmetic means, standard deviations, Pearson's correlation coefficient, and t-test and F-test, along with standard partial regression coefficients and Cronbach's alpha, were also used in the data analysis. Statistical analyses revealed that 74.6% and 78.1% of respondents demonstrated low to moderate levels of awareness regarding the uses of solar energy and its economic, social, and environmental benefits, as well as its contribution to achieving the Sustainable Development Goals, respectively. Furthermore, the respondent's age, years of education, family size, knowledge sources, geographical exposure, organizational membership, and openness to new ideas all positively influenced the variation in their understanding of solar energy uses and its economic, social, and environmental benefits.

KEYWORDS: Solar energy – Economic, social, and environmental benefits of solar energy use – Sustainable development.

1 INTRODUCTION AND RESEARCH PROBLEM

Sustainable development, in its economic, social, and environmental dimensions, aims to meet the growing and evolving human needs of present generations while ensuring the ability to meet the needs of future generations, in a manner that guarantees the fulfillment of their aspirations for a better standard of living and the achievement of progress and well-being in all areas of life.

In our current era, numerous problems have emerged in most countries around the world as a result of the irrational development and use of natural resources, leading to the emergence of two major problems that threaten the achievement of sustainable development goals: namely pollution and the depletion of these natural resources. These problems are no longer merely local, confined to national borders, but have become regional and global issues, affecting people in both developing and developed countries alike and contributing to the threat to stability in these nations (Abdul-Tif et al., 2018, p. 225)

For this reason, it has become essential to care for and preserve natural resources and protect them from pollution and depletion in order to achieve the Sustainable Development Goals, which include environmental sustainability, supporting economic growth, reducing poverty, and achieving social justice. Perhaps one of the most important ways to achieve this is to rely on sustainable (renewable) energy as an alternative to traditional energy, the use of which countries—especially developed ones—are seeking to reduce. Solar energy is considered one of the key strategic options for meeting future energy needs, both locally and globally, as it is the backbone of the modern economy. It enables investments, the launch of new industries, and innovations to create job opportunities and inclusive growth for all, as it is available in most countries around the world. The solar energy that reaches the Earth in a single hour would be sufficient to power the entire world for a full year if it were properly harnessed. Every second, the sun emits 400 trillion trillion joules of energy, It is also a clean energy source that does not pollute natural resources; it is renewable and will last forever, a secure source that cannot be monopolized. Furthermore, it is locally sourced, which aligns with the reality of development in remote and rural areas, and it can be manufactured locally; its operation does not require complex machinery (Hopkins, 2021, p. 1). It also helps meet these areas' electricity needs at an affordable cost, leading to improved agricultural productivity and meeting household and agricultural needs, as well as providing better services to residents and enhancing daily economic and social activities (Al-Shayak, 2016, p. 3). It is therefore essential to increase access to renewable energy; there is no doubt that the development of renewable energy, including solar power, leads to a transformation of the fundamental pillars of development in many sectors, thereby improving quality of life and fostering stability and growth (Abdul Latif, 2018, p. 226).

Like other countries that have taken the initiative to focus on and increase investment in renewable energy sources particularly solar energyand to deploy them on a large scale, Egypt, as the most populous country in Africa and the Arab region, has a population that is growing faster than any other in the world. This steady population growth has led to a rapidly increasing demand for energy, placing a heavy burden on the country's energy resources. Egypt is set to become one of Africa's highest consumers of oil and gas, which is why we import both (World Bank, 2016).

Furthermore, Egypt's social, economic, and environmental development depends on the energy sector, which accounts for 13.1% of GDP. Consequently, the Egyptian government has adopted a strategy to diversify energy sources known as the Integrated and Sustainable Energy Strategy through 2035, aimed at ensuring the continued security and stability of the country's energy supply. This strategy involves achieving leadership, accelerating the development of renewable energy, and implementing energy efficiency measures to strike a balance between economic and social development and the protection of natural resources. Consequently, the energy sector will be able to meet the requirements of sustainable development regarding energy resources and maximize the utilization of these sources, This is the foundation upon which sustainable development is based (Bouamra, Tawakcht, 2023, p. 18).

The adoption of renewable energy technologies in Egypt is gaining momentum, and as of today, the total installed capacity of renewable energy sources stands at 3.7 gigawatts, comprising 2.8 gigawatts of hydropower and approximately 0.9 gigawatts of solar and wind power. In accordance with the Integrated and Sustainable Energy Strategy through 2035, the Egyptian government has set targets

for renewable energy to account for 40% of the total electricity supply required by 2035 (International Energy Agency, 2019, pp. 5–6). Based on an analysis of the Remap roadmap for the future of renewable energy in Egypt, renewable energy could provide 22% of total final energy supply by 2030.

Furthermore, given the declining costs of renewable energy technologies, their increased deployment will lead to a reduction in total energy costs of $900 million in 2030, equivalent to a cost reduction of $7 per MWh. This holds true even before taking into account the reduction in external costs resulting from air pollution, which will yield widespread social and health benefits valued at US$4.7 billion annually by 2030 (United Nations, 2022)

Egypt is also a country rich in resources and immense potential to achieve these ambitious goals, as it boasts an abundance of renewable energy resources and significant potential for expanding the use of renewable energy in general, including hydroelectric and wind power, and solar energy in particular. Egypt's geographical location between latitudes 22° and 36.31° north gives it some of the highest levels of solar irradiance in the world (State Information Service, 2021). This makes solar energy by far the best option among other energy sources.

Aswan Governorate is also distinguished by being one of the sunniest regions in the world during the day, with a high concentration of sunlight throughout the year, sometimes reaching nearly 4,000 hours of sunshine annually, making it a focal point in an integrated and sustainable energy strategy. Optimal utilization of these resources makes its solar power plants the most prolific in electricity production, not only locally but globally at present. Studies have shown that the high levels of sunshine in Aswan contribute to reducing carbon dioxide emissions by 2 million tons annually, which is equivalent to planting approximately 700,000 trees. This environmental achievement strengthens Egypt's position in achieving sustainable development goals and reducing dependence on traditional energy sources (United Nations, 2024).

Recognizing the scale of Egypt's energy challenges amid the ongoing shortage of conventional fuels and the need to secure additional energy sources, solar energy is readily available in nature. Egypt's natural characteristics position it not only as a consumer of solar energy but also as a future exporter, thereby enabling the achievement of sustainable development goals.

Therefore, it is necessary to raise rural residents' awareness of the applications of solar energy technology and its economic, social, and environmental benefits in light of achieving the Sustainable Development Goals, given that awareness has a clear impact on the acceptance of this technology. This can be achieved by conceptualizing the issues and bringing them together (Eagleton, (2011, p. 135). From this perspective, **the research problem can be summarized in the following questions:**

- To what extent are rural residents aware of the uses of solar energy?
- Is there a relationship between rural residents' awareness of solar energy uses and the achievement of sustainable development goals?
- What are the barriers that limit rural residents' use of solar energy?
- What are rural residents' suggestions for overcoming the barriers to solar energy use?

Research Objectives: Based on the research problem, the research objectives are defined as follows:

1- To identify the level of rural residents' awareness of solar energy applications and their benefits.

2- To identify the level of rural residents' awareness of the concept of sustainable development.

3- To identify the level of rural residents' awareness of how solar energy contributes to achieving the Sustainable Development Goals.

4- To determine the nature of the bivariate relationships between the independent variables studied and the levels of rural residents' awareness of solar energy applications and their benefits.

5- To determine the multiple correlation and regression relationships between the quantitative independent variables studied collectively and the levels of rural residents' awareness of solar energy uses and benefits.

6- To describe the nature of the correlation between the level of rural residents' awareness of solar energy uses and benefits and their level of awareness of solar energy's contribution to sustainable development goals.

7- Describe the differences in rural residents' awareness of solar energy applications and their benefits when classified based on the three study villages.

8- Identify the barriers that limit rural residents' use of solar energy.

9- Identify the most important proposals for overcoming the barriers to solar energy use from the perspective of rural residents.

Significance of the Research: The significance of this research lies in highlighting the importance of solar energy by emphasizing the role it plays in fostering development in remote rural areas, Furthermore, understanding rural residents' awareness regarding solar energy use and its economic, social, and environmental benefits in light of achieving sustainable development goals on a scientific and objective basis leads to the translation of information and knowledge in this field into sound behaviors, as awareness influences individuals' ability to set their goals and make decisions regarding their lives.

Research Hypotheses

1. There is a correlation between the quantitative independent variables under study, namely: (age of the respondent, number of years of education, household size, average electricity bill, agricultural land ownership, ownership of household appliances, ownership of agricultural machinery, ownership of farm animals, monthly household income, knowledge sources, geographic openness, opinion leadership, membership in organizations, willingness to adopt new technologies, attitude toward solar energy use, and informal social participation) and the levels of rural residents' awareness of solar energy uses and benefits.

2-There are significant differences between the mean scores of rural residents' awareness of solar energy uses and benefits when classified according to variables (household type, employment status, and occupation of the respondent).

3- The independent quantitative variables studied collectively make a significant contribution to explaining the variation observed in rural residents' awareness of solar energy uses and benefits.

4- There is a correlation between rural residents' awareness scores regarding solar energy uses and benefits and their awareness of solar energy's contribution to sustainable development goals.

5- There are significant differences in the mean scores of rural residents' awareness regarding solar energy uses and benefits when classified according to the three study villages.

Previous Studies

The following is an overview of the most significant of these studies:

Iman Mahfouz's study (2005) aimed to demonstrate the relationship between energy and economic development. The study found that nuclear energy is the most capable source of meeting future electricity needs, followed by wind energy, then solar energy, and that new and renewable energy sources are capable of generating a national surplus.

Bronough and Tallahasee's study (2009) aimed to identify the positive economic impact of solar energy and concluded that investment in solar energy yields numerous positive economic effects, including: the creation of many permanent, high-paying jobs, as solar energy production supports 15 to 30 jobs per megawatt produced, which impacts economic development; the construction of large-scale projects will lead to lower prices and increased innovation through economies of scale, thereby stimulating creativity in products, manufacturing, and construction methods.

The study by Sheehy, Nate (2010) aimed to identify the role of renewable energy in economic development and concluded that renewable energy in general, and solar energy in particular, helps achieve economic development by establishing an environmental and economic balance, increasing the elasticity of demand for fossil fuel products when their prices rise, and creating a new investment market that opens up numerous investment projects and job opportunities.

Al-Sharqawi's study (2011) aimed to identify the economic dimensions of solar energy use in Egypt and concluded that solar energy is an economic resource with the economic conditions necessary for its use as an alternative energy source to traditional resources, and that solar energy can be integrated with these sources to achieve economic efficiency in their use and extend the lifespan of traditional sources for the benefit of future generations; and that investment in solar energy systems has become necessary due to the increasing demand for electricity while energy production from traditional sources has begun to decline.

Susan Al-Kanani's study (2016) aimed to identify the role of solar energy in achieving the Sustainable Development Goals globally in general and in Egypt in particular, and concluded that: global energy consumption—both current and future—is growing at a faster rate than production, achieves a production capacity many times greater than that of all other energy sources combined; the decreasing cost of photovoltaic solar cells; it contributes to solving the problem of unemployment; and the continuous increase in Egypt's energy imports. It yields numerous benefits, such as reducing the environmental impact of energy, combating poverty, improving quality of life, securing energy and electricity supplies for the population, conserving traditional energy sources, providing water through desalination of seawater and sustainable urban development in new cities, rationalizing and heating water, treating wastewater, and reducing Egypt's electricity budget costs.

A study by Abdullatif, et al. (2018) aimed to examine Egyptian citizens' attitudes toward the use of solar energy, identify the areas where solar energy is utilized instead of conventional energy, and clarify the main reasons for their preference for solar energy. The study revealed that the use of solar energy varies according to need and sector, particularly in the agricultural sector, and that the majority of installation projects were in the field of agricultural development. The study also noted that the use of solar energy has evolved in recent years due to the efforts of all state institutions to replace traditional energy with renewable energy in general, and solar energy in particular, to avoid the risks associated with traditional energy, especially pollution. Furthermore, the study highlighted the importance of solar energy for achieving sustainable development and environmental security.

Study (2021) Hannan et al. aimed to study the impact of renewable energy and artificial intelligence on achieving the Sustainable Development Goals (SDGs). The results indicated that renewable energy has a positive impact on achieving 75 of the SDGs. Additionally, artificial intelligence can assist renewable energy in achieving 42 of the 169 goals.

The study by Habiba et al. (2022) aimed to identify the level of farmers' orientation toward the use of agricultural and residential solar energy technology, as well as the independent variables correlated with the degree of farmers' orientation toward the use of agricultural and residential solar energy technology. It found that the level of farmers' orientation toward the use of agricultural and residential solar energy technology was 8.55%, and that there is a significant relationship between the degree of farmers' orientation toward the use of agricultural and residential solar energy technology and each of the following independent variables: the respondent's age, number of family members, years of education, average electricity bill, ownership of household appliances, participation in agricultural extension activities, level of ambition, involvement in local community affairs, membership in organizations, adequacy of the family's monthly income, and the respondent's employment and professional status.

Ghanem's Study (2023) aimed to examine the impact of renewable energy production on the level of sustainable development in Egypt during the period (1990–2020), relying on weak sustainability (real per capita wealth) and strong sustainability (ecological deficit per capita) to express Egypt's level of sustainable development. It found a nonlinear relationship between the level of renewable energy and real wealth per capita, whereby the impact of renewable energy on environmental sustainability becomes positive when renewable energy exceeds 93.2% of total energy. as a 1% increase in renewable energy production relative to total energy will lead to an increase in per capita real wealth of $158.8 per person and a reduction in the ecological deficit of 0.1004 global hectares per person in the long term.

Al-Anzi's study (2023) aimed to highlight the role of renewable energy in achieving sustainable development. It concluded that the utilization of renewable energy is the essence of the sustainable development process, the core of comprehensive development, and an effective tool for it through respect for the ecosystem, meeting future needs, and achieving long-term development by relying on present capabilities.

A review of previous studies reveals that most of them focused on the role of renewable energy in achieving sustainable development, while some focused solely on the economic aspect of development and neglected the social aspect. However, it is noteworthy that few studies have examined the social and environmental benefits of solar energy. Therefore, the current study focused on the economic, social, and environmental benefits of solar energy by assessing rural residents' awareness of its uses and benefits, as well as their understanding of its role in achieving sustainable development. Undoubtedly, studying rural residents' awareness of the uses of this renewable energy is of particular importance in designing awareness and guidance programs that meet their needs and enhance the economic and social benefits of this energy in rural communities, which ultimately contributes to sustainable rural development.

2 THEORETICAL APPROACHES OF THE STUDY (THEORETICAL PERSPECTIVES ON THE CONSCIOUSNESS OF RURAL PEOPLE):

- Functionalist theory: This theory, whose foundations were laid by Auguste Comte and Herbert Spencer, emphasizes the fundamental idea that every component of the social structure performs an important function, through which it seeks to satisfy the needs of human beings in society. One of the fundamental principles affirmed by this theoretical approach is that society always strives to achieve balance and harmony among its parts; thus, if an imbalance occurs in any part, it affects the rest of society and its stability as a whole (Al-Ramih, 2021, p. 35).

The name of functionalist theory is closely associated with Parsons, who posited that the social system of action stems from specific needs, the fulfillment of which is entrusted to the parts responsible for them, and that the social system strives to maintain a state of stability through balanced relationships between its parts, just as occurs within the body of a living organism. Here, Parsons opened the door to the idea of adaptation as a means of achieving equilibrium (Abdel Rabbo et al., 2022, p. 169).

In his functional theory, Malino-Vesky-Prinsloo also focuses on the aspect of adaptation, which is one of the fundamental principles of functional constructivism: adaptation to the environment, meaning society's ability to adapt to external and internal changes to ensure its continuity. Here, the overarching goal or function is society's adaptation to its surroundings and new changes, (Tilewin, 2011, p. 87).

In light of this theory, rural society is viewed as a social system that constantly strives to maintain stability and balance. This is achieved when its components and structures—whether families or economic, educational, or political institutions—fulfill their functions. However, in the face of conflicting material changes, a disruption in the functioning of these components may occur, thereby affecting the society's equilibrium and stability unless it attempts, in one way or adapt to the social environment and its material changes. Therefore, rural communities' awareness of solar energy applications is considered a mechanism for adapting to rapid economic changes and rising costs of traditional energy, enabling members of rural society to meet the challenges of rural development and achieve sustainability.

-Theory of Innovation Diffusion: This theory explains and interprets how innovations spread among a population likely to adopt them. Innovations include modern technologies, new practices, or new ideas. Furthermore, those who adopt these innovations can be individuals or organizations, and at the macro level (the population). the theory of innovation diffusion refers to the dissemination of creative innovations as a communication process through which people in the social system learn about and become familiar with various new innovations and benefit from the potential outcomes of these innovations via communication channels such as the media, working to persuade them to adopt these innovations (Pachirgi, 2018, pp. 92–93).

The process of adopting and diffusing technological innovations consists of five sequential stages: the awareness or knowledge stage, the interest or persuasion stage, the decision stage, the implementation stage, and the adoption stage (Abdul-La, 2014, p. 93).

In light of this theory, it can be said that the adoption or dissemination of any technological innovation, such as solar energy, goes through successive stages. It begins with the awareness stage, in which individuals become aware of its specific characteristics and the benefits it can provide, followed by a stage of interest and persuasion, during which the individual may develop a positive or negative attitude toward it based on their perception of its advantages, ease of use, and benefits, This is followed by a decision to adopt the technology, particularly by early adopters or community leaders who play an active and influential role in promoting collective awareness of solar energy among the vast majority of rural residents.

Thus, rural residents' awareness of the uses of solar energy, its benefits, and its role in sustainable development is simply the result of the process of adoption and diffusion of this innovation within rural society.

3 RESEARCH METHODOLOGY

First: Scientific Terminology and Procedural Concepts:

A. Scientific Terminology:

- Solar Energy: Radiation captured from sunlight and converted into energy for use as electricity or other forms of energy; or the electromagnetic radiation from the sun that reaches the Earth and is converted into energy (Rosser, 2021, p. 2).

Sustainable Development:

Sustainable development is defined as "the process that recognizes the need to achieve economic growth compatible with the environment's capacity, based on the premise that economic development and environmental conservation are complementary rather than contradictory processes" (Ghanem and Abu Zant, 2007, p. 25). Sustainable development can only be achieved through the integration and close interconnection of the economic, social, and environmental aspects of development (Farahatia and Kamal, 2008, p. 282).

-**Consciousness: or Consciousness Awareness:**

Shaldan defined consciousness (2006, p. 11) as a mental state through which a person perceives the world around them, and defines it as a person's perception and understanding of themselves, their external world, and their sense of belonging as a result of reflecting on the objective world, work, and action. Consciousness is linked to behavior because it leads to the adoption of practical individual and collective stances, and language also plays an important role in consciousness.

Meanwhile, Ma'ruf (2010) views it as perception based on sensation and knowledge that aids in making specific decisions regarding a particular issue. As for Rabab Muhammad and Heba Muhammad (2020), they defined consciousness as a state of perception and understanding in which a person directly perceives themselves and their surroundings, and it is the foundation of all knowledge.

B. Procedural Concepts:
-Awareness of solar energy applications and their economic, social, and environmental benefits: This refers to the research subject's understanding and familiarity with information and facts related to solar energy, through which they can adopt a healthy lifestyle and practices that enable the achievement of sustainable development goals.

Second: Research Area, Scope, and Sample:
Aswan Governorate was selected as the geographical area for this study, and three districts were randomly selected from among the governorate's seven districts, namely: Daraw, Kom Ombo, and Edfu. Then, one village was randomly selected from each district: Banban Qibli, Fares (villages with solar power stations), and Al-Ziniqa (a village without solar power stations), in that order. The number of rural households in the selected villages was then counted, resulting in a total of 6,870 rural households included in the study. To calculate the sample size, the Krejcie-Morgan (1970) was used to calculate the sample size, resulting in a sample of 347 households. This number was distributed among the three villages according to each village's proportion of the total study population, as shown in Table 1.

Table (1) Number of Respondents According to the Research Sample

Number of items in the sample	Total number of entries	The Village	The Center
109	2160	Banban Qibli	Daraw
131	2600	Faris	Kom Ombo
107	2110	Al-Zaniqa	Edfu
347	6870	Total	

Source: Information and Decision Support Center, Aswan Governorate, Unpublished Data, 2025.

Data was collected using a questionnaire administered through personal interviews with respondents during November and December 2025.

Third: Research Variables and How They Were Measured:
- Age of the respondent: This refers to the number of full years from the respondent's date of birth to the date of data collection. It is expressed as an absolute number in years, with a mean of 41.85 years and a standard deviation of 9.91.
- Number of years of education: This refers to the number of years of formal education received by the respondent or his wife at the time of data collection. It is expressed as an absolute number in years. The arithmetic mean was 9.52 years, with a standard deviation of 6.43.
- Household size: This refers to the number of members in the respondent's household, including the spouse, children, and other relatives who reside together in a single dwelling and share a common social and economic life at the time of data collection. The arithmetic mean was 6.41 individuals, with a standard deviation of 1.56.
- Family type: This refers to whether the respondent's family consists of only two generations (nuclear), more than two generations, or includes multiple wives (extended/compound). It was measured using a nominal scale with two categories, coded as (2, 1) respectively.
- The respondent's employment and occupational status: This refers to whether the respondent works in any paid occupation outside the home, whether in the public or private sector, or is unemployed. It was measured using a nominal scale consisting of the two previous categories and coded as (2, 1) in order.
- Average electricity bill: This was calculated based on the estimated monthly electricity bill in Egyptian pounds. The arithmetic mean was 299.86 pounds, with a standard deviation of 97.99.
- Agricultural land holdings: This refers to the total area of agricultural land in qirats used by the respondent's household for agricultural production, whether owned, leased, or shared, and was expressed as an absolute number in qirats at the time of data collection. The arithmetic mean was 2.96 qirats, with a standard deviation of 1.01.
- Household appliance ownership: This refers to the number of household appliances owned by the respondent's household. The scores were then summed to express the total score for household appliance ownership. The arithmetic mean was 12.88 appliances, with a standard deviation of 2.46.
- Ownership of agricultural machinery: This refers to the number of agricultural machines owned by the respondent's household. The scores were then aggregated to calculate the total score for agricultural machinery ownership, with an arithmetic mean of 1.25 machines and a standard deviation of 0.91.
- Ownership of farm animals: This refers to the number and types of livestock owned or held by the respondent's household, represented by the following categories: buffalo, local cattle, Friesian cattle, sheep, goats, and donkeys. These were measured by converting them into livestock units using the following scales: buffalo and Friesian cows:

1.25 livestock units; local cows: 1 livestock unit; sheep: 0.2 livestock units; goats: 0.07 livestock units; and donkeys: 0.75 livestock units (Suleim, 2015, p. 155). The livestock units were then summed to represent the total livestock ownership score, with an arithmetic mean of 2.78 livestock units and a standard deviation of 2.10.

- Monthly household income: This refers to the total cash income of the household, estimated monthly in Egyptian pounds at the time of data collection. The arithmetic mean was 6,060.52 pounds, with a standard deviation of 1,173.29.

- Knowledge sources: This refers to the sources to which the respondent is exposed and from which they derive their knowledge regarding the uses of solar energy and its benefits in light of achieving the Sustainable Development Goals and the extent of their commitment to this. It was measured through six sources: the Internet, television programs, written sources (newspapers, magazines, scientific books), family and friends, extension service officials, and solar energy companies. This was measured using a scale consisting of four responses (always, sometimes, rarely, never), and scores of 4, 3, 2, 1) respectively, and the extent of benefit from the source was rated on a scale of 3 responses (to a great extent, to a moderate extent, to a small extent). The scores were then summed to obtain the total score for the knowledge sources. The arithmetic mean was 15.02 points, with a standard deviation of 2.98.

-Geographical mobility: This refers to the extent to which the respondent visits (neighboring villages, the district to which the village belongs, other districts within the governorate, and other governorates). It was measured using four statements on a four-point scale (always, sometimes, rarely, never), with scores of 4, 3, 2, and 1 assigned in that order. The scores were then summed to calculate the total score for geographic openness. The arithmetic mean was 9.29 points, with a standard deviation of 2.07.

-Leadership: This refers to the extent to which the respondent possesses leadership qualities, their influence on fellow farmers, and their ability to provide them with advice and guidance. It was measured using four statements on a scale consisting of four responses (always, sometimes, rarely, never). Scores of 4, 3, 2, and 1 were assigned in that order. The scores were then summed to calculate the total score for leadership. The arithmetic mean was 10.71, with a standard deviation of 2.71.

-Membership in organizations: This refers to the extent of the respondent's participation in various organizations, including: (Agricultural Cooperative Association, Village Local Council, civil, religious, or charitable association, and political party), on a scale consisting of four responses: (not a member, regular member, committee member, board member), with scores of 1, 2, 3, and 4 assigned in that order. The scores were then summed to obtain the total score for organizational membership. The arithmetic mean was 9.04, with a standard deviation of 2.69.

(Agricultural Cooperative Association, Local Community Development Association, School Parent-Teacher Association, political party).

- Readiness to adopt new things: This refers to the extent to which the respondent is willing and inclined to adopt anything new (technological innovations), and was measured using (8) statements on a scale consisting of (3) response options: (Agree, Somewhat Agree, Disagree). Scores of (3, 2, 1) were assigned in order for positive statements, and scores of (1, 2, 3) were assigned in order for negative statements. The reliability of the scale was assessed using the alpha coefficient, which was found to be 0.79—a value indicating the scale's reliability. The scores were summed to yield the total score for readiness to adopt the innovation. The arithmetic mean was 16.74, with a standard deviation of 3.26.

- Attitude toward solar energy use: This refers to the respondent's willingness and inclination to use solar energy, whether at home or on a farm. It was measured using five statements on a three-point scale (Agree, Somewhat agree, Disagree), with scores of 3, 2, 1), respectively. The scale's reliability was estimated using the alpha coefficient, which was 0.78—a value indicating the scale's reliability. The scores were summed to obtain the total score for the tendency toward solar energy use. The arithmetic mean was 10.28 points, with a standard deviation of 2.46.

- Informal social participation: This refers to the respondent's participation in everyday social activities and social events to strengthen social ties and relationships among individuals and the communities in which they live, as well as the extent of their consistency in doing so. It was measured using six statements on a scale consisting of four response options: (Always, Sometimes, Rarely, Never), with scores of 4, 3, 2, and 1 points, respectively. The scores were summed to yield the total score for informal social participation. The mean score was 16.75, with a standard deviation of 3.42.

-Awareness of solar energy applications and their benefits: This refers to the respondent's understanding and familiarity with accurate information regarding the use of solar energy, whether at home or on a farm, and its economic, social, and environmental benefits. It was measured using 39 statements distributed across three categories: domestic uses (5 statements), agricultural uses (13 statements), economic, social, and environmental benefits of solar energy use for individuals, society, or the state (21 items), using a 3-point response scale: (Agree, Somewhat Agree, Disagree). Scores were assigned as (3, 2, 1) respectively. The reliability of the scale measuring solar energy uses and their benefits was assessed using the alpha coefficient, which was found to be 0.926—a value indicating the scale's reliability. Scores were summed across each dimension to yield the total score for solar energy uses and their economic, social, and environmental benefits. The arithmetic mean was 80.06 points, with a standard deviation of 17.78.

-Concept of sustainable development: This was measured by asking respondents about their understanding of sustainable development through five statements, which were scored 1, 2, 3, 4, and 5, respectively.

-The Contribution of Solar Energy to Sustainable Development Goals: This was measured by asking respondents about the contribution of solar energy to sustainable development goals through 16 statements, using a 3-point scale with the following responses: (Agree, Somewhat Agree, Disagree). Scores of 3, 2, and 1 were assigned in that order. The reliability of the sustainable development scale was estimated using the alpha coefficient, which was found to be 0.75, indicating the scale's reliability. The scores were summed to represent the total score for sustainable development. The arithmetic mean was 32.31 points, with a standard deviation of 5.55.

-Barriers to solar energy use: This was measured by asking respondents to rate the extent to which difficulties limit the use of solar energy, whether at home or on the farm, using a scale consisting of 13 barriers. The response categories were "Agree," "Somewhat agree," and "Disagree," and scores of 3, 2, and 1 were assigned, respectively. Frequencies and percentages were calculated and ranked in descending order accordingly.

- Suggestions for addressing barriers to solar energy use: This was measured by asking the respondent if they had suggestions for addressing the challenges that limit the use of solar energy, using a scale consisting of 7 suggestions. The response categories were "Agree," "Somewhat agree," and "Disagree," and scores of 3, 2, 1) respectively. Frequencies and percentages were calculated and ranked in descending order accordingly.

Fourth: Statistical Analysis Tools: Frequency tables and percentages, arithmetic mean, standard deviation, Pearson's correlation coefficient, t-tests, and F-tests were used, in addition to standard partial regression coefficients and Cronbach's alpha.

Fifth: Methodology: Descriptive and analytical methods were used.

Sixth: Statistical Hypotheses: To statistically test the validity of the research hypotheses, they were formulated in their null form.

VII. Description of the Research Sample

Table (2) presents a description of the characteristics of rural residents, showing that one-fifth of rural residents (40.1%) fall into the middle age group (39–51 years) and have 9–15 years of education, while nearly one-fifth (38.9%) have an average household size ranging from 6 to 7 members, half (50.4%) live in extended families, nearly one-fifth of rural residents (39.8%) are self-employed, and more than one-fifth (44.4%), (45.5%) have an average monthly electricity bill and agricultural land holdings in the medium range (250–350) pounds and (2.5–3.5) feddans, respectively; one-fifth (43.5%) have medium levels of household appliances; and more than one-third (37.7%), (37.5%) own one agricultural machine, and their livestock holdings are in the medium category; two-thirds of rural residents (64%) have a monthly household income in the medium category (5,300–7,100) pounds, and more than half of rural residents have moderate knowledge resources (58.8%), while half have moderate levels of geographic openness and opinion leadership (50.4%), (49.3%) respectively. Nearly half of rural residents have low organizational membership (46.1%), and nearly half (47.6%) have moderate readiness to adopt new technologies. One-fifth of rural residents (41.2%) have moderate interest in using solar energy, and finally, one-fifth of rural residents (42.7%) have high levels of informal social participation.

Table (2) Numerical and Percentage Distribution of Rural Residents According to Their Personal Characteristics

Independent variables	Number	(%)	Independent variables	Number	(%)
1. Age of the subject			**10. Ownership of farm animals**		
Low (25–38) years	131	37,7	No livestock	76	21,9
			Small (fewer than 3) livestock units	130	37,5
Medium (39–51) years	139	40,1	Medium (4–5) livestock units	120	34,6
High (52–65) years	77	22,2	Large (6 or more) livestock units	21	6
Total	347	100	Total	347	100
2. Number of years of education			**11. Monthly household income**		

Low (under 9 years)	80	23,1
Medium (9–15 years)	144	41,5
High (16 years and older)	123	35,4
Total	347	100
3. Household size		
Low (fewer than 6) people	91	26,2
Medium (6–7) people	135	38,9
High (8 or more) people	121	34,9
Total	347	100
4. Type of family		
Simple	Low (4–8) points	Low (4–8) points
Extended / Compound	Medium (9–11) points	Medium (9–11) points
Total	High (12–16) points	High (12–16) points
5. The respondent's employment and professional status		
Government employee	73	21
Self-employed	138	39,8
Skilled worker	38	11
Farm worker	86	24,8
Unemployed	12	3,4
Total	347	100
6. Average electricity bill		
Low (less than 250) pounds	93	26,8
Medium (250–350) pounds	154	44,4
High (400 pounds or more)	100	28,8
Total	347	100
7. Agricultural Land Tenure		
Small (less than 2.5 carats)	100	28,8
Medium (2.5–3.5 carats)	158	45,5
Large (4 carats or more)	89	25,6
Total	347	100
8. Size of household appliances		
Low (less than 12)	118	34
Moderate (12–14)	151	43,5
High (15 or more)	78	22,5
Total	347	100
9. Ownership of agricultural machinery		
No inventory	80	23,1
1 unit	131	377
2 units	103	29,7
3 units	33	9,5
Total	347	100

Low (less than 5,200) pounds	86	24,8
Medium (5,300–7,100) pounds	197	56,8
High (7,200) pounds	64	18,4
Total	347	100
12. Knowledge Sources		
Low (6–12) points	88	25,4
Medium (13–17) points	204	58,8
High (18–24) points	55	15,8
Total	347	100
13. Geographic Expansion		
Low (4–8) points	Low (4–8) points	Low (4–8) points
Medium (9–11) points	Medium (9–11) points	Medium (9–11) points
High (12–16) points	High (12–16) points	High (12–16) points
Total	Total	Total
14. Opinion Leadership		
Low (4–8) points	109	31,4
Medium (9–11) points	171	49,3
High (12–16) points	67	19,3
Total	237	100
15. Membership in Organizations		
Low (4–8) points	160	46,1
Medium (9–11) points	149	42,9
High (12–16) points	38	11
Total	347	100
16. Preparing to Implement the New System		
Low (8–13) degrees 122 3 60 17,100	122	35,1
Medium (14–18) degrees 165 47,6	165	47.6
High (19–24) degrees	60	17.3
Total	347	100
17. The Trend Toward Solar Energy Use		
Low (5–8) points	97	28
Medium (9–11) points	143	41,2
High (12–15) points	107	30,8
Total	347	100
18.Informal social participation		
Low (6–12) degrees 64 18,4	64	18,4
Medium (13–17) degrees	135	38.9
High (18–24) degrees	148	42.7
Total	347	100

RESULTS AND DISCUSSION

First: Rural Residents' Level of Awareness Regarding Solar Energy Applications and Benefits:

Table (3) presents rural residents' level of awareness regarding residential solar energy applications, The results showed that more than half of rural residents (53.6%) have moderate awareness of solar energy applications and their benefits, while 25.4% have high awareness, compared to 21% who have low awareness of solar energy applications and their benefits.

Table (3): Distribution of Rural Residents by Level of Awareness of Solar Energy Applications and Their Benefits

%	Number	Categories
21	73	Low (39–65)
53,6	186	Medium (66–90)
25,4	88	High (91–117)
100	347	Total

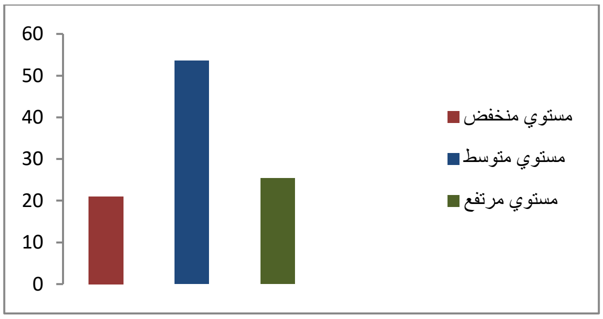

Figure 1: Distribution of rural residents by level of awareness regarding solar energy applications and their benefits

For further clarification, we present the percentages for each statement regarding rural residents' awareness of solar energy applications and their benefits, as shown in Table 4 below:

A. Residential solar energy applications:

The results showed that, based on the arithmetic mean, the top-ranked statement was "home lighting" with an arithmetic mean of 2.47, while the lowest-ranked statement was "charging any battery-powered device" with an arithmetic mean of 1.80.

B. Applications of solar energy in agriculture:

The results showed the ranking of the statements based on their arithmetic mean. In first place was "generating electricity for agriculture," with an arithmetic mean of 2.40 points, while in last place was "adjusting farming seasons to align with the annual seasons," with an arithmetic mean of 1.72 points.

Table (4): Percentage distribution of rural residents' responses to statements regarding awareness of solar energy uses and benefits

Arithmetic mean	Awareness Campaigns on Solar Energy Applications and Benefits						Phrases
	Disagree		Somewhat agree		Agree		
	%	Number	%	Number	%	Number	
A. Residential Solar Energy Applications							
2,47	21,3	74	10,1	35	68,6	238	- Home lighting
2,34	23,9	83	18,2	63	57,9	201	- Powering electrical appliances
2,18	37,2	129	7,8	27	55	191	- Cooking with a solar cooker
2,05	38,6	134	18,2	63	34,2	150	- Heating water with a solar water heater to meet various household needs
1,80	54,5	189	10,9	38	34,6	120	- Charging any battery-powered device
2,17							Overall average
B. Applications of solar energy in agriculture							
2,40	23,1	80	13,5	47	63,4	220	- Generating electricity for agriculture
2,21	33,4	116	11,8	41	54,8	190	-(Powering pumps) for crop irrigation
2,17	31,1	108	20,5	71	48,4	168	-Powering agricultural equipment and machinery
2,10	39,5	137	11,5	40	49	170	-Powering ventilation, cooling, and heating fans
2,06	39,5	137	15,3	53	45,2	157	- Cooling agricultural products
2,03	43,8	152	9,5	33	46,7	162	- Drying crops to preserve them longer without spoilage
2,00	44,4	154	12,1	42	43,5	151	- Milling grains
1,99	46,1	160	8,4	29	45,5	158	- Desalination of water for drinking purposes
1,82	50,7	176	17	59	32,3	112	- Drying seeds to increase their viability
1,80	53,3	185	13,3	46	33,4	116	- Distilling water in areas with limited clean water supplies
1,78	57,6	200	7,5	26	34,9	121	- Pasteurizing milk on livestock farms
1,76	57,9	201	8,4	29	33,7	117	- Farming using greenhouses or plastic tunnels
1,72	59,4	206	8,9	31	31,7	110	- Adjusting planting seasons to align with the annual cycle
1,99							Overall average
C. The Social, Economic, and Environmental Benefits of Solar Energy							
2,59	13,5	47	14,4	50	72	250	- Creating job opportunities and eliminating unemployment
2,53	16,4	57	14,4	50	69,2	240	- Reducing the monthly cost of regular electricity bills
2,37	25,1	87	13,3	46	61,7	214	- Providing electricity to remote and rural areas at an affordable cost
2,31	26,5	92	15,9	55	57,6	200	- Increasing the value of properties equipped with solar energy systems
2,26	30,8	107	12,7	44	56,5	196	- Protecting consumers from oil price fluctuations
2,23	32,3	112	12,4	43	55,3	192	- Generating and increasing income and improving the standard of living for community members
2,21	33,4	116	11,8	41	54,8	190	- Reducing electricity consumption from the grid
2,12	33,7	117	21	73	45,2	157	- Reducing the cost of energy-related services
2,11	34,6	120	19,9	69	45,5	158	- Transitioning from reliance on non-commercial energy sources to reliance on commercial sources
2,09	39,8	138	11,5	40	48,7	169	- The sun is an inexhaustible source of energy that can be harnessed almost anywhere
2,07	38,3	133	16,1	56	45,5	158	- Local sources are suitable for the realities and development needs of remote and rural areas
2,06	38	132	17,6	61	44,4	154	- Ensuring that industry and commercial projects comply with environmental conservation standards

2,04	43,2	150	9,8	34	47	163	Environmental sustainability (reducing harmful greenhouse gas emissions)
2,03	43,8	152	9,5	33	46,7	162	- Reducing treatment costs resulting from environmental pollution
1,92	43,2	150	21,3	74	35,4	123	- Expansion (increased energy supply) in areas not connected to the main power grid
1,77	57,1	198	92	32	33,7	117	- Provision of the energy necessary for drinking water supply and sanitation services
1,75	58,5	203	8,1	28	33,4	116	- Revitalization of the local economy and improvement of development indicators
1,73	54,8	190	17,3	60	28	97	- Requires simple and low-cost maintenance compared to traditional energy sources
1,71	58,2	202	12,7	44	29,1	101	- Improvement of agricultural productivity and expansion of irrigation methods
1,70	60,5	210	9,2	32	30,3	105	- The technology used is straightforward and can be manufactured locally
1,68	61,7	214	8,3	29	30	104	- Makes a significant contribution to enhancing daily economic and social activities
2,06							- Accelerates programs related to water supply, healthcare, education, and communications

C. Benefits of Solar Energy Use:

The results showed that, based on the arithmetic mean, the top-ranked statement was "creating job opportunities and eliminating unemployment," with an arithmetic mean of 2.59 points, while the lowest-ranked statement was "accelerating programs related to water supply, healthcare, education, and communications," with an arithmetic mean of 1.68 points.

D. Ranking of solar energy applications and their benefits according to the weighted arithmetic mean:

The data in Table (4) show that the household uses category, measured by 5 statements, ranked first with a weighted average of 2.17 points, followed in second place by the benefits of solar energy uses category, measured by 21 statements with an average of 2.06 points, and in last place was the agricultural solar energy uses dimension, which was measured using 13 statements with an average of 1.99 points, respectively.

Second: Sustainable Development

A. The Concept of Sustainable Development:

The results in Table (5) show that more than half of rural residents (57.1%) stated that the concept of sustainable development is "the rational and prudent use of available local potential and resources," about two-fifths of rural residents (40.3%) stated that it is "meeting the needs of present generations," about one-third (32.6%) stated that it is "ensuring the needs of future generations," and slightly more than one-quarter (27.4%) stated that it is "achieving long-term development," and finally, 8.9% stated that it "consists of three elements of sustainability: economic, social, and environmental," while approximately one-fifth of rural residents (21%) were aware of the integrated concept of sustainable development.

Table (5) Distribution of Rural Residents' Responses According to Their Awareness of the Concept of Sustainable Development

%	**Number n = 347**	**Key Concepts of Sustainable Development**
57,1	198	The rational and prudent use of available local capabilities and resources
40,3	140	Meeting the needs of present generations
32,6	113	Ensuring the needs of future generations
27,4	95	Achieving long-term development
8,9	31	Sustainability consists of three elements: economic, social, and environmental
21	73	All of the above

B. Rural Residents' Awareness of Solar Energy's Contribution to Sustainable Development Goals:

Table (6) presents rural residents' awareness of solar energy's contribution to sustainable development goals. The results indicate that half of rural residents (49.3%) have an average level of awareness regarding solar energy's contribution to sustainable development goals, 21.9% have a high level of awareness, while 28.8% were found to have a low level of awareness.

Table (6): Distribution of Rural Residents by Level of Awareness of Solar Energy's Contribution to Sustainable Development Goals

%	**Count**	**Categories**
28,8	100	Low (16–26°)
49,3	171	Moderate (27–37°)
21,9	76	High (38–48°)
100	347	Total

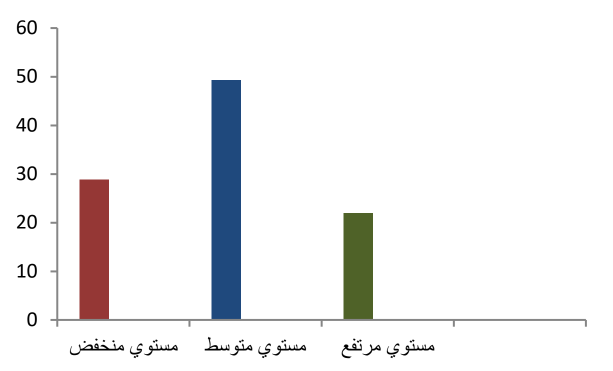

Figure 2: Percentage distribution of rural residents' responses based on their awareness of solar energy's contribution to the Sustainable Development Goals

For further clarification, we present the results for each statement regarding rural residents' awareness of the relationship between solar energy and the achievement of the Sustainable Development Goals, as shown in Table 7 below:

The results showed that, based on the arithmetic mean, the top-ranked statement was: Solar energy production helps reduce poverty and increase access to necessities such as food and shelter, with an arithmetic mean of 2.88 points, while the lowest-ranked statement was: Developing and implementing pilot projects for various suitable renewable energy systems, with an arithmetic mean of 1.53 points.

Table (7): Percentage distribution of rural residents' responses to statements regarding awareness of solar energy's contribution to sustainable development goals

Arithmetic mean	Awareness of the Role of Solar Energy in Achieving the Sustainable Development Goals						Phrases
	Disagree		Somewhat agree		Agreed		
	%	Number	%	Number	%	Number	
2,88	4,3	15	3,7	13	91,9	319	- Solar energy production helps reduce poverty and increase access to basic necessities such as food and shelter
2,20	34,3	119	11,5	40	54,2	188	- Solar energy helps meet a community's long-term energy needs
2,17	27,4	95	28,5	99	44,1	153	- Sustainable development depends on producing energy in an environmentally sound manner
2,15	28,5	99	28	97	43,5	151	- Solar energy provides access to energy for communities that previously lacked it
2,12	31,1	108	26,2	91	42,7	148	- Solar energy production helps increase productivity and stimulate economic growth
2,09	39,5	137	12,1	42	48,4	168	- Solar energy production helps mitigate the negative effects of climate change
2,03	43,8	152	9,5	33	46,7	162	- It helps diversify energy supplies and reduce dependence on imported fuels
2,01	43,2	150	12,4	43	44,4	154	- The future of the Egyptian economy is linked to solar energy production
1,99	46,1	160	8,4	29	45,5	158	- Energy production and consumption are at the heart of economic development and social progress
1,98	46,7	162	8,1	28	45,2	157	- Adapting to solar energy ensures a better future
1,97	40,6	141	22,2	77	37,2	129	- It combines environmental protection with economic growth and social well-being
1,92	42,4	147	23,6	82	34	118	- It reduces the incidence and severity of human health problems (improving public health)
1,80	53,3	185	13,3	46	33,4	116	- Does not cause climate or environmental damage, unlike (traditional sources) such as oil, coal, and natural gas
1,76	57,9	201	8,4	29	33,7	117	- Improves access to modern and sustainable energy
1,71	60,5	210	8,4	29	31,1	108	- Its environmental, social, and economic benefits help achieve sustainability goals
1,53	65,4	227	15,9	55	18,7	65	- Develop and implement pioneering projects for various suitable renewable energy systems

Third: The bivariate relationships between the quantitative independent variables under study and the levels of rural residents' awareness of solar energy applications and their benefits in light of achieving the Sustainable Development Goals:

1. Describe the nature of the relationships between the quantitative independent variables under study and the levels of rural residents' awareness of solar energy applications and their benefits:

The first statistical hypothesis states that "there is no correlation between the quantitative independent variables under study, namely: (respondent's age, number of years of education, household size, average electricity bill, agricultural land ownership, ownership of household appliances, ownership of agricultural machinery, ownership of livestock, monthly household income, knowledge sources, geographic openness, opinion leadership, membership in organizations, willingness to adopt new technologies, attitude toward solar energy use, and informal social participation) and the levels of rural residents' awareness of solar energy uses and benefits."

The results in Table (8) show a positive and statistically significant correlation at the 0.01 level between each of the following: the respondent's years of education, monthly household income, knowledge sources, geographic openness, organizational membership, readiness to adopt new technologies, and attitude toward solar energy use, and the levels of rural residents' awareness of solar energy uses and benefits. The values of the simple correlation coefficient were 0.308, 0.269, 0.443, 0.376, 0.393, 0.276, and 0.146, respectively.

While a statistically significant negative correlation was found at the 0.01 level between the age of the respondent and family size, and the rural population's awareness of solar energy uses and returns (with simple correlation coefficients of -0.392 and -0.323, respectively), no significant correlation was found between the average electricity bill, agricultural land ownership, household appliance ownership, agricultural machinery ownership, farm animal ownership, opinion leadership, and informal social participation, and the rural population's awareness of solar energy uses and returns. Therefore, we can partially reject the first statistical hypothesis and partially accept the research hypothesis.

Table (8): Values of simple correlation coefficients (Pearson) between the studied quantitative independent variables and the degrees of rural awareness of the uses and returns of solar energy

Values of simple correlation coefficients	Variables
-0.392**	Age of the respondent
0.308**	Years of education of the respondent
-0.323**	Family size
0.010	Average electricity bill
0.065	Agricultural land ownership
0.034	Ownership of household appliances
0.059	Ownership of agricultural machinery
0.026	Ownership of farm animals
0.269**	Monthly household income
0.443**	Knowledge sources
0.376**	Geographical exposure
0.047	Opinion leadership
0.393**	Membership in non-governmental organizations
0.276**	Readiness to adopt new practices
0.146**	Attitude towards using solar energy
0.001	Informal social participation

**At a significance level of 0.01 * At a significance level of 0.05

The results showed a positive and significant correlation between the number of years of education of the respondents and the degree of awareness of the use of solar energy. That is, the more years of education the respondents had, the greater the rural people's awareness of the uses of solar energy and its returns. This can be explained by the fact that education contributes to raising the level of knowledge and awareness of individuals, and increases their ability to understand modern technologies and comprehend their economic and environmental benefits. Education also helps to expand the sources of information for individuals related to renewable energy.

It was also shown that there is a positive and significant relationship between the monthly income of the family and the degree of awareness, meaning that the higher the monthly income of the family, the greater the awareness of rural people regarding the uses and returns of solar energy. This may be due to the fact that high-income families are more able to keep up with modern technologies and pay attention to different energy alternatives, in addition to their ability to bear the initial costs of installing solar energy systems, which prompts them to search for information related to it and learn about its benefits

The results also showed a positive and significant correlation between both knowledge sources and geographical openness, and the level of awareness. In other words, the greater the knowledge sources and geographical openness, the greater the rural population's awareness of the uses and benefits of solar energy. This indicates that multiple sources of information, such as media, agricultural extension agents, seminars, and extension programs, contribute to increasing rural populations' knowledge of modern technologies, including solar energy. Furthermore, geographical openness, which is characterized by frequent movement outside one's village or interaction with other communities, helps individuals acquire new experiences and information, thus increasing their awareness of modern technologies.

It was also shown that there is a positive and significant relationship between membership in informal organizations, willingness to adopt new things, and the trend towards using solar energy, and the degree of awareness. That is, the more membership in formal organizations there is, and the more willingness to adopt new things and the trend towards using solar energy there is, the more rural people are aware of the uses and returns of solar energy. This can be explained by the fact that individuals involved in social or development organizations are more exposed to awareness activities and programs. Also, individuals who are willing to adopt new innovations or have positive attitudes towards solar energy are more interested in searching for information related to it, which is reflected in the high level of their awareness of it

Conversely, the results showed a significant negative correlation between the age of the respondents and their level of awareness. This means that the older the respondents, the less aware rural residents were of the uses and benefits of solar energy. This may be because older age groups are often less receptive to new technologies and less likely to follow new information sources compared to younger age groups.

A negative correlation was also found between family size and level of awareness. The larger the family, the less aware rural residents were of the uses and benefits of solar energy. This may be because larger families may face greater economic and social burdens, which reduces their interest in keeping up with new technologies or considering alternative energy sources.

-2Differences between the average scores of rural residents' awareness of solar energy uses and returns in light of achieving the Sustainable Development Goals when classified according to the variables of (family type, and the respondent's employment and occupational status):

The second hypothesis states that "there are no significant differences between the average scores of rural residents' awareness of solar energy uses and returns when classified according to the variables of (family type, and the respondent's employment and occupational status)." To test the validity of this hypothesis, a t-value was calculated to measure the average scores of rural residents' awareness of solar energy uses and returns in light of achieving the Sustainable Development Goals when classified according to the variable of (family type).

The value of “F” was calculated to test the average scores of rural people’s awareness of the uses and returns of solar energy in light of achieving the Sustainable Development Goals when classifying them according to the variable (the professional and occupational status of the respondent).

2-a-Test of the differences between the mean scores of rural residents' awareness of the uses and returns of solar energy in light of achieving the Sustainable Development Goals when classified according to the variable (family type):

It is clear from the results in Table No. (9) that the mean values of rural residents' awareness of the uses and returns of solar energy in light of achieving the Sustainable Development Goals were (82.02, 78.07) degrees, with a standard deviation of (19.50, 15.65) degrees for the simple and extended families, respectively. The calculated t-value for testing the significance of the difference between the means was (2.08), which is significant at the probability level of 0.05. This indicates that there are significant differences in the levels of rural residents' awareness of the uses and returns of solar energy in light of achieving the Sustainable Development Goals according to the variable of family type, in favor of residents of simple families.

Table No. (9) Results of the “T” test for the differences between the average scores of rural people’s awareness of the uses of solar energy and its returns in light of achieving the Sustainable Development Goals when classified according to the variable (type of family)

T value	Standard deviation	Arithmetic average	Groups	Independent variables
2,08*	19,50	82,02	Simple	Family type
	15,65	78,07	Extended	

**At a significance level of 0.01 * At a significance level of 0.05

This result can be explained by the fact that the nature of the family structure may influence the level of knowledge and awareness of individuals regarding modern technologies. Simple families are typically characterized by a greater degree of independence in family decision-making and may be more flexible in adopting new ideas and technologies compared to extended families, which may be more inclined towards traditional decision-making patterns due to the number of family members and their differing opinions.

Furthermore, the higher level of awareness among members of simple families may be attributed to the fact that this family structure provides greater opportunities to access diverse information sources and facilitates the rapid dissemination of knowledge among a smaller number of individuals. This contributes to increased interest in learning about modern technologies, including the uses of solar energy and its economic and environmental benefits. Conversely, extended families may face some challenges that may relatively limit the level of awareness of these technologies, such as increased economic and social burdens, or the dependence of some family members on traditional patterns in the use of energy sources, which may reduce interest in searching for new alternatives such as solar energy.

2-B- F-test for the significance of differences between the average scores of rural residents’ awareness of the uses and returns of solar energy in

light of achieving the Sustainable Development Goals when classified according to the variable (the respondent's work and professional status):

The results of Table (10) show that the average scores of rural residents' awareness of the uses and returns of solar energy in light of achieving the Sustainable Development Goals according to the work and professional status (unemployed, working in agriculture, craftsman, self-employed, government employee) reached (75.21, 80.44, 83.21, 84.82, 94.17) degrees, with a standard deviation of (16.15, 16.69, 15.79, 20.07, 19.22) degrees respectively

The calculated value of "F" was 6.46, which is a statistically significant value at the level of 0.01, indicating that there are significant differences between the average scores of rural people's awareness of the uses of solar energy and its returns in light of achieving the Sustainable Development Goals, according to the practical and professional status of the respondent.

These results thus support the rejection of the second statistical hypothesis.

Table (10): Results of the "F" test to test the significance of differences between the average scores of rural residents' awareness of the uses and returns of solar energy in light of achieving the Sustainable Development Goals when classified based on the respondent's work and professional status

F value	Standard deviation	Arithmetic average	Groups	Independent variables
6,46**	16,15	75,21	Unemployed	The professional and occupational status of the respondent
	16,69	80,44	Works in agriculture	
	15,79	83,21	Craftsman	
	20,07	84,82	Self-employed	
	19,22	94,17	Government employee	

**At a significance level of 0.01 * At a significance level of 0.05

This result can be explained by the fact that the nature of one's work or profession is a significant factor influencing an individual's level of awareness and knowledge. Some professions offer greater opportunities to access diverse information sources and interact with official institutions or development programs concerned with renewable energy and sustainable development. It is noteworthy that government employees achieved the highest average level of awareness, which may be attributed to their higher level of education, in addition to the nature of their work, which may provide them with greater access to government policies and development programs related to the use of renewable energy sources.

The relatively higher level of awareness among freelancers and artisans compared to others can be explained by the fact that the nature of their work may require them to seek out modern methods to reduce costs and increase productivity, which may lead them to focus on modern technological alternatives, including the use of solar energy.

Conversely, the relatively lower average levels of awareness among the unemployed may be attributed to their limited exposure to information and expertise related to modern technology, as well as their weak direct connection to economic activities or institutions that could contribute to disseminating knowledge about renewable energy.

Fourth: The collective contribution of the studied quantitative independent variables to explaining the variance in rural residents' awareness of solar energy uses and benefits :

The third statistical hypothesis states that "the studied quantitative independent variables do not collectively make a uniquely significant contribution to explaining the variance in rural residents' awareness of solar energy uses and benefits." To verify this hypothesis, a stepwise multiple regression analysis model was used.

To identify the predictive and explanatory ability of the studied independent variables in explaining the variation in rural populations' awareness of the uses and returns of solar energy in light of achieving sustainable development goals, and to use the step-wise multiple regression analysis model, the linearity condition in the study data and the normality of the data distribution were verified, and the results were as follows:

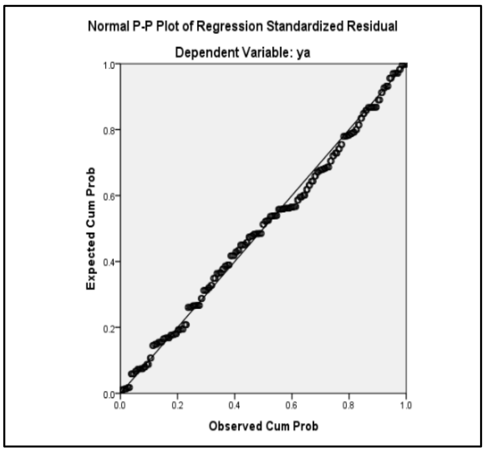

Figure (1): Histogram.

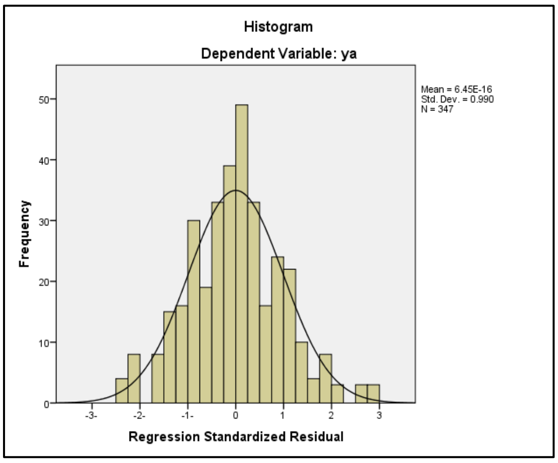

Figure (2): Residues cluster around the line.

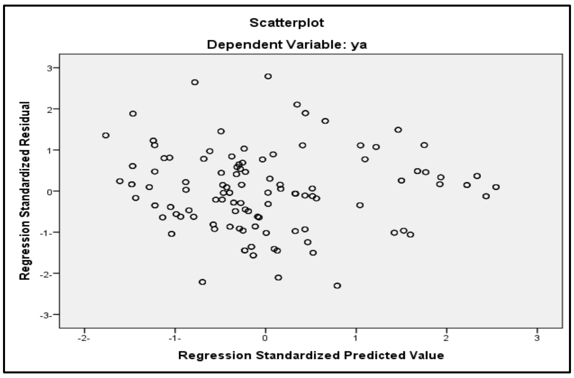

Figure (3): Spread of residuals with expected values

Figures (1, 2, and 3) clearly demonstrate the random distribution of the residuals and their adherence to a specific pattern. They also confirm the fulfillment of the linearity conditions in the study data and the normality of the sample distribution, all of which are prerequisites for conducting a stepwise multiple regression analysis (standardized partial regression). The results in Table (11) show that the variables of: respondent's age, years of education, family size, knowledge sources, geographical openness, organizational membership, and readiness to adopt new practices are correlated with rural residents' awareness of the use of solar energy and its benefits, with a multiple correlation coefficient of 0.694. The calculated F-value was 39.22, which is statistically significant at the 0.01 level.

Therefore, it can be concluded that there is a multiple correlation between the seven independent variables combined and the rural population's awareness of the uses and returns of solar energy. The coefficient of determination indicates that the seven independent variables combined explain 48.1% of the variance in the rural population's awareness of the uses and returns of solar energy.

Upon reviewing the relative importance of the seven independent variables according to the absolute value of the standard partial regression coefficient, it becomes clear that the knowledge resources variable reached 0.392 and ranks first in terms of its impact on the rural population's awareness of the uses and returns of solar energy. The age of the respondent variable reached 0.290 and ranks second. The family size variable reached 0.221 and ranks third. The geographical openness variable reached 0.159 and ranks fourth. The organizational membership variable reached 0.153 and ranks fifth. The years of education of the respondent variable reached 0.150 and ranks sixth. The readiness to adopt new ideas variable reached 0.137 and ranks seventh and last. Therefore, we can partially reject the third statistical hypothesis and accept the research hypothesis.

Table (11) Values of standard partial regression coefficients between the quantitative independent variables and the degrees of rural awareness of the uses and returns of solar energy

Standard partial regression coefficient values	**Independent variables**
-0.290**	Age of the respondent
0,150**	Years of education of the respondent
-0,221**	Family size
	Average electricity bill
	Farm land ownership
	Ownership of household appliances
	Ownership of agricultural machinery
	Ownership of farm animals
	Monthly household income
0,392**	Knowledge sources
0,159**	Geographical exposure
	Opinion leadership
0,153**	Organizational membership
0,137**	Readiness to adopt new practices
	Attitude towards using solar energy
	Informal social participation
0,694	Multiple correlation coefficient R values
0,481	Coefficient of determination R^2 values
39,22**	Value o F

** At a significance level of 0.01 * At a significance level of 0.05

When analyzing the relative importance of the independent variables according to the absolute value of the standard partial regression coefficient, it becomes clear that the knowledge sources variable ranks first. This confirms the pivotal role of various information sources in shaping individuals' awareness of modern technologies. Media outlets, guidance programs, seminars, and communication with various institutions all contribute to transferring knowledge related to renewable energy to rural populations.

The respondent's age variable came in second place, indicating that age is a factor influencing the level of awareness of modern technologies, as the degree of interaction with information and technology varies according to an individual's age group.
While family size ranked third, this may reflect the influence of economic and social conditions related to family size on individuals' interest in modern technologies and their engagement with related information.

Geographical openness ranked fourth, indicating that individuals' interaction with other communities and their movement outside their village contribute to increased exposure to new ideas and experiences, thus raising awareness about the use of solar energy.

Organizational membership ranked fifth, as social and rural organizations provide greater opportunities for social interaction and the exchange of information and experiences among individuals.
While the number of years of education ranked sixth, underscoring the importance of education in raising awareness and knowledge among individuals, its impact was relatively less pronounced compared to some other variables.
The readiness to adopt new technologies ranked seventh and last, reflecting the role of individuals' attitudes and psychological predispositions in accepting and adopting modern technological innovations, including the use of solar energy.

Fifth: Correlation between rural residents' awareness of solar energy uses and returns and solar energy's contribution to achieving the Sustainable Development Goals:

The fourth statistical hypothesis states that "there is no correlation between rural residents' awareness of solar energy uses and returns and their awareness of solar energy's contribution to achieving the Sustainable Development Goals".
Table (12) shows a positive correlation at the 0.01 probability level between rural residents' awareness of solar energy uses and returns and their awareness of solar energy's contribution to achieving the Sustainable Development Goals, with a simple correlation coefficient of 0.614.
These results support the rejection of the fourth statistical hypothesis

Table (12) Pearson Correlation Coefficients between rural residents' awareness of solar energy uses and returns and solar energy's contribution to sustainable development goals

Simple correlation coefficient values	Variables
0,614**	Awareness of achieving solar energy goals for sustainable development

**At a significance level of 0.01 * At a significance level of 0.05

Sixth: Differences between the average scores of rural residents' awareness of solar energy uses and returns when classified based on the three villages studied:

The fifth statistical hypothesis states that "there are no differences between the average scores of rural residents' awareness of solar energy uses and returns when classified based on the three villages studied".

From the data in Table (13), it is clear that the average scores of rural residents' awareness of solar energy uses and returns in the three villages studied (Baniyan Qibli, Faris, and Al-Zaniqa) were 84.30, 79.20, and 75.82, respectively. The calculated F-value for testing the significance of the differences between these averages was 7.200, which is statistically significant at the 0.01 level. This indicates the existence of significant differences between the average scores of rural residents' awareness of solar energy uses and returns in the three studied villages.

Table (13): Results of simple variance analysis of differences between the average scores of rural residents' awareness of the uses and returns of solar energy in the three studied villages

village arithmetic mean			F calculated	Mean squares	Bayonet degrees	Sum of squares	Source of variation (difference)
Zinaika	Knight	A tribal structure					
75,82	79,20	84,30	7,200**	2197,566	2	4395,131	Between groups
				305,217	344	104994,598	Within groups
					346	109389,729	Total

**At a significance level of 0.01 * At a significance level of 0.05

The results indicate that the geographical location and social context of each village influence the level of rural residents' awareness of solar energy uses and benefits. The higher average level of awareness in Banyan Qibli village compared to other villages reflects the potential influence of factors such as education levels, the availability of guidance and development programs, access to knowledge sources, or the nature of economic and social activities in the village, all of which may contribute to fostering knowledge and interest in modern energy technologies.
These differences may also reflect variations in access to information and modern experiences among the

villages. Some villages may be more open to training programs, seminars, and development initiatives focused on renewable energy, thus enhancing their residents' awareness compared to villages with less access to such opportunities.

To clarify the nature of the differences in the results of the analysis of variance between the average scores of rural residents' awareness of solar energy uses in the three studied villages, the LSD test was conducted. The results, shown in Table (14), indicate that the highest significant difference (8.48) was found between Banyan Qibli village and Al-Zaniqa village, favoring Banyan Qibli village. A significant difference (5.10) was also found between Faris village and Al-Zaniqa village, favoring Faris village, respectively.

These results thus support the rejection of the fifth statistical hypothesis.

Table No. (14): Results of the LSD test to determine the significance of differences between the average scores of rural residents' awareness of the uses and returns of solar energy in the three studied villages.

Zinaika	Knight	A tribal structure	Averages	Ranking
		zero	84,30	Tribal building
	zero	3,380	79,20	Faris
zero	5,10**	8,48**	75,82	Al-Zaniqa

**At a significance level of 0.01 * At a significance level of 0.05

These results indicate that the residents of Banyan Qibli village have a higher level of awareness regarding the uses and benefits of solar energy compared to the residents of Al-Zaniqa village, while the residents of Faris village have a higher level of awareness than those of Al-Zaniqa. This reflects clear differences between the villages in terms of knowledge and attitudes towards renewable energy. These differences can be explained by societal, geographical, and economic variations between the villages, such as the availability of agricultural and energy extension programs, education levels, access to knowledge resources, and the nature of economic and social activities that encourage the adoption of modern technologies. These differences may also reflect the effectiveness of development and awareness efforts in some villages compared to others.

Seventh: Obstacles to Solar Energy Use from the Rural Perspective:

1-Problems Related to Agricultural Solar Energy Use:

Reviewing rural residents' responses to the statements regarding obstacles to agricultural solar energy use:

Table (15) shows that the most significant problem limiting rural residents' use of agricultural solar energy is the initial investment cost of solar energy systems, at 70.9% and with a mean score of (2.52). The least significant problem is the corrosion of submersible water pumps in irrigation wells, at 7.33% and with a mean score of.(1.88)

2-Problems related to the use of solar energy in homes:

Reviewing the responses of rural residents to the statements regarding obstacles to the use of solar energy in homes:

Table (15) shows that the most frequently cited problem, according to the arithmetic mean, was the limited availability of solar-powered household appliances at 69.2%, with an arithmetic mean of (2.48). The least frequently cited problem was the need for frequent maintenance of solar energy storage batteries at 9.34%, with an arithmetic mean of.(1.90)

Table (15): Percentages of distribution of rural residents' responses to statements regarding obstacles to the use of solar energy

Obstacles	Degrees of approval						Arithmetic average
	agree		to some extent		Disagree		
	number	%	number	%	number	%	
A- Problems related to the use of solar energy in agriculture:							
- The initial investment cost of solar energy systems is high.	246	9,70	35	1,10	66	19	52,2
	192	3,55	28	1,8	127	6,36	19,2
- Continuous exposure to direct sunlight damages the wiring.	167	1,48	70	2,20	110	7,31	16,2
- Dust and dirt affect the system's components.	160	1,46	73	21	114	9,32	13,2
- Storing water for nighttime irrigation requires expensive concrete tanks.	161	4,46	32	2,9	154	4,44	02,2
- Increasing electricity production requires large areas for system installation.	125	36	80	1,23	142	9,40	95,1
- Using surplus energy at night requires expensive storage batteries.	122	2,35	73	21	152	8,43	91,1
- More energy is needed to deepen irrigation wells.	117	7,33	70	2,20	166	1,46	88,1

B- Problems related to the use of solar energy in homes:							
- Limited availability of solar-powered home appliances	240	2,69	32	2,9	75	6,21	48,2
- Fluctuating prices of solar-powered home appliances	203	5,58	64	4,18	80	1,23	23,2
- Lack of reliable sources for purchasing home appliances	190	7,54	26	5,7	131	8,37	17,2
- Short lifespan of solar energy storage batteries	172	6,49	40	5,11	135	9,38	11,2
- Frequent maintenance required for solar energy storage batteries	121	9,34	72	7,20	154	4,44	91,1

Table (15) indicates that the most significant obstacle, based on the arithmetic mean, was the high initial investment cost of solar energy systems. This reflects the fact that high initial costs represent the biggest barrier preventing rural residents from adopting solar energy in agricultural activities.

The least significant obstacle was the corrosion of submersible water pumps in irrigation wells, suggesting that this problem has less of an impact on rural residents' practical decisions compared to the economic challenges associated with initial costs.

Regarding domestic use, Table (15) shows that the most significant obstacle was the limited availability of solar-powered household appliances, reflecting their limited adoption among rural populations, which may restrict the actual utilization of solar energy in homes.

The least significant obstacle was the need for frequent maintenance of solar energy storage batteries, indicating that maintenance issues are not the primary impediment to using solar energy in homes, compared to limitations related to device availability and cost.

Therefore, it can be concluded that economic and promotional barriers represent the most significant challenges facing rural communities when adopting solar energy systems, whether for agricultural or domestic use, while technical problems such as maintenance or equipment wear and tear are relatively less impactful. These findings highlight the importance of designing financial and technical support programs, increasing awareness, and facilitating access to solar devices and systems, thereby contributing to the effective use of solar energy in rural communities and supporting the Sustainable Development Goals.

Eighth: Proposals to Address Obstacles to Solar Energy Use from the Rural Perspective:

Reviewing rural residents' responses to proposals for addressing obstacles to solar energy use:

Table (16) shows that the most frequently cited proposals, according to the arithmetic mean, focused on providing innovative solutions and suggestions to reduce the initial cost of solar energy systems and increase their economic feasibility (55%), with an arithmetic mean of (2.17). This is likely due to the fact that the low cost of solar energy strongly encourages rural residents and farmers to use it, as it has become an economical and sustainable alternative that significantly reduces electricity and irrigation costs, thus increasing crop productivity and supporting energy independence in rural areas.

The last of those proposals included developing programs and supporting local capacities in rural areas that promote the use of sustainable solar energy by 34.6% and an arithmetic mean of (1.89) degrees.

Table (16) Distribution of rural residents according to proposals to address obstacles to the use of solar energy

Obstacles	Degrees of approval						Arithmetic average
	agree		to some extent		Disagree		
	number	%	number	number	%	number	
- Providing innovative solutions and proposals to reduce the initial cost of systems and increase their economic viability.	191	55	25	7,2	131	37,8	2,17
	161	46,4	74	21,3	112	32,3	2,14
- Promoting renewable energy technologies to encourage their use.	172	49,6	40	11,5	135	38,9	2,11
- Government support for solar energy equipment and devices.	169	48,7	30	8,6	148	42,7	2,06
- Developing educational and training curricula and opportunities to raise knowledge, awareness, and capacity in solar energy issues for sustainable development purposes.	127	36,6	80	23,1	140	40,3	1,96
- Providing encouraging financing mechanisms that enable the purchase of solar energy system equipment.	124	35,7	75	21,6	148	42,7	1,93
- Providing consulting services to improve efficiency (operation, maintenance, and follow-up).	120	34,6	69	19,9	158	45,5	1,89

Table (16) indicates that the most frequently cited proposals, based on the arithmetic mean, were: finding innovative solutions and proposals to reduce the initial cost of solar energy systems and increase their economic viability. This reflects rural residents' awareness of the importance of addressing the economic obstacle that represents the biggest impediment to using solar energy, and their desire to find effective alternatives to reduce the financial burdens associated with the initial installation of solar systems.

The least frequently cited proposals, based on the arithmetic mean, were: implementing development programs and supporting local capacities in rural areas to promote the use of sustainable solar energy. This can be explained by the fact that rural residents may prefer practical and direct solutions that impact cost and economic benefit in the short term.

While some may see development programs and institutional support as a long-term solution or less obvious in their direct impact on the use of solar energy.

These findings indicate that the economic viability of solar energy systems is a primary concern for rural communities when facing obstacles. This underscores the importance of providing innovative solutions such as reducing system costs, offering financing options, or encouraging community initiatives and partnerships to lessen the financial burden. Furthermore, continued support for development programs is crucial to enhance local capacities in the long term .

Therefore, it can be concluded that promoting the efficient use of solar energy in rural communities requires a combination of practical economic solutions and ongoing institutional support to ensure the widespread adoption and sustainable viability of solar energy. This, in turn, contributes to achieving the Sustainable Development Goals and improving the quality of life in rural areas.

Recommendations:

In light of the study's findings and the subsequent discussion, the following recommendations can be made:

-The study's results showed that rural residents living in simple households are more aware of the uses and benefits of solar energy. Therefore, the study recommends conducting awareness campaigns specifically targeting extended families to ensure that information reaches them effectively, as this type of family is still prevalent in rural communities and represents a significant percentage. In the research sample, extended families constituted the largest proportion of the respondents' households.

-One of the study's findings is that government employees are more aware of the uses and benefits of solar energy in achieving sustainable development goals. Therefore, the study recommends leveraging the expertise of government employees by engaging them as opinion leaders who can play a significant role in disseminating knowledge among rural communities, given their greater awareness. The study also recommends conducting training courses and workshops within villages, focusing specifically on informal workers (farmers, freelancers, and artisans), as they are the least exposed to information.

-The results showed that the knowledge sources variable ranked first in terms of its impact on rural residents' awareness of the uses and benefits of solar energy, followed by the age of the respondent, then family size, then geographical openness, then membership in non-rural organizations, followed by the number of years of education, and finally the willingness to adopt new practices. Therefore, the study recommends the following:

*Intensifying awareness programs broadcast on television, diversifying the information presented in newspapers and magazines, and providing extension service officials with the necessary knowledge to ensure that accurate and simplified information about the uses of solar energy reaches all rural groups.

*Designing guidance programs that consider the age differences among rural residents, making them simplified for older adults.

*Organizing field visits to other villages and areas with greater solar energy use to increase geographical reach, which contributes to knowledge transfer and exchange among rural residents.

*Encouraging rural residents to join informal organizations, given their important role in raising awareness about the uses of solar energy.

*Intensifying literacy programs and training courses that focus on renewable energy, as education is crucial for disseminating knowledge and awareness.

*Relying on rural residents who are willing to adopt new technologies and share their successful experiences with others, which will enhance their acceptance and use of these new technologies.

-The results also showed that the biggest obstacle to rural people’s awareness of the uses and returns of solar energy is the high initial investment cost of solar energy systems. Therefore, the study recommends providing government support in the form of easy financing facilities such as low-interest loans or the possibility of installing solar energy systems in installments to reduce the financial burden, which will contribute to increasing rural people’s willingness to use them and increasing their awareness of their returns

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