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Geothermal Energy in Jordan: Public Perception and Expert Insights from a National Survey

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Abstract

Jordan possesses considerable geothermal resources, predominantly within the low-enthalpy range (generally below 100˚C), which are well suited for direct-use applications such as space heating, greenhouse agriculture, aquaculture, and balneological activities rather than large-scale electricity generation. These resources occur mainly as hot springs and geothermal wells distributed across several geothermal fields, with temperatures ranging from approximately 27˚C to 70˚C. Despite this potential, geothermal energy remains largely underutilized within Jordan's national energy mix. This study investigates public perception and expert perspectives on geothermal energy as a pathway toward sustainable development in Jordan. A national survey involving 418 respondents was conducted to assess public awareness, acceptance, and willingness to adopt geothermal and other renewable energy technologies. The results indicate strong public interest in renewable energy utilization, although economic constraints, limited infrastructure, and insufficient institutional support remain key barriers. Complementary interviews with renewable energy experts confirm Jordan's substantial geothermal potential while emphasizing the need for enhanced community awareness, supportive policy frameworks, and targeted investment. The findings highlight geothermal energy as a viable and sustainable solution for addressing Jordan's energy challenges, particularly in reducing energy costs, supporting sustainable agriculture, and improving energy security. To fully realize these benefits, strategic measures are required, including regulatory modernization, investment incentives, stakeholder collaboration, and public outreach initiatives. Overall, geothermal energy emerges as an economically feasible and environmentally sustainable component of Jordan's long-term energy transition strategy.

Keywords

Geothermal Energy, Sustainable Development, Public Perception, Expert Insights, Renewable Energy Policy, Jordan

1. Introduction

In Jordan, the utilization of renewable energy primarily focuses on wind and solar energy systems. The country's advantageous position as one of the leading nations in solar and wind energy resources has established it as a prominent market for harnessing these energy sources. Recently, extensive research has underscored Jordan's renewable energy potential. Notably, the combination of its strategic location, favorable topography, and climate positions Jordan as a promising region for renewable energy development globally. Expanding the use of renewable energy systems is crucial for significantly reducing greenhouse gas emissions in the country (Alkhalidi et al., 2022). Renewable energy sources are not viewed as energy sources only, but rather as tools to address several aspects, the most important of which are: enhancing energy security, reducing the environmental impacts associated with traditional fossil energy, reducing harmful greenhouse gas emissions, improving opportunities in education, and creating new job opportunities, in addition to reducing poverty and increasing gender equality (Acikgoz, 2011).

One type of renewable energy that could be seriously considered is geothermal energy, as Jordan is located near a tectonically active frontier. Although Jordan is willing to lower the nation's energy cost by utilizing the variety of energy sources, high temperature applications will not be feasible under the current conditions due to the comparatively low enthalpy temperature. Nonetheless, Jordan might be able to make advantage of the geothermal resources that are available. A variety of temperature applications, including space heating, greenhouse agriculture, aquaculture, and balneological activities, would be utilized, according to the majority of earlier studies and publications (Al-Hinti et al., 2017; Saudi & Swarieh, 2015; Sunna, 2015; Al-Zyoud, 2019; Al-Khasawneh et al., 2019; Forster et al., 2007; Rashed, 2024).

This study has been carried out through questionnaires and interviews with three experts in the field of geothermal energy in Jordan. The main aim of this study is to discuss the potential of geothermal energy in Jordan and its future applications, and to measure the societal acceptance of proposed geothermal energy projects and the extent of their awareness, understanding, and assimilation by the hosting communities through structured questionnaires and by interviews with researchers and experts in the field of geothermal energy in Jordan. Low-enthalpy geothermal resources, which dominate the geothermal potential of Jordan, are particularly appropriate for direct thermal applications rather than power generation. Given Jordan's geological and thermal conditions, these resources can play

a critical role in district heating, agricultural applications, and tourism-related uses, offering cost-effective and environmentally sustainable energy solutions.

2. Methodology

The methodology of any research study is fundamentally determined by selecting the most appropriate study design (Omair, 2015). A research design provides a comprehensive framework or strategy for the study, defining whether it is descriptive or experimental and identifying the target population of interest (Bowling, 2014). This study employs a quantitative methodology. Quantitative methods are utilized to describe current conditions, explore relationships, and analyze cause-and-effect phenomena (Gay et al., 2012). Quantitative research designs are broadly categorized into descriptive studies and more detailed analytical studies (Omair, 2015). The quantitative methodology was applied by creating a questionnaire containing a set of questions related to the topic, distributing it widely, and then analyzing and evaluating the responses obtained from the participants in the questionnaire.

The qualitative aspect of the study relies on data collected through pre-recorded notes taken during expert interviews. These interviews focused on professionals in geothermal energy across Jordan, with active engagement between the researcher and participants being essential. Feedback from these interviews was integrated with the results of the questionnaire, creating a cohesive understanding through both qualitative and quantitative lenses. Two tools were employed for this study, encompassing questionnaires and interviews with experts.

2.1. Study Area

Jordan, with an area of 89,329 km^2, is located between 29˚10' - 33˚45'N and 34˚55' - 39˚20'E (jgs-jo, 2024). The study was conducted by randomly selecting participants for the current study. Figure 1 shows the divisions of Jordan by governorates.

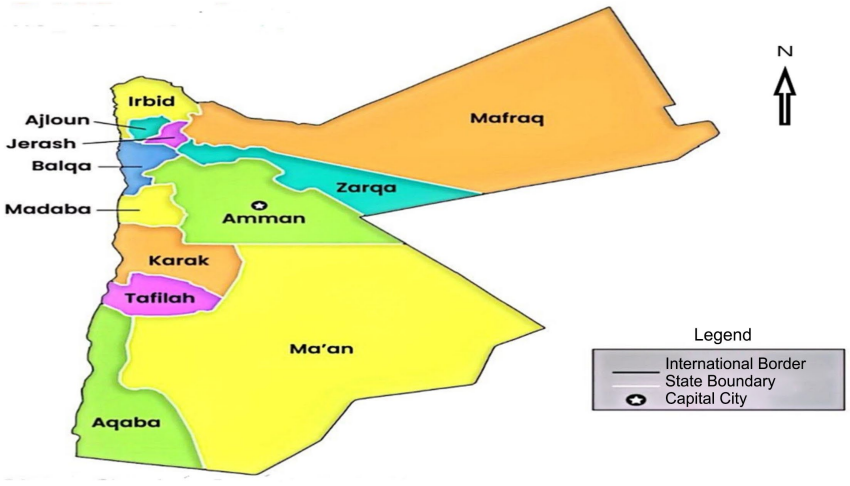

Figure 1. Study area location.

2.2. Sample Size of the Study

Although the study targeted households across the south, center, and north of Jordan, the online distribution method limited control over the exact geographical balance of respondents. Therefore, the sample represents a nationwide perception rather than a strictly stratified regional sample. This limitation is acknowledged and discussed accordingly. The main obstacle for researchers is determining the appropriate sample size, because it greatly affects the integrity and accuracy of statistical methods (Rahi, 2017). The Cochrane (1963) equation, which was formulated from the beginning to deal with large populations, was used to determine the sample size. To obtain a representative sample with specific dimensions, Cochran (1963) modeled Equation (1) for a large population.

$$n_o = \frac{z^2 pq}{e^2} \tag{1}$$

where:

n_o = The sample size.

z = It is the two-tailed area under the normal distribution with $z = 1.96$ and q = 0.05.

e = It is the acceptable sampling error.

p = It is the proportion of the population that possesses the desired attribute

$$n_o = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2} = 385 \text{ of households.}$$

According to the formula, at least 385 individuals should be included in the study. However, this study included 418 Jordanian individuals, which is preferable because a larger sample size leads to better and more accurate results. The largest possible number of questionnaires was randomly distributed across social media platforms, including applications such as Facebook and WhatsApp, and sent via email, and we received 418 responses and interactions.

2.3. Structure of Questionnaire

The questionnaire was developed by reviewing previous studies related to the current research topic to achieve the research objectives, and it consisted of 28 questions distributed into six sections as follows:

1) The primary objective of the first section is to evaluate the demographic and social characteristics of the research participants, which include gender, age, educational level, nature of work, and place of residence.

2) The second section, which included seven questions, aims to measure the participants' level of awareness of renewable energy in Jordan.

3) The third section included five questions related to measuring the level of awareness of geothermal energy in Jordan.

4) The fourth section included five questions related to the extent of the contribution of geothermal energy exploitation to the energy sector in Jordan.

5) The fifth section included five questions related to investment in geothermal energy projects in Jordan.

6) The sixth section included six questions about the future of geothermal energy in Jordan.

7) Data were collected by implementing an electronic questionnaire, developed using Google Drive forms. The questionnaire was disseminated across social media platforms, including Facebook, WhatsApp, and sent via email. The description of the questionnaire is detailed as follows in Table 1.

Table 1. Description of the questionnaire tool.

The Section	Description
First Section: Socio-Demographic and Economic Characteristics	▪ It includes gender, place of residence, age, educational level, and nature of work.
Second Section: Awareness of Renewable Energy	▪ Participants' level of awareness of renewable energy and its applications. ▪ Participants' level of awareness about the possibility of renewable energy to reduce the damage caused by fossil fuels and reduce the energy bill. ▪ The level of participants' awareness of the existence of a renewable energy project in Jordan. ▪ The level of participants' awareness of the possibility of determining the locations of renewable energy projects in Jordan. ▪ The level of participants' desire to switch to using renewable energy of various types. ▪ The level of participants' awareness of the issues that might encourage them to use renewable energy. ▪ The level of participants' awareness of the serious obstacles to the use of renewable energy.
Third Section: Questions Related to Measuring the Level of Awareness of Geothermal Energy	▪ Participants' level of knowledge of geothermal energy. ▪ The level of awareness of participants that geothermal energy is one of the types of renewable energy. ▪ Participants' level of belief in the existence of geothermal energy in Jordan. ▪ Participants' level of knowledge about the locations of geothermal energy in Jordan. ▪ Participants' level of familiarity with how to increase community awareness about the benefits of geothermal energy in Jordan.
Fourth Section: Questions Related to the Extent of the Contribution of Geothermal Energy Exploitation to the Energy Sector in Jordan	▪ The level of awareness of participants regarding the extent to which geothermal energy can contribute to the security of energy supply in Jordan. ▪ Participants' level of awareness of the possibility of integrating geothermal energy into the current energy infrastructure in Jordan. ▪ The level of awareness of participants about the possibility of exploiting geothermal energy for several uses. ▪ Participants' level of familiarity with the sectors that most use geothermal energy. ▪ Participants' level of belief in the efficiency of geothermal energy and the excellence of its sustainability, regardless of its geographical location.

Continued

	▪ The level of participants' belief that geothermal energy in Jordan is in the process of evaluation and exploration. ▪ Participants' level of awareness of current geothermal energy projects in Jordan.
Fifth Section: Questions Related to Investment in Geothermal Energy Projects in Jordan	▪ Participants' level of familiarity with geothermal energy project sites in Jordan. ▪ The level of participants' belief in the possibility of a partnership between the public sector and the private sector in the field of investment in geothermal energy projects. ▪ The participants' level of knowledge regarding any agreements to explore geothermal energy sites in Jordan
	▪ The level of participants' belief in the possibility of exploiting geothermal energy and the extent of its economic feasibility. ▪ The level of participants' belief that the high cost of geothermal energy projects is the direct reason for not exploiting them in Jordan.
Sixth Section: Questions Related to the Future of Geothermal Energy in Jordan	▪ The level of participants' belief that the energy strategies of successive governments in Jordan give priority to attracting investment in the field of geothermal energy in Jordan. ▪ Participants' level of belief in the matters that must be followed to encourage the exploitation of geothermal energy in Jordan. ▪ The level of participants' awareness of the possibility of increasing public awareness of the benefits of exploiting geothermal energy in Jordan. ▪ The level of participants' awareness in applications based on the exploitation of geothermal energy in Jordan.

2.4. Validity and Reliability of the Questionnaire

Reliability and validity are used to evaluate the study as the basic unit of analysis and are considered among the most important standards that must be achieved in scientific research studies (Louangrath, 2018). This section provides a detailed explanation of the procedures that were used to ensure the validity and reliability of the study.

2.5. Validity of the Questionnaire

The validity test measures the degree of agreement between the observed value and the expected value (Brians, 2016). The content validity scale is considered one of the types of validity that can be judged by specialized experts to ensure the suitability of the measurement used. To facilitate validation, experts must be present with researchers to ensure content validity (Taherdoost, 2016). A content validity approach was applied to ensure whether each question addressed the research objectives appropriately and impartially and was relevant to the topic. Academic reviewers with extensive experience in geothermal energy examined the initial research instruments to ensure their suitability for the study. The questions were revised, modified, or reformulated according to the judges who provided feedback on their validity and appropriateness.

2.6. Reliability of the Questionnaire

Reliability is an index to measure the degree to which a test result or data used is consistent and consistent across different applications (Sarmah & Hazarika, 2012). Four cut-off points for reliability have been proposed and divided by score: very high reliability is (0.90 and above), high reliability is (0.70 - 0.90), moderate reliability is (0.50 - 0.70), and poor reliability is (0.50 and below). To evaluate the stability of the study tool, the Cronbach's alpha coefficient was used and calculated using the Cronbach's alpha equation (Cronbach, 1951) as follows (Equation (2)).

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right) \tag{2}$$

where α is Cronbach's alpha, k is the number of items in a scale, σ_i is the variance of the test scores, and σ_t is the sum of the variances of item scores. The findings of Cronbach's alpha coefficient for the dimensions of the questionnaire are shown in Table 2.

Table 2. The results of Cronbach's alpha coefficient regarding the dimensions of the study questionnaire.

Dimensions	Cronbach's Alpha coefficient	Discussion
Level of awareness of renewable energy	0.75	High
Level of awareness of geothermal energy	0.82	High
The extent of the contribution of geothermal energy exploitation to the energy sector in Jordan	0.79	High
Investing in geothermal energy projects in Jordan	0.87	High
The future of geothermal energy in Jordan	0.87	High

The Cronbach alpha values provided indicate the internal consistency or reliability of the questions within each section of the assessment. Generally, a Cronbach alpha value above 0.70 is considered acceptable for research purposes, indicating that the items in each section are measuring the same underlying construct consistently. In this case, all sections exhibit good internal consistency, with alpha values ranging from 0.75 to 0.87. These values suggest that the questions within each section are reliably measuring the intended aspects of awareness, contribution, investment, and prospects related to geothermal energy in Jordan.

3. Statistical Analysis Procedures

The survey data coding and entry process was carried out using Microsoft Excel, while SPSS (Statistical Package for the Social Sciences) was used to conduct statistical analysis of the study responses. The statistical analysis has been carried out through the following steps:

1) Data sorting and arrangement: Google Sheets was used to organize and classify the data, which helped arrange the responses and ensure ease of access and

subsequent analysis.

2) Data coding and checking for missing values: The data were coded in Excel to ensure that the data were structured appropriately for statistical analysis. The data were also checked for missing or incomplete values to ensure the accuracy of the results and analysis.

3) Descriptive statistics: Descriptive statistics were conducted using SPSS to summarize and describe the data comprehensively. This included using frequencies and percentages to describe the socio-demographic characteristics of the study sample, in addition to analyzing the responses to the study tool questions to provide a clear and comprehensive picture of the results.

Interviews

Interviews were conducted with three researchers and experts to explore issues related to renewable energy and geothermal technologies in the modern era, with a focus on the challenges and opportunities presented by these alternative energy sources. The three experts interviewed were purposively selected based on their complementary professional backgrounds and direct involvement in the renewable and geothermal energy sectors in Jordan. Engineer Bassam Sunna has extensive experience in geothermal resource assessment and applications, Dr. Ali Al-Swarieh is an academic and researcher specializing in geothermal and hydrogeological systems, and Engineer Mohammad Abu Zaid is actively engaged in renewable energy research and innovation. This combination ensured balanced perspectives from academia, applied research, and the energy sector. The discussions emphasized the critical importance of transitioning to clean energy to reduce carbon emissions and mitigate the environmental impacts of climate change. The experts also highlighted recent advancements in solar, wind, and geothermal energy technologies. Specific attention was given to identifying potential geothermal energy sites in Jordan, examining the geothermal energy sector in the country, and exploring its potential applications. These applications were discussed in the context of their ability to enhance energy production efficiency. Additionally, the conversation underscored the need for robust government policies to encourage investment in renewable energy and to develop sustainable infrastructure that supports this transition. **Figure 2** illustrates the main themes discussed with the researchers and experts.

4. Questionnaire Analysis

This presents a detailed discussion of the results obtained in response to the main research questions. The initial section of this chapter presents an analysis of the socio-demographic characteristics of the study participants, providing essential contextual information for the subsequent discussions. Furthermore, each subsequent part scrutinizes the findings, offering comprehensive insights and interpretations derived from the data collected. This chapter endeavors to elucidate the implications of our research findings, contributing to the scholarly discourse on geothermal energy in Jordan and its future applications.

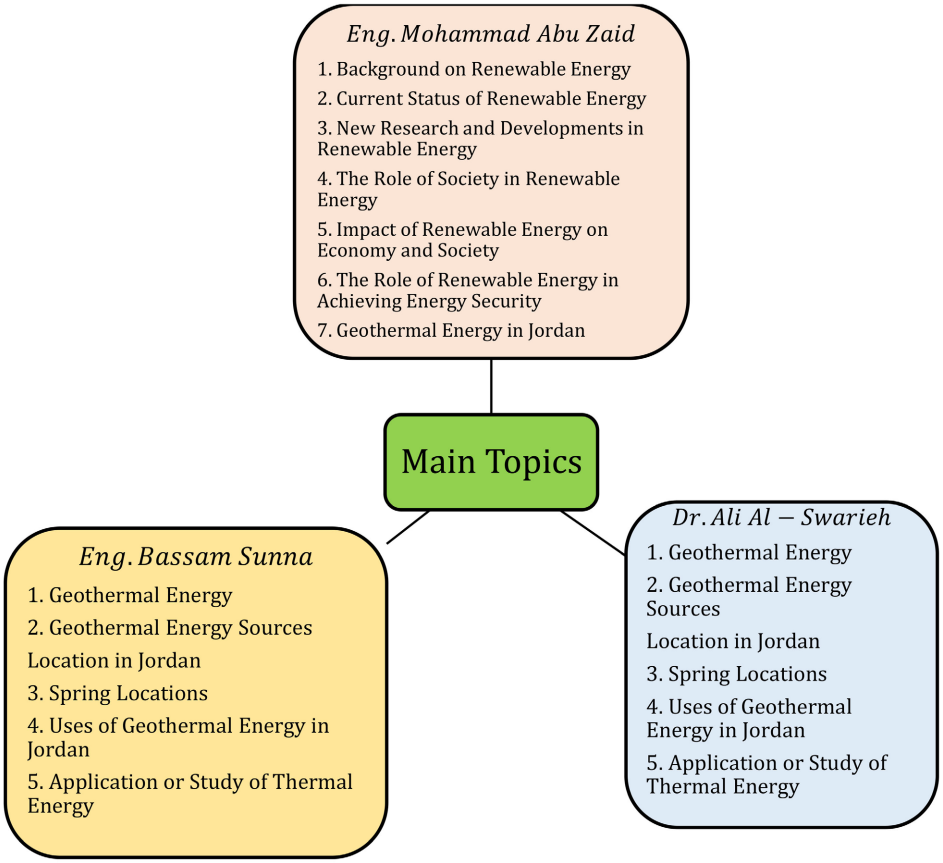

Figure 2. Description of the conducted interview.

4.1. Limitation of the Study

This study has several limitations that should be acknowledged. First, the questionnaire was distributed primarily through online platforms and social media, which may introduce sampling bias and limit representation of populations with limited internet access. Second, although the sample size was statistically adequate, the geographical distribution of respondents may not perfectly reflect the intended population across all regions of Jordan. Third, the qualitative component relied on interviews with only three experts, which, while providing valuable insights, may not capture the full diversity of professional perspectives within the geothermal energy sector.

4.2. Socio-Demographic Characteristics

The socio-demographic data collected in this study are presented in Table 3 as follows: This data includes demographic characteristics of the participants, such as age, gender, educational level, marital status, and other important demographic characteristics that help in understanding the social composition of the sample participating in the study. Table 3 presents this information in an organized manner to facilitate its analysis and comparison with other study variables. Figure 3 shows the distribution of study participants by each city.

Table 3. Socio-demographic characteristics of study participants.

Demographic Variables	N (%)
Sex	
Male	228 (54.7%)
Female	189 (45.3%)
City	
Aqaba	274 (65.7%)
Ma'an	26 (6.2%)
Tafileh	5 (1.2%)
Karak	18 (4.3%)
Ma'daba	4 (1.0%)
Al-Salat	5 (1.2%)
Amman	57 (13.7%)
Al-Zarqa	8 (1.9%)
Jerash	5 (1.2%)
Ajlon	0 (0%)
Al-Mafraq	2 (0.5%)
Irbid	13 (3.1%)
Age	
18 - 25 years	40 (9.6%)
25 - 45 years	247(59.2%)
46 - 55 years	88 (21.1%)
More than 55 years	42 (10.1%)
Educational Level	
Higher Education	97 (23.3%)
Bachelor's	200 (48.0%)
Diploma	58 (13.9%)
High school	57 (13.7%)
Vocational	5 (1.2%)
Type of Work	
Public sector	198 (47.5%)
Private sector	124 (28.7%)
Student	25 (6.0%)
Other	70 (16.8%)

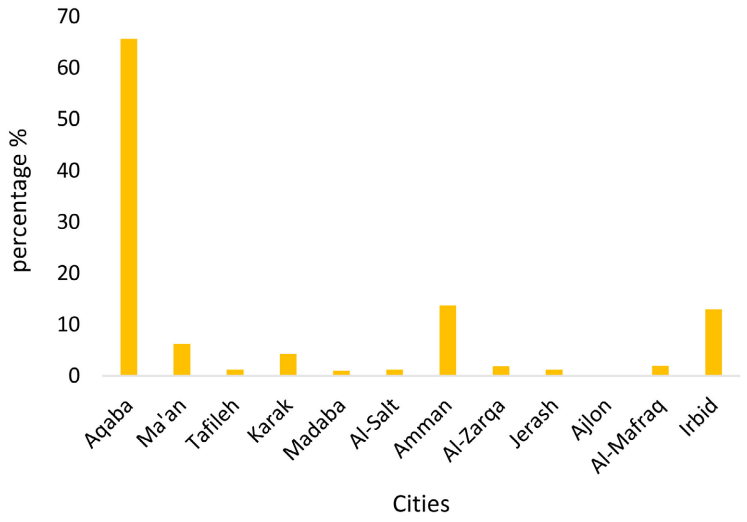

Figure 3. Distribution of study participants by city.

Table 3 presents the socio-demographic characteristics of the study participants along with their corresponding frequencies and ratios. Among the participants, 228 (54.7%) are male, while 189 (45.3%) are female. Aqaba emerges as the most represented city, with 274 participants (65.7%), followed by Amman with 57 (13.7%) participants. Regarding age groups, 247 participants (59.2%) fall within the 25 - 45 years bracket, whereas the 18 - 25 years group comprises 40 participants (9.6%). In terms of educational level, 200 participants (48.0%) hold bachelor's degrees, and 97 (23.3%) have higher education qualifications. Employment-wise, the public sector employs 198 participants (47.5%), followed by the private sector with 124 (28.7%). These frequencies and ratios provide a clear snapshot of the socio-demographic diversity within the participant pool, which is essential for contextualizing subsequent discussions on geothermal energy in Jordan and its potential applications.

4.3. Exploring Attitudes

In this section, this study delves into an exploration of attitudes towards the adoption of renewable energy, considering perspectives and key considerations among individuals. Renewable energy stands as a beacon of hope in the quest for sustainable energy solutions, offering a pathway towards mitigating the environmental damage caused by fossil fuels while potentially alleviating consumers' energy bills. This study navigates through the intricate landscape of renewable energy adoption. This study aims to uncover insights into the awareness and receptivity towards renewable energy projects, particularly within the context of Jordan. Moreover, we seek to understand the underlying motivations and barriers that shape individuals' desires to transition to various forms of renewable energy. From considerations of cost and potential savings to the broader implications for environmental preservation and legislative frameworks, this section endeavors to illuminate the multifaceted dynamics surrounding the embrace of renewable energy

technologies. Figure 4 shows the participants' perception of knowledge on renewable energy and its applications.

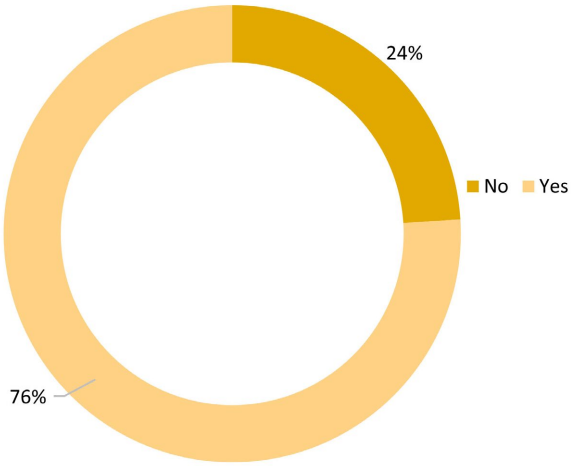

Figure 4. The participants' perception of knowledge of renewable energy and its applications.

According to Figure 4, among the participants, 316 (76%) expressed confidence in their understanding of renewable energy and its applications, while 101 (24%) indicated a lack of knowledge in this domain. This distribution underscores both the presence of a substantial proportion of individuals knowledgeable about renewable energy and the existence of a significant segment with limited understanding, emphasizing the importance of education and awareness-building initiatives in this field. Moreover, this study examines the perceived significance of renewable energy, particularly in its capacity to mitigate the adverse effects of fossil fuels and alleviate consumers' energy expenses, as shown in Figure 5.

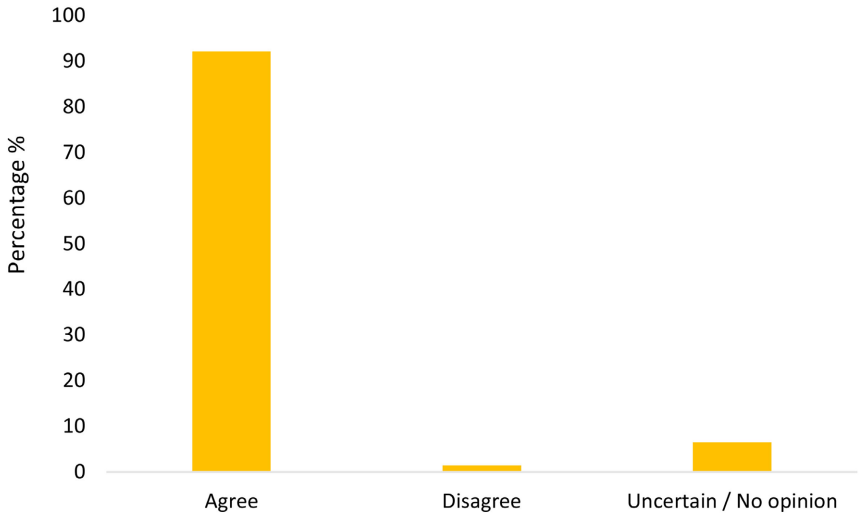

Figure 5. Importance of renewable energy in reducing fossil fuel damage and consumer energy bills.

The data presented in Figure 5 show that a significant majority, comprising 92.1% of respondents, expressed agreement with the statement, acknowledging renewable energy's role in reducing environmental damage and lowering energy bills. Only a small minority, accounting for 1.4% of participants, disagreed with the statement, while 6.5% indicated uncertainty or lack of opinion. This overwhelming consensus underscores a widespread recognition of renewable energy's dual benefits in promoting environmental sustainability and financial savings, reaffirming its significance in the transition towards a cleaner and more economically viable energy future.

Figure 6 explores participants' awareness of renewable energy projects within Jordan. This inquiry serves to gauge the extent to which individuals are informed about initiatives aimed at harnessing renewable energy sources within the country. Understanding the level of awareness among participants is crucial for assessing the effectiveness of existing communication and outreach efforts related to renewable energy projects in Jordan. Through this investigation, this study aims to shed light on the degree of familiarity with such initiatives among the surveyed population, providing valuable insights into the current state of public knowledge regarding renewable energy endeavors within the nation.

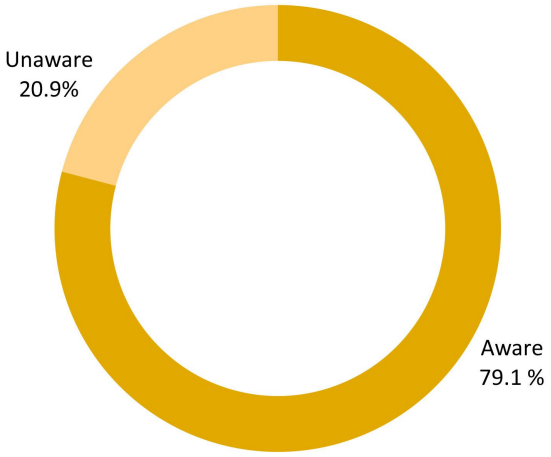

Figure 6. Awareness of renewable energy projects in Jordan.

As shown in Figure 6, a significant majority, comprising 79.1% of respondents, indicated that they were aware of the existence of such projects within the country. Conversely, 20.9% of participants reported being unaware of renewable energy initiatives in Jordan. This distribution underscores a noteworthy level of awareness among the surveyed population regarding the presence of renewable energy projects in the nation, signifying a positive indication of public engagement and knowledge in this domain.

As shown in Figure 7, the study delves into participants' sentiments regarding their inclination towards adopting various types of renewable energy sources. This exploration aims to gauge the level of interest and willingness among individuals

to transition from conventional energy sources to renewable alternatives. Understanding participants' desires to embrace renewable energy is pivotal for assessing the potential for widespread adoption and for identifying key factors that may influence such decisions. Through this investigation, this study aims to uncover insights into the motivations and considerations driving individuals' preferences for renewable energy, shedding light on the opportunities and challenges associated with transitioning towards a more sustainable energy future.

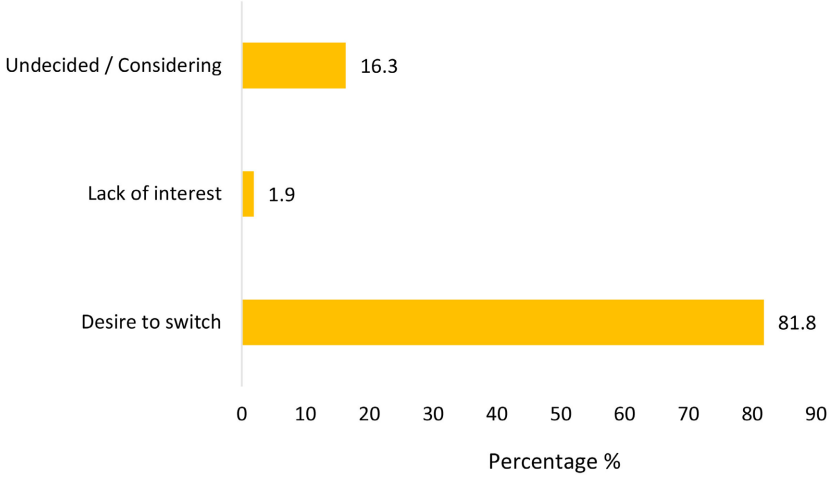

Figure 7. Desire to switch to using various types of renewable energy.

A substantial majority, comprising 81.8% of respondents, expressed a desire to switch to using renewable energy (**Figure 7**). Conversely, only a small proportion, accounting for 1.9% of participants, indicated a lack of interest in adopting renewable energy. Notably, 16.3% of respondents reported being undecided or considering the possibility of transitioning to renewable energy, indicating a degree of ambivalence or uncertainty. This distribution highlights a significant level of enthusiasm among participants towards embracing renewable energy solutions, albeit with some variability in the degree of commitment. Understanding these sentiments is crucial for informing efforts to promote renewable energy adoption and address potential barriers to implementation effectively.

4.4. Factors Encouraging Renewable Energy Use

Table 4 provides the factors that incentivize the adoption of renewable energy along with the significant obstacles that may hinder its widespread implementation. By examining both the drivers and challenges associated with renewable energy adoption, the study aims to provide a holistic understanding of the considerations and complexities involved in transitioning towards sustainable energy solutions.

Table 4 provides a comprehensive overview of the factors encouraging the adoption of renewable energy and the serious obstacles hindering its widespread implementation. Among the factors encouraging adoption, participants high-

lighted cost savings as the most significant driver, with 52.3% expressing its importance, followed by the desire to contribute to environmental protection (26.7%) and the overall affordability of renewable energy options (21.0%). Conversely, participants identified several serious obstacles to adoption, with the most prevalent concern being the perceived increase in costs associated with renewable energy (61.8%). Additionally, challenges related to the availability of renewable energy sources (17.0%) and potential changes in legislation (21.2%) were also noted as significant barriers. This nuanced examination underscores the complex interplay between motivations and challenges influencing individuals' decisions regarding renewable energy adoption.

Table 4. Factors encouraging renewable energy use and serious obstacles to adoption.

Items		Responses	
		N	Percent%
Factors encouraging the adoption of renewable energy.	Cost	148	21.0%
	Savings on your bill	369	52.3%
	Contributing to protecting the environment	188	26.7%
Serious obstacles to the adoption of renewable energy.	Sources are not available.	77	17.0%
	Increase in cost	280	61.8%
	Change in legislation (laws)	96	21.2%

4.5. Level of Awareness of Geothermal Energy

This study delves into an examination of the level of awareness surrounding geothermal energy among the study participants. Geothermal energy represents a promising renewable energy source with significant potential for sustainable power generation. Through this analysis, this study aims to assess the extent to which individuals are informed about geothermal energy and its applications. By exploring participants' awareness levels, it is possible to gain valuable insights into the current state of knowledge and perceptions surrounding this renewable energy source. This investigation serves to elucidate the opportunities and challenges associated with promoting geothermal energy adoption and underscores its role in the broader context of renewable energy utilization.

Table 5 provides a comprehensive overview of the level of awareness of geothermal energy among the study participants. This table presents the frequencies and percentages of participants' responses, offering insights into the extent of knowledge and familiarity with geothermal energy within the surveyed population.

Among respondents, 42.7% indicated having knowledge of geothermal energy, while the majority, accounting for 57.3%, and reported lacking familiarity with this renewable energy source. Additionally, 60.9% of participants were aware that geothermal energy is a type of renewable energy, while 39.1% were not aware of this fact. Furthermore, a significant proportion of respondents (59.0%) believed

that geothermal energy is available in Jordan, suggesting a considerable level of awareness or belief in the existence of geothermal resources within the country. These findings highlight varying levels of awareness and understanding of geothermal energy among the surveyed population, underscoring the importance of education and outreach initiatives to enhance knowledge and promote the adoption of this sustainable energy source.

Table 5. Level of awareness of geothermal energy.

Items		Frequency	Percent%
Do you have a knowledge of geothermal energy?	Yes	178	42.7%
	No	239	57.3%
Did you know that the geothermal energy is a type of renewable energy?	Yes	254	60.9%
	No	163	39.1%
Do you think there is a geothermal energy in Jordan?	Yes	246	59.0%
	No	171	41.0%

4.6. Awareness Strategies for Geothermal Energy

Table 6 presents the frequencies and percentages of responses regarding strategies to enhance awareness of geothermal energy. Participants were asked to indicate their perceptions of effective methods for increasing awareness and understanding of geothermal energy.

Table 6. The frequencies and percentages of responses regarding strategies to enhance awareness of geothermal energy.

Items		Responses	
		N	Percent%
How can community awareness be increased about the benefits of geothermal energy in Jordan?	By educating school and university students.	275	31.5%
	By increasing the effectiveness of investment in it.	202	23.1%
	By scientific research.	171	19.6%
	By consumer awareness.	225	25.8%

Among the responses, educating school and university students emerged as the most prominent strategy, with 31.5% of participants advocating for this approach. This highlights the recognition of education as a fundamental tool for instilling knowledge and understanding of geothermal energy from a young age. Additionally, substantial percentages of participants emphasized the importance of increasing investment effectiveness (23.1%), scientific research (19.6%), and consumer awareness (25.8%) as crucial avenues for enhancing community awareness of geothermal energy. These findings underscore the multifaceted nature of promoting awareness and emphasize the need for comprehensive strategies that target various stakeholders to maximize the impact of geothermal energy advocacy

efforts in Jordan.

4.7. Geothermal Energy Exploitation in the Energy Sector in Jordan

In this section, this study delves into a comprehensive exploration of the feasibility and implications of integrating geothermal energy into Jordan's energy sector. This study addresses key questions surrounding its potential contributions to energy security, its compatibility with existing infrastructure, its versatility across multiple applications, the sectors that stand to benefit the most, and the overall efficiency and durability of geothermal energy across various geographical locations. Figure 8 shows the results of the participants' responses regarding the awareness level.

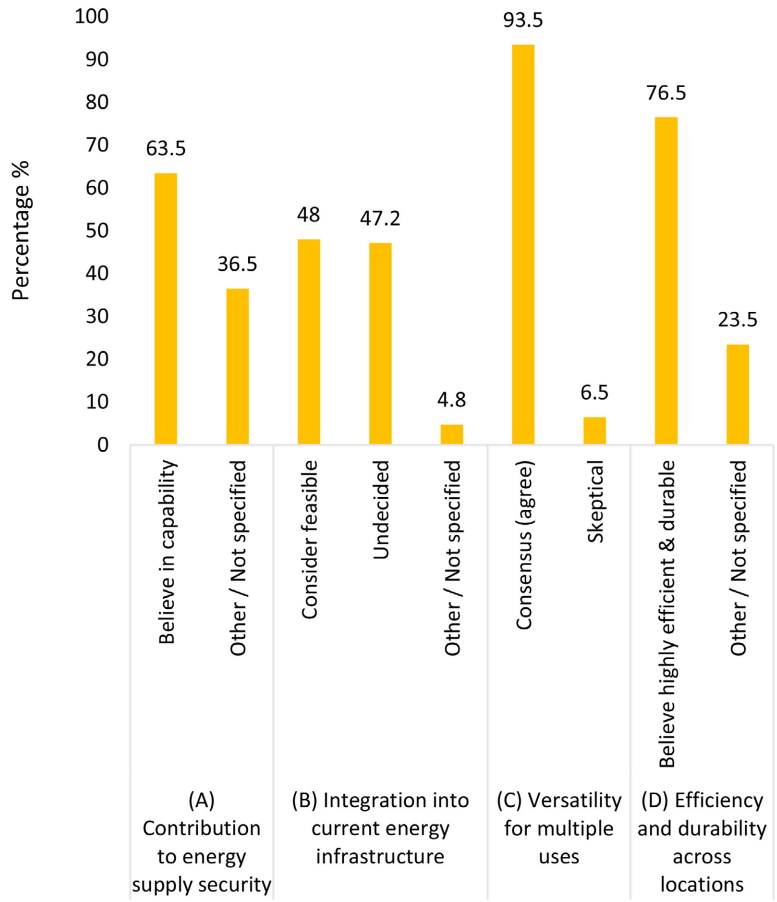

Figure 8. Survey of participant's results regarding the level of awareness.

In Figure 8(A), the participants exhibit a considerable level of optimism towards the potential of geothermal energy to enhance energy supply security in Jordan, with 63.5% expressing belief in its capability. Figure 8(B) reflects mixed perceptions regarding the integration of geothermal energy into the current energy infrastructure, with 48.0% of participants considering it feasible. However, uncertainties persist, as 47.2% remained undecided about its integration. Figure

8(C) highlights overwhelming consensus among participants (93.5%) regarding the versatility of geothermal energy for multiple uses. Conversely, only a small percentage (6.5%) expressed skepticism about its utility across various sectors. Finally, Figure 8(D) reveals that a majority of respondents (76.5%) believe geothermal energy to be highly efficient and durable, irrespective of geographical location, emphasizing confidence in its reliability and effectiveness as a renewable energy source.

Figure 9 provides insights into the sectors that most utilize geothermal energy. The data illustrate participants' perceptions of the primary sectors benefiting from geothermal energy utilization. The majority of respondents (61.4%) indicated "all of the above," suggesting a widespread acknowledgment of geothermal energy's versatility across multiple sectors, including agriculture, industry, and tourism. Additionally, a significant portion of participants identified industry (21.3%) as a key sector utilizing geothermal energy, emphasizing its importance in supporting industrial activities. Agriculture (6.0%) and tourism (5.0%) were also recognized as sectors benefiting from geothermal energy, albeit to a lesser extent. These findings underscore the diverse applications and potential of geothermal energy in various sectors of the economy.

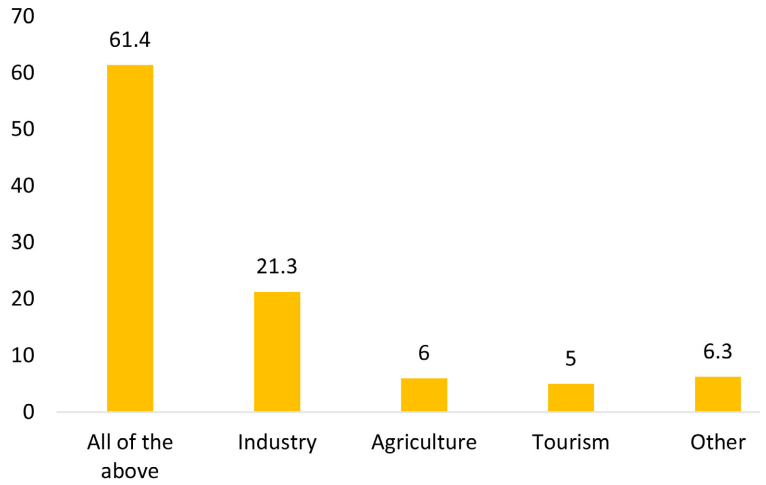

Figure 9. Participants' level of belief in the efficiency of geothermal energy and the excellence of its sustainability, regardless of its geographical location.

4.8. Investing in Geothermal Energy Projects in Jordan

This section delves into the landscape of investing in geothermal energy projects in Jordan, assessing various facets related to evaluation, exploration, and potential partnerships between the public and private sectors. Subsequently, each subsection examines critical inquiries to gauge the current state and perceptions surrounding geothermal energy initiatives in the country. The opening subsection addresses the evaluation and exploration of geothermal energy, probing participants' opinions regarding the progress of geothermal energy in Jordan.

Key questions include whether geothermal energy is currently undergoing eval-

uation and exploration processes, participants' awareness of existing geothermal projects, beliefs regarding potential partnerships between the public and private sectors, and any knowledge of agreements aimed at exploring geothermal energy sites in Jordan. Through this exploration, this study aims to provide insights into the existing landscape and future prospects of geothermal energy investment in Jordan. Table 7 provides insights into participants' perspectives on investing in geothermal energy projects in Jordan.

Table 7. Investment in geothermal energy projects in Jordan.

Items		Frequency	Percent%
In your opinion, is geothermal energy in Jordan in the process of evaluation and exploration?	Yes	146	35.0%
	No	59	14.1%
	Maybe	212	50.8%
Have you heard about current geothermal energy projects in Jordan?	Yes	84	20.1%
	No	333	79.9%
Do you believe in the possibility of a partnership between the public sector and the private sector in the field of investment in geothermal energy projects in Jordan?	Yes	197	47.2%
	No	29	7.0%
	Maybe	191	45.8%
Have you heard of any agreements to explore geothermal energy sites in Jordan?	Yes	67	16.1%
	No	350	83.9%

Regarding the evaluation and exploration of geothermal energy, a significant portion of respondents (35.0%) believe that geothermal energy in Jordan is currently undergoing evaluation and exploration processes, while 14.1% expressed disagreement and 50.8% remained uncertain. However, awareness of current geothermal energy projects in Jordan appears limited, with only 20.1% of participants indicating knowledge of such projects. When considering the possibility of partnership between the public and private sectors in geothermal energy investment, responses were more evenly distributed, with 47.2% expressing belief in such partnerships, 7.0% disagreeing, and 45.8% remaining unsure.

Additionally, a small proportion of participants (16.1%) reported being aware of agreements to explore geothermal energy sites in Jordan, suggesting a relatively low level of knowledge regarding ongoing exploration efforts. These findings highlight varying perceptions and levels of awareness regarding geothermal energy investment in Jordan, underscoring the need for further education and promotion of geothermal energy initiatives.

4.9. The Future of Geothermal Energy in Jordan

This section delves into the economic viability of geothermal energy exploitation, probing whether its utilization aligns with Jordan's economic landscape. Furthermore, it explores the challenges posed by the high costs associated with geothermal energy projects, investigating whether these costs serve as a barrier to its ex-

ploitation in Jordan. Moreover, this section scrutinizes the extent to which successive governments prioritize attracting investment in geothermal energy within their energy strategies. Additionally, this section delves into strategies aimed at fostering the adoption and utilization of geothermal energy, including raising consumer awareness, incentivizing investment, updating legislation, and enhancing collaboration between the public and private sectors. Table 8 shows the participants' perceptions toward the future of geothermal energy in Jordan.

Table 8. Participants' perceptions toward the future of geothermal energy in Jordan.

Items		Frequency	Percent%
Do you think that exploiting geothermal energy is economically feasible?	Yes	245	58.8%
	No	13	3.1%
	Maybe	159	38.1%
Do you think that the high cost of geothermal energy projects is the direct reason for not exploiting it in Jordan?	Yes	168	40.3%
	No	40	9.6%
	Maybe	209	50.1%
Do you think that the energy strategies of successive governments in Jordan give priority to attracting investment in the field of geothermal energy in Jordan?	Yes	99	23.7%
	No	147	35.3%
	Maybe	171	41.0%

Regarding the economic feasibility of geothermal energy exploitation, the majority of respondents (58.8%) believe it to be economically feasible, while a small percentage (3.1%) disagree and (38.1%) remain uncertain. However, when considering the high costs associated with geothermal energy projects, opinions are more divided, with (40.3%) attributing the lack of exploitation to project costs, (9.6%) disagreeing, and (50.1%) remaining uncertain. Furthermore, perceptions regarding governmental prioritization of geothermal energy investment are mixed, with only (23.7%) of participants believing that successive governments give priority to attracting investment in this field, (35.3%) disagreeing, and (41.0%) uncertain.

Table 9 shows perceptions and recommendations for exploiting geothermal energy in Jordan. It provides valuable insights into participants' perspectives on the steps required to encourage the exploitation of geothermal energy in Jordan, methods for increasing public awareness of its benefits, and potential applications of geothermal energy in various sectors.

Regarding steps to encourage exploitation, most respondents (38.0%) emphasize the importance of encouraging investment in geothermal energy, followed by spreading awareness among consumers (35.9%) and updating relevant legislation (26.1%). To increase public awareness, respondents suggest increasing the effectiveness of participation by the government and private sectors (35.2%), holding local workshops and conferences (34.4%), and introducing geothermal energy

into the school curriculum (30.5%).

Table 9. Perceptions and recommendations for exploiting geothermal energy in Jordan.

Items		Responses	
		N	Percent%
What are the steps that must be followed to encourage the exploitation of geothermal energy in Jordan?	Spreading awareness among consumers.	267	35.9%
	Encouraging investment in it.	283	38.0%
	Updating relevant legislation.	194	26.1%
How can public awareness be increased about the benefits of exploiting geothermal energy in Jordan?	By increasing the effectiveness of the participation of the government sector and the private sector.	264	35.2%
	By holding local workshops and conferences to spread the culture of its use.	258	34.4%
	By introducing it into the school curriculum, albeit in a simplified manner.	229	30.5%
What are the applications based on exploiting geothermal energy in Jordan, from your point of view?	In hotels, resorts, and hospital places.	227	27.3%
	In heating homes.	170	20.4%
	On farms and fish ponds.	146	17.5%
	In energy production.	290	34.8%

Additionally, respondents identified several potential applications of geothermal energy in Jordan, with energy production (34.8%) emerging as the most prominent, followed by utilization in hotels, resorts, and hospital places (27.3%), heating homes (20.4%), and on farms and fishponds (17.5%). These findings highlight the multifaceted strategies and opportunities for promoting and utilizing geothermal energy in Jordan.

5. Discussion

Quantitative survey results were explicitly integrated with expert interview insights (e.g., public cost concerns linked to investment barriers highlighted by experts). The socio-demographic characteristics of the study participants are analyzed, providing essential contextual information for the ensuing discussions. The participants' attitudes towards renewable energy adoption are explored, highlighting their awareness, perceptions, and willingness to embrace renewable energy sources. Factors encouraging renewable energy use and obstacles to adoption are identified, offering insights into the complexities of transitioning towards sustainable energy solutions. Furthermore, the level of awareness of geothermal energy among participants is examined, along with strategies to enhance community awareness of its benefits. The feasibility and implications of integrating geother-

mal energy into Jordan's energy sector are discussed, addressing considerations such as economic viability, infrastructure compatibility, and sectorial utilization. The future of geothermal energy in Jordan is then analyzed, focusing on its economic feasibility, cost considerations, and governmental priorities. Finally, perceptions and recommendations for exploiting geothermal energy in Jordan are summarized, highlighting steps to encourage its exploitation, methods for increasing public awareness, and potential applications across various sectors.

The findings presented in this study underscore the significant potential of renewable energy, particularly geothermal energy, in Jordan's energy landscape. While there is a considerable level of awareness and willingness to embrace renewable energy sources among participants, challenges such as cost and infrastructure constraints remain prevalent. However, there is optimism regarding the economic feasibility and versatility of geothermal energy, with opportunities for investment and partnership between the public and private sectors. The findings highlight the necessity for coordinated efforts to raise awareness, encourage investments, modernize regulations, and strengthen collaboration among stakeholders. By adopting these approaches, Jordan can pave the way for a more sustainable and resilient energy future for the country.

It can be argued that the survey results indicate that 61.8% of respondents consider high costs a major barrier to renewable energy adoption. This concern is directly supported by expert interviews, where Eng. Bassam Sunna emphasized that the lack of initial investment incentives and financial risk-sharing mechanisms remains a primary obstacle to geothermal development in Jordan. Similarly, while 52.3% of respondents identified energy bill savings as a key motivator, experts highlighted that targeted government subsidies and public–private partnership frameworks are essential to translate this public interest into actual geothermal projects. The findings suggest that public concern over cost and strong interest in long-term savings necessitate clear policy interventions. These include introducing financial incentives, reducing upfront investment risks, and establishing public–private partnership frameworks tailored to low-enthalpy geothermal projects. Strengthening legislation and increasing transparency in geothermal exploration agreements would further enhance investor confidence and public acceptance.

The interviews with Engineer Bassam Sunna, Dr. Ali Al Swarieh and Engineer Mohammad Abu Zaid, provide valuable insights into the state and potential of geothermal energy in Jordan. They confirm several key observations that are consistent with the findings regarding the utilization and applications of this renewable energy resource.

Firstly, Eng. Sunna emphasizes the underutilization of geothermal resources in Jordan. Despite its abundance, geothermal energy is primarily harnessed for tourism and therapeutic purposes, rather than for broader energy production. This aligns with previous analyses indicating a lack of comprehensive exploitation of Jordan's geothermal potential. Moreover, the interview underscores the versatility

of geothermal energy applications. Eng. Sunna discusses a wide range of potential uses, including heating, electricity generation, agriculture, industry, healthcare, and tourism. These echo previous assessments of the diverse opportunities presented by geothermal energy, suggesting its potential to contribute to various sectors of Jordan's economy and society .

Additionally, the interview with Dr. Ali Swarieh highlights the extensive distribution of geothermal resources throughout Jordan, including numerous hot springs and wells containing hot water. Dr Swarieh's identification of these resources reaffirms the country's significant geothermal potential, particularly in regions adjacent to geological features conducive to geothermal activity.

The interview with renewable energy researcher Eng. Mohammed Abu Zaid focused on pioneering projects aimed at improving the efficiency of photovoltaic cells using natural materials, in addition to developing new technologies that rely on other energy sources to improve energy production. In his discussion, Abu Zaid mentioned that the progress made by Jordan in the fields of solar and wind energy, expressing hope to move towards research related to geothermal energy. He stressed the role of society in supporting renewable energy through awareness and participation in the use of clean technologies, while highlighting the positive impact of renewable energy on the Jordanian economy by creating job opportunities and reducing dependence on imported fuels.

Overall, the interviews with Eng. Mohammad Abu Zaid, Eng. Bassam Sunna, and Dr. Ali Swarieh provide critical insights that substantially enhance our understanding of the current status and future prospects of geothermal energy development in Jordan. Their perspectives underscore the notable progress achieved in renewable energy technologies while simultaneously revealing the urgent need for intensified exploration, scientific assessment, and strategic investment in geothermal resources. Collectively, their contributions highlight geothermal energy as a largely untapped yet highly promising component of Jordan's renewable energy portfolio, capable of supporting long-term national energy and sustainability objectives. Beyond its technical and economic feasibility, the sustainable utilization of geothermal resources represents a cornerstone for environmentally responsible energy development. Properly managed geothermal systems offer a low-carbon, continuous, and reliable energy source with minimal land disturbance and significantly lower lifecycle emissions compared to conventional fossil-fuel-based power generation. The experts emphasize that adopting best practices in resource assessment, reservoir management, and reinjection strategies is essential to ensure the long-term sustainability of geothermal reservoirs, prevent resource depletion, and maintain environmental integrity. Importantly, the expansion of geothermal energy can play a decisive role in mitigating carbon dioxide (CO_2) emissions, thereby contributing to climate change mitigation and environmental protection. By substituting fossil fuel–based electricity and thermal energy with geothermal alternatives, Jordan can substantially reduce greenhouse gas emissions, improve air quality, and lessen the adverse impacts of climate change on

ecosystems, water resources, and public health. This transition is particularly critical for safeguarding the planet from accelerating CO_2 accumulation, which poses severe risks to climate stability, biodiversity, and future generations. Furthermore, the interviews stress the importance of integrating geothermal development within a broader framework of sustainable development and community engagement. Public awareness, stakeholder participation, and local capacity building are vital to fostering social acceptance and maximizing the socio-economic benefits of geothermal projects. When implemented responsibly, geothermal energy can enhance energy security, reduce reliance on imported fossil fuels, and stimulate economic growth through job creation, technological innovation, and the development of a skilled green workforce.

In conclusion, leveraging Jordan's unique geothermal potential through sustainable management practices offers a strategic pathway toward achieving national energy resilience, reducing CO_2 emissions, and advancing the country's sustainable development goals. The insights provided by these experts reaffirm that geothermal energy, if responsibly developed, can serve as a vital pillar in Jordan's transition toward a low-carbon, environmentally sustainable, and economically robust energy future.

6. Conclusion and Recommendation

Previous research on geothermal energy in Jordan had largely overlooked optimal exploitation methods. This study identifies the direct use of geothermal energy as the most efficient and practical approach for the country's needs. The main conclusions and recommendations are the following:

1) The study highlights the significant potential of geothermal energy in Jordan, underscored by the presence of numerous hot springs and wells with temperatures ranging between 27˚C and 70˚C and flow rates from 2 to 900 m^3/h. These resources offer an acceptable flow rate for various energy applications .

2) Interviews with experts revealed that Jordan possesses substantial geothermal resources, which, if properly utilized, could reduce reliance on fossil fuels, support the economy, and enhance energy security. However, greater community awareness and institutional support are essential to harness this potential effectively.

3) A questionnaire distributed to participants assessed social and demographic characteristics and attitudes toward adopting renewable energy in Jordan.

4) The findings indicate a positive trend, with respondents showing readiness to transition to renewable energy. These results underscore the need for more awareness and initiatives to promote geothermal energy adoption.

5) It can be recommended to form a national committee with experts from government, the private sector, universities, and energy agencies to evaluate geothermal energy resources and develop a time-bound utilization plan, and to promote investment in geothermal energy in both the public and private sectors.

6) Increasing community awareness about the benefits of geothermal energy

and updating regulations to support geothermal energy exploitation is well recommended.

7) Experts' insights confirm that geothermal energy can be a key component in Jordan's shift to a low-carbon, environmentally sustainable, and economically stable energy future if it is produced properly.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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