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Identifying and Explaining Public Preferences for Renewable Energy Sources in Qatar

Ahmed K. Nassar

Policy, Planning and Development Program, Department of International Affairs, College of Arts and Sciences, Qatar University, Doha P.O. Box 2713, Qatar; anassar@qu.edu.qa

Abstract: As a major natural gas and oil producer, Qatar has made significant strides towards its energy transition. This paper uses a survey research design with statistical tests to investigate citizens' preferences for a wide range of energy resources. In this study, participants were asked to prioritize energy sources based on their environmental impact, price, benefits to Qatar's economy, support of energy security, and ability to create jobs. The results showed that approximately two-thirds of the sample (n = 354) preferred renewable energy sources, particularly solar, which ranks first. Renewable energy sources were more likely to be favored by the group with greater knowledge of energy sources than those with limited knowledge, except for solar energy, which was preferred by both groups. Additionally, both natural gas and wind rank second in terms of preference, followed by hydropower. In contrast, nuclear power was not ranked, indicating a strong opposition to this type of energy. The study provides an evidence-based example of the tendency of citizens in a hydrocarbon-rich country to prefer renewable energy sources and natural gas. The energy policymakers need to collaborate with local communities so that citizens can participate in important future energy discussions to develop a personal connection to climate solutions.

Keywords: preferences; renewable energy; non-renewable energy; knowledge; questionnaire; Qatar

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1. Introduction

Renewable energy is currently the primary focus of investment in the energy sector. Recently, we have reached about 3 terawatt of generated green energy capacity worldwide, increasing the stock of renewable energy by 9.1% [1]. Even though hydropower makes up about one terawatt of the total global renewable energy capacity of renewable energy sources (REs), solar and wind are still the most dominant new sources of renewable energy. According to [2], the total amount of clean energy installed from wind and solar sources throughout the world surpassed one terawatt, which is equal to the size of the United States' entire power system. With a 19% increase in capacity, solar energy led the way, followed by wind energy with a 13% increase [1].

The energy transition has become a worldwide phenomenon that is already causing significant economic, cultural, and technological shifts. Countries all over the world are setting ambitious targets to replace their fossil-fuel-based energy sources with renewable energy one. Public opinions about energy sources are critical to energy policy and public support of future energy choices [3,4]. In addition, the public has a key role to play in the development of energy planning and strategy. However, in various populations, especially in hydrocarbon-rich countries where their economy revenues are heavily reliant on fossil fuels, studies involving public opinion on energy sources are lacking. Public acceptability and perception towards renewable energy sources are important because of their relationship to policy making and to evaluate the energy transition social acceptance to support and advance the UN's sustainable development goal 7 (Affordable and clean energy) and goal 13 (Climate Action) [5,6].

The six Gulf Cooperation Council (GCC) countries are among the world's major oil and natural gas reserves and productions. For example, the total oil reserves of the GCC countries amount to 30.5% of the total proven global reserves in 2020 [7]. Saudi Arabia ranks first in the volume of reserves with a rate of 17.2%, while Qatar comes in fourth place with 1.5% at the global level. Additionally, the total oil production in the GCC countries amounted to 22.7% of the total global production for the same year. As for natural gas, the GCC countries' reserves amount to 20.8% of the total proven global reserves of natural gas in 2020, where Qatar's share is 13.1%, occupying third place in the world after Russia and Iran. Furthermore, the total production of natural gas in the GCC countries amounted to 10.5% of the total global production for the same year. Qatar also ranked second in the world in the export of liquefied natural gas, accounting for 21.7% of the total global export [8]. It is worth noting that the United Arab Emirates (UAE) and to the less extent Oman are the only countries in the gulf to use coal-fired power plants accounting for about 0.2% of the world's total consumption [9].

The Gulf region is rich in renewable energy sources, with particularly high sun radiation levels. Therefore, it has a high potential for solar power production. Another renewable is the wind resources with high potential power generation in three Gulf countries, namely Saudi Arabia, Oman, and Kuwait due to the abundance of wind resources with low annual variability [10]. Two renewable energy resources, geothermal and biomass, may hold greater potential but have not been well explored and invested in the region, especially in Saudi Arabia and Oman [11,12]. Despite the abundance of renewables potential in the GCC countries, by the end of 2021, the share of their renewables reached approximately 0.2% of the global total renewable energy [8]. The UAE can be considered a regional leader in renewable energy adoption, accounting for 77% of total regional renewable energy installed capacity in year 2021, followed by Saudi Arabia (13%) and Oman (6%) (Figure 1).

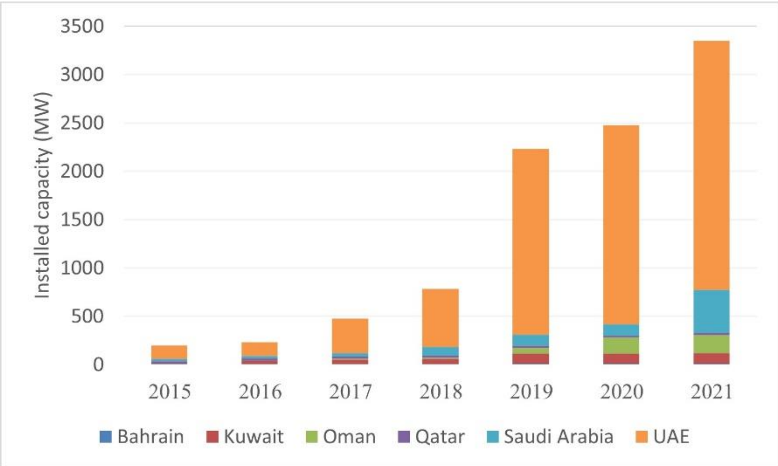

Figure 1. Renewable energy installed capacity in the GCC countries, 2015–2021 [13].

The UAE is the only country in the Gulf that uses nuclear energy to generate electric power, with a share of 1.3% of its total electricity production, and it accounts for 0.4% of global nuclear energy consumption in 2021 [8]. It is expected after operating its four reactors to cover 25% of its domestic needs from electric energy. It is worth noting that the six GCC countries had decided in 2006 to develop a joint nuclear program to produce electricity. However, most of these countries withdrew from this project in light of the Japanese Fukushima reactor accident.

Recently, hydrocarbon-rich GCC countries attracted the attention of policymakers, and the renewable energy technology markets with ambitious plans to increase the share of renewables in the energy mix, led by the UAE, Saudi Arabia, and Qatar. Despite the fact that only 0.76% of the world population lives in GCC countries, the region contributes to 3.3% of the global greenhouse emissions in 2021 [8], hence its per capita emissions are quite high, necessitating energy transition to REs. Therefore, UAE's 2050 strategy included targeting the country to produce about 50% of electricity through REs, 38% of gas, 12% of clean coal, and 6% of nuclear energy [14]. The UAE aims to invest about 164 billion dollars by 2050 to meet the increasing demand for energy, with a tendency to reduce the carbon footprint in electricity generation by 70%, which in turn leads to cost savings of approximately 191 billion dollars. As for Saudi Arabia, it plans to generate about 50% of its electricity through renewable sources by 2030, as part of its pledge to reduce carbon emissions. Saudi Arabia has also started work on the construction of the city of NEOM which relies entirely on clean energy, the first part of which is planned to be completed in 2025. Within a broader scope and to support these plans, Saudi Arabia announced the Middle East Green Initiative, aiming to expand the Middle East's contribution of sustainable energy generation to more than 7% through the exchange of knowledge about advanced energy technologies among the countries of the Middle East.

As for the State of Qatar, it has begun to focus on renewable energy even though it possesses one of the highest hydrocarbon savings from natural gas in the world because of two major reasons. In 2021, the country contributed 0.3% of global greenhouse gas emissions, so the first step is to diversify energy sources from renewables to contribute to global decarbonization efforts [15]. In this context and according to the Paris Agreement, Qatar has committed to reducing 25% of its greenhouse gas emissions by 2030 as part of its Nationally Determined Contributions (NDCs). The second reason is to reduce local reliance on traditional energy to work on exporting more natural gas abroad for higher revenues [16] because 100% of the current local production of electricity comes from natural gas. Therefore, the energy transition has become one of the top priorities for the Qatari government, and policymakers are seeking to develop future political solutions to the energy sector to reach Qatar's national vision 2030 [17]. The renewable energy market in Qatar is expected to grow at an annual growth rate of about 20% to reach about 73 billion dollars during 2023. As part of Qatar's commitment to REs, particularly solar energy, an agreement has been reached to establish and operate the AlKharsaah Solar Power Plant in collaboration with international companies. The total capacity of the project is expected to reach about 800 megawatts of electricity, equivalent to 10% of the peak demand for electricity in Qatar. This project comes also as part of the energy sector's contribution to fulfilling the country's obligations in the 2022 World Cup file. In late 2021 and to stress the importance of climate change and energy transformation, Qatar established the Ministry of Environment and Climate Change, and the transformation of Qatar Petroleum into QatarEnergy.

Renewable energy is becoming increasingly recognized as an effective tool for addressing climate change [18–21]. Therefore, public opinion studies on energy issues have revealed strong support with different degrees for REs [22–25], and polarized views about non-renewables including coal, nuclear energy, natural gas, and oil [26–29]. Most studies assessing public acceptance of renewable energy sources have been conducted in fossil fuel importing countries or countries with highly diversified economies [24,30–34]. To the best of our knowledge, literature that investigates the public acceptance of REs in hydrocarbon-rich countries are lacking. Therefore, this is an interesting opportunity for examining public preferences for REs and non-REs in a major fossil fuel exporting country.

Collecting data about the public preferences for energy sources can provide information to help determine the services required by the community. An energy source preference refers to a preference for one or more qualities of one source over those of another [31]. Ref. [5] used opinion and attitude terms interchangeably. However, [35] assumed that preferences and attitudes are not exactly the same and there was a gap between the two terms. However, preferences according to [36] are attitudes toward one object in relation to another. Because of their connection to behavior, preferences are at the heart of decision theory, and they are intimately linked to desires as conative states [37]. The distinction between the two is that desires are focused on a single object, whereas preferences are based on a comparison of two options, one of which is favored over the other [38].

Therefore, the objectives of the study were to: (1) investigate the most preferable of nine energy sources other than chance, and (2) study the association between participants who view themselves as knowledgeable on energy sources and those who have limited or no knowledge.

2. Materials and Methods

In this study, the Paired Comparisons method (PC) introduced by [39] was used to obtain nominal scales for the nine mutually exclusive categories of energy sources (non-renewables: oil, natural gas, nuclear, coal, and renewables: solar, wind, bioenergy, hydropower, geothermal). These are the primary energy sources that are utilized or have the potential to be used in Qatar and the region. Figure 2 illustrates the flowchart for the methodology used.

The PC method is simply a binary choice of judgments [40] and it is defined by [41] as a method for comparing a pair of objects or items in a systematic way (one-on-one). For example, an individual is given a pair of items and asked to choose the item that meets a given criteria, such as being the most preferable; the process is repeated until every item in the set has been compared to every other item.

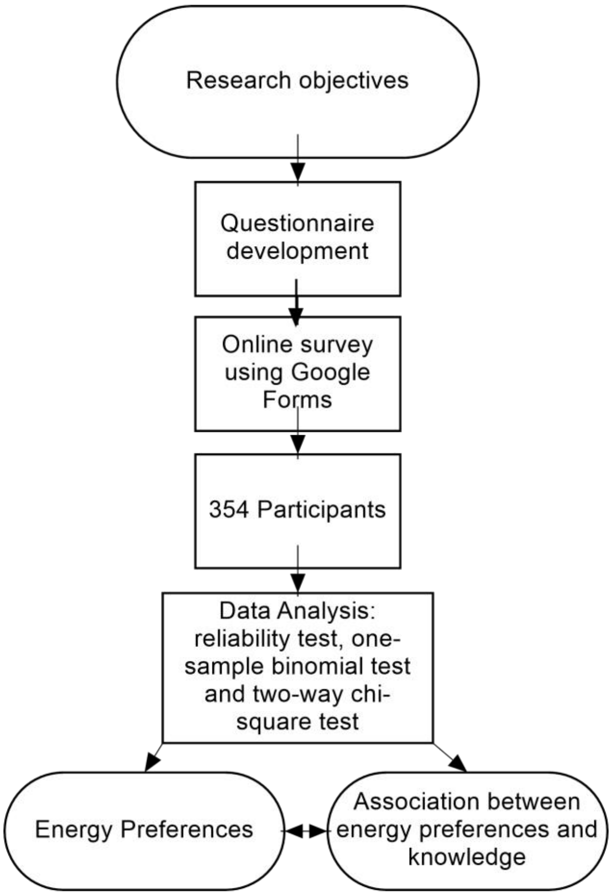

Figure 2. Methodology flowchart.

This method has been used in a wide variety of applications to assist in the decision-making process, such as sustainability evaluation [42]; sensory analysis to investigate preference and choice behavior [43]; engineering [44]; ecology and environment [45,46]; economics and policy [40]; and educational measurements [47].

The main advantage of the PC method is that it reduces the probability of unreliability by utilizing data from all possible pairs. It is also useful for eliciting judgements and preferences using the simplest instructions. It is, however, a time-consuming process. As an example, if respondents are asked to rate nine items or sources of energy based on 5 or more points of scale, they will only answer nine items; whereas, in a PC method, they must select the more preferred item from each of 36 pairs of items using the following formula:

$[n(n-1)]\,/2$ where n is the number of items. It is concluded that PC advantages outweigh its disadvantages [43,46].

2.1. Data Collection

There were 354 valid responses to an online questionnaire created with Google Forms. The snowball sampling method was used, and participants were encouraged to share the online survey with their acquaintances. Only participants who volunteered to take part in the survey through e-mail and social media were selected for the study, thus ensuring the study was bias-free. In order to protect the privacy of the respondents, strict precautions were taken during the survey. Sample participants were diverse in terms of gender and educational backgrounds, and they were offered no incentives. However, only individuals over the age of 18 were allowed to participate in the survey. Additionally, a nonprobability sample approach was adopted, in which survey respondents were selected at random and without regard for any previous characteristic other than age. Data were collected from 1 October 2021 to 30 April 2022 following years of the country interest in REs to fulfill its obligations for the 2022 World Cup file. However, Qatar's economy is heavily dependent on natural gas and oil, and its prosperity and wealth are closely tied to these resources. Thus, this study presents a unique opportunity to test the opinions of a sample of the public whose country is highly dependent on fossil fuels.

In order to measure respondents' preferences, we asked the following question in Arabic, which is translated as follows: "The following list of energy sources has been arranged in pairs. Please choose which of the following sources you believe is most preferable to you based on its environmental impact, price, benefit to Qatar's economy (economic security), support of energy security, and ability to create jobs. The total energy sources are nine, including non-renewables such as oil, gas, nuclear energy, and coal; and renewables such as solar, wind, bioenergy, hydropower, and geothermal".

The questionnaire consisted of 36 pairs of nine energy resources (arranged from Q2 to Q37), and a first question asking if the person had pre-knowledge of five or more energy sources from their study or other sources such as the media (TV, internet, newspaper, etc.) or if they had limited or no knowledge of four or less (Q1). There were 153 knowledgeable and 201 unknowledgeable respondents in the two groups, therefore both populations are statistically comparable.

2.2. Statistical Analysis

2.2.1. Instrument Reliability

Reliability is an essential approach to evaluate the quality of the measurement tools used. Cronbach's Alpha is one of the main methods of estimating the reliability of a measurement instrument [48]. Internal consistency can range from zero to one for Cronbach's Alpha. A basic rule of thumb is that an alpha of 0.6–0.7 suggests an acceptable level of reliability whereas an alpha of 0.8 or higher indicates a very high level of reliability [49]. On the other hand, an alpha of 0.95 or higher might indicate redundancy, which is not always desirable. The result of reliability for the 36 preferences (alpha = 0.88) indicates a very good level of reliability.

2.2.2. Data Analysis

The Statistical Program for the Social Sciences (SPSS) 25.0 was used to carry out the analyses. In order to test the significance of Paired Comparisons, [50] suggests using goodness of fit to compare the proportions of the model underlying paired comparisons solution with observed proportions of a hypothetical solution (0.50, 0.50/chance proportion). Practically, if discrepancies between observed and derived proportions were small, the solution is relevant and internally consistent. Therefore, to see if the observed frequencies of the nine sources of energy preferences are different from the hypothetical solution, a one-sample binomial test is used.

In addition, a two-way chi-square was used to test the association between the group of participants who view themselves as knowledgeable about energy sources and those who were with limited or no knowledge, as self-reported by the participants in Q1 of the questionnaire. It is noteworthy that several studies examining the relationship between prior knowledge of consumers and a specific product category separated the concept of objective knowledge and subjective knowledge [51,52]. Subjective knowledge, sometimes referred to as perceived or self-assessed knowledge, relates to what people view they know about a product, whereas objective knowledge refers to how much knowledge an individual actually has. Because this study deals with the preferences of nine energy sources, it is difficult to assess and measure participants knowledge of each energy source. Therefore, the current study deals with the concept of subjective knowledge that was used in other energy preference studies [31].

3. Results and Discussion

In order to identify participants' preferences of energy resources (Objective 1), the one-sample binomial test in Table 1 was generated. The test was based on the sample of n = 354 participants who selected the preferable dichotomous source of energy as compared with the one on each of the 36 pairs. Participants' choices of preferred energy sources were influenced by several factors, as mentioned in the questionnaire. Bar graphs (see, e.g., Figure 3) that illustrate observed frequencies versus hypothesized expected frequencies (0.50/0.50 chance) revealed that observed frequencies are different from hypothesized in all bars, except those for questions 3, 6, 19 and 24.

Table 1. One-Sample Binomial test using SPSS 25 with a hypothetical model occur with 0.50 and 0.50.

Questionnaire Questions	*p*-Value	Decision	Preferred Energy Source	% *	F **	Rank
Q2 = Coal and Natural Gas	0.000	Reject	Natural Gas	92	6	2.5 ***
Q3 = Hydropower and Oil	0.123	Retain				
Q4 = Bioenergy and Coal	0.000	Reject	Bioenergy	75	3	4
Q5 = Nuclear and Solar	0.000	Reject	Solar	90	8	1
Q6 = Oil and Geothermal	0.184	Retain				
Q7 = Natural gas and Nuclear	0.000	Reject	Natural gas	88		
Q8 = Nuclear and Wind	0.000	Reject	Wind	80	6	2.5 ***
Q9 = Solar and Coal	0.000	Reject	Solar	97		
Q10 = Bioenergy and Natural Gas	0.000	Reject	Natural Gas	62		
Q11 = Wind and Hydropower	0.000	Reject	Wind	73		
Q12 = Natural Gas and Oil	0.000	Reject	Natural Gas	76		
Q13 = Hydropower and Nuclear	0.000	Reject	Hydropower	70	4	3
Q14 = Natural Gas and Solar	0.000	Reject	Solar	83		
Q15 = Bioenergy and Geothermal	0.001	Reject	Bioenergy	59		
Q16 = Oil and Coal	0.000	Reject	Oil	78	2	5.5
Q17 = Solar and Hydropower	0.000	Reject	Solar	93		

Q18 = Wind and Coal	0.000	Reject	Wind	93		
Q19 = Bioenergy and Oil	0.366	Retain				
Q20 = Natural Gas and Geothermal	0.000	Reject	Natural Gas	64		
Q21 = Hydropower and Coal	0.000	Reject	Hydropower	84		
Q22 = Solar and Bioenergy	0.000	Reject	Solar	91		
Q23 = Nuclear and Oil	0.000	Reject	Oil	77		
Q24 = Natural Gas and Wind	0.099	Retain				
Q25 = Solar and Geothermal	0.000	Reject	Solar	89		
Q26 = Nuclear and Coal	0.022	Reject	Coal	56	1	6
Q27 = Wind and Bioenergy	0.000	Reject	Wind	70		
Q28 = Hydropower and Geothermal	0.000	Reject	Hydropower	73		
Q29 = Oil and Solar	0.000	Reject	Solar	87		
Q30 = Geothermal and Coal	0.000	Reject	Geothermal	65	2	5.5
Q31 = Solar and Wind	0.000	Reject	Solar	91		
Q32 = Natural Gas and Hydropower	0.000	Reject	Natural Gas	67		
Q33 = Nuclear and Geothermal	0.000	Reject	Geothermal	64		
Q34 = Bioenergy and Hydropower	0.002	Reject	Hydropower	58		
Q35 = Wind and Geothermal	0.000	Reject	Wind	76		
Q36 = Oil and Wind	0.000	Reject	Wind	77		
Q37 = Nuclear and Bioenergy	0.000	Reject	Bioenergy	63		

* Percentage of respondents who selected a preferred source of energy as compared with its paired. ** Frequency of sources of energy that the respondents preferred. *** Rank with halves number implies that they share the same frequency.

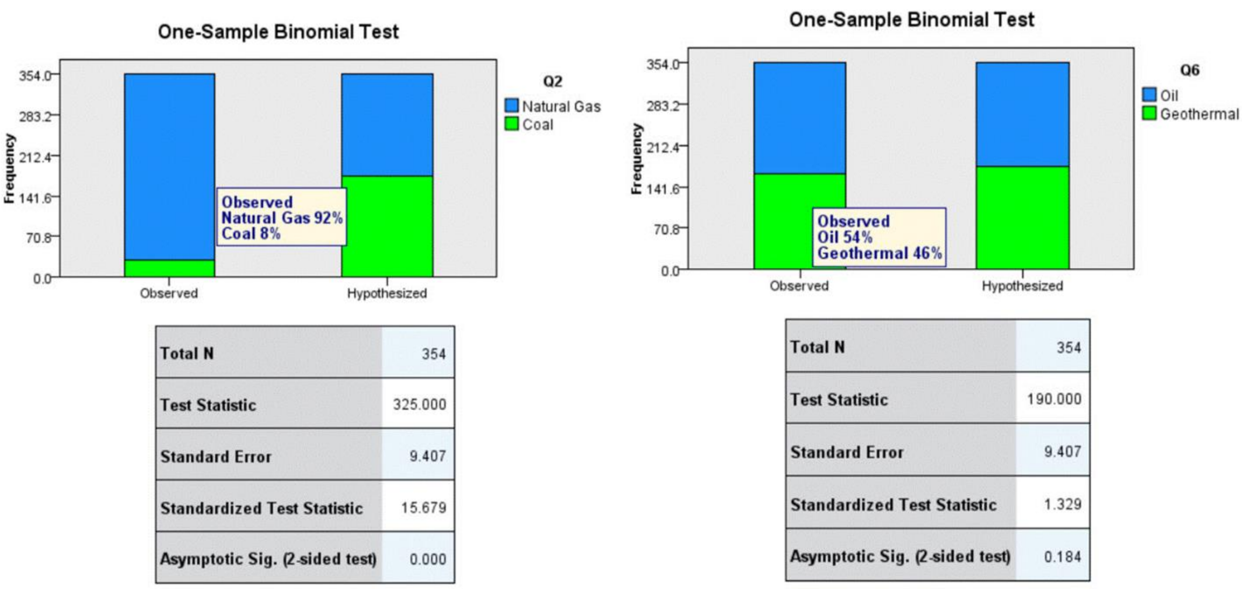

Figure 3. One-sample binomial test to show the observed frequency compared to the hypothetical frequency of 0.50/0.50 chance for Q2 (rejected) and Q6 (retained), as an example.

Using the findings from Q1 (i.e., knowledgeable or unknowledgeable) in the questionnaire, we tested the 36 statistical null hypotheses related to each question using a two-way Chi square (Table 2) to find the association between participants who view themselves to be knowledgeable on energy resources and those who do not (Objective 2).

Table 2. Two-by-Two Chi square with Phi correlation between the respondents who view themselves to be knowledgeable on energy resources and those who do not.

Pairs	Sources of Energy	Unknowledgeable	Knowledgeable	X^2	*p*-Value	Phi φ	Effect Size *
Q2	Coal	12.4%	2.6%	11.146	0.001	0.20	Small
	Natural Gas	87.6%	97.4%				
Q3	Hydropower	38.8%	79.7%	70.601	0.000	0.50	Medium
	Oil	65.2%	20.3%				
Q4	Bioenergy	63.2%	90.2%	33.60	0.000	0.31	Small
	Coal	36.8%	9.8%				
Q5	Nuclear	16.9%	2%	20.758	0.000	0.24	Small
	Solar	83.1%	98%				
Q6	Geothermal	26.9%	71.9%	70.842	0.000	0.50	Medium
	Oil	73.1%	28.1%				
Q7	Natural gas	86.1%	90.2%	1.386	0.239	0.10	
	Nuclear	13.9%	9.8%				
Q8	Nuclear	31.8%	3.9%	42.686	0.000	0.40	Small
	Wind	68.2%	96.1%				
Q9	Coal	5.5%	0.0%	8.642	0.003	0.20	Small
	Solar	94.5%	100%				
Q10	Bioenergy	25.4%	53.6%	29.499	0.000	0.30	Small
	Natural-Gas	74.6%	46.4%				
Q11	Hydropower	26.9%	28.1%	0.067	0.796	0.01	
	Wind	73.1%	71.9%				
Q12	Natural Gas	59.7%	98%	70.551	0.000	0.50	Medium
	Oil	40.3%	2%				
Q13	Hydropower	61.7%	81%	15.513	0.000	0.21	Small
	Nuclear	38.3%	19%				
Q14	Natural Gas	19.9%	13.7%	2.323	0.128	0.08	
	Solar	80.1%	86.3%				
Q15	Bioenergy	61.7%	56.2%	1.082	0.298	0.06	
	Geothermal	38.3%	43.8%				
Q16	Coal	22.4%	22.2%	0.001	0.970	0.00	
	Oil	77.6%	77.8%				
Q17	Hydropower	2.5%	13.7%	16.122	0.000	0.21	Small
	Solar	97.5%	86.3%				
Q18	Coal	12.4%	0.0%	20.476	0.000	0.24	Small
	Wind	87.6%	100%				
Q19	Bioenergy	27.4%	73.9%	75.309	0.000	0.50	Medium
	Oil	72.6%	26.1%				
Q20	Geothermal	22.9%	53.6%	35.490	0.000	0.32	Small
	Natural Gas	77.1%	46.4%				
Q21	Coal	25.4%	4.6%	27.429	0.000	0.30	Small
	Hydropower	74.6%	95.4%				
Q22	Bioenergy	9.5%	8.5%	0.097	0.756	0.02	
	Solar	90.5%	91.5%				
Q23	Nuclear	17.9%	30.7%	7.940	0.005	0.20	Small
	Oil	82.1%	69.3%				
Q24	Natural Gas	74.6%	28.1%	75.828	0.000	0.50	Medium
	Wind	25.4%	71.9%				
Q25	Geothermal	10.0%	11.8%	0.298	0.585	0.03	
	Solar	90.0%	88.2%				

Q26	Coal	57.7%	54.2%	0.423	0.515	0.04	
	Nuclear	42.3%	45.8%				
Q27	Bioenergy	32.8%	25.5%	0.671	0.413	0.04	
	Wind	67.2%	74.5%				
Q28	Geothermal	24.9%	28.8%	0.004	0.951	0.00	
	Hydropower	75.1%	71.2%				
Q29	Oil	22.4%	0.7%	36.298	0.000	0.32	Small
	Solar	77.6%	99.3%				
Q30	Coal	50.7%	14.4%	50.485	0.000	0.40	Small
	Geothermal	49.3%	85.6%				
Q31	Solar	87.1%	95.4%	7.183	0.007	0.14	
	Wind	12.9%	4.6%				
Q32	Hydropower	13.4%	58.2%	78.921	0.000	0.50	Medium
	Natural Gas	86.6%	41.8%				
Q33	Nuclear	50.7%	17.0%	42.874	0.000	0.35	Small
	Geothermal	49.3%	83.0%				
Q34	Bioenergy	46.3%	35.3%	4.309	0.038	0.11	
	Hydropower	53.7%	64.7%				
Q35	Wind	80.6%	75.8%	1.177	0.278	0.06	
	Geothermal	19.4%	24.2%				
Q36	Oil	28.4%	17.0%	6.251	0.012	0.13	
	Wind	71.6%	83%				
Q37	Nuclear	44.8%	26.1%	12.979	0.000	0.20	Small
	Bioenergy	55.2%	73.9%				

* Effect Size scale is according to Cohen's (1988) criteria, which measures the practical significance after the statistically significant results.

Since most of the p-values in Table 2 are ≤0.05, the null hypotheses were rejected, except for Q7, Q11, Q14–16, Q22, Q25–28, Q31 and Q34–36, accordingly, we can conclude:

1. Both knowledgeable and unknowledgeable respondents preferred solar over nuclear, hydropower, oil, and coal. These results were statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size based on Cohen's criteria [53].
2. The wind was preferred over nuclear and coal by both unknowledgeable and knowledgeable respondents. These results were statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size based on Cohen's criteria. Wind, however, was preferred over natural gas among the knowledgeable respondents. This result was statistically significant ($p \leq 0.005$), and practically accepted according to the medium effect size based on Cohen's criteria.
3. Both knowledgeable and unknowledgeable respondents preferred natural gas over coal and oil. These results were statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size for natural gas versus coal, and the medium effect size for natural gas versus oil. However, only unknowledgeable respondents preferred natural gas over bioenergy, geothermal, wind and hydropower sources. These results were statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size for natural gas versus bioenergy and geothermal, and the medium effect size for natural gas versus hydropower based on Cohen's criteria.
4. Both unknowledgeable and knowledgeable respondents preferred hydropower over nuclear and coal. These results were statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size based on Cohen's criteria. However, only the knowledgeable group preferred hydropower when compared to oil. This result

was statistically significant ($p \leq 0.005$), and practically accepted according to the medium effect size using Cohen's criteria.

5. Both unknowledgeable and knowledgeable groups preferred bioenergy over nuclear and coal. These results were statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size using Cohen's criteria. However, only knowledgeable citizens preferred bioenergy over oil. This result was statistically significant ($p \leq 0.005$)), and practically accepted according to the medium effect size based on Cohen's criteria.
6. Only knowledgeable respondents preferred geothermal over oil, nuclear and coal. These results were statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size using Cohen's criteria for both geothermal versus nuclear and coal. However, it was practically accepted according to the medium effect size for geothermal versus oil.
7. Both unknowledgeable and knowledgeable respondents preferred oil over nuclear. This result was statistically significant ($p \leq 0.005$), and practically accepted according to the small effect size based on Cohen's criteria.

The findings in Table 1 showed that there is overlap between the preferences for REs and non-REs, with solar energy being the most preferred energy source, followed by both wind and natural gas. Qatar's location is ideal for photovoltaic investment, as it has a strong and consistent solar brightness throughout the calendar year, and ample space for solar farms (see Figure 4). Additionally, the local media has played a key role in publicizing solar energy during Qatar's bid announcement to host the World Cup in 2022. As announced, the Qatar World Cup Stadium, training facilities, and spectator areas will be equipped with solar-powered cooling systems to reduce the carbon footprint of these facilities and to fulfill Qatar's commitment during the World Cup in 2022 [54]. Therefore, it is likely that these reasons explain the great support solar energy received from both knowledgeable and unknowledgeable participants in comparison with other renewable energy sources (see Table 2).

Even though participants recognize the benefits of solar and wind energy sources in Qatar, similar to other studies conducted in different countries [55–57], they preferred natural gas over other sources of energy, including other renewables. This was inconsistent with other studies where participants supported this source much less [55,56]. Nevertheless, natural gas was preferred over other energy sources by people living in small and large urban areas in EU member states [58]. However, Table 2 revealed that participants are split on whether wind or natural gas energy is preferable to each other. More specifically, the majority of unknowledgeable participants group preferred natural gas when compared to all other energy sources, except solar, whereas the majority of knowledgeable group preferred all REs when compared to natural gas.

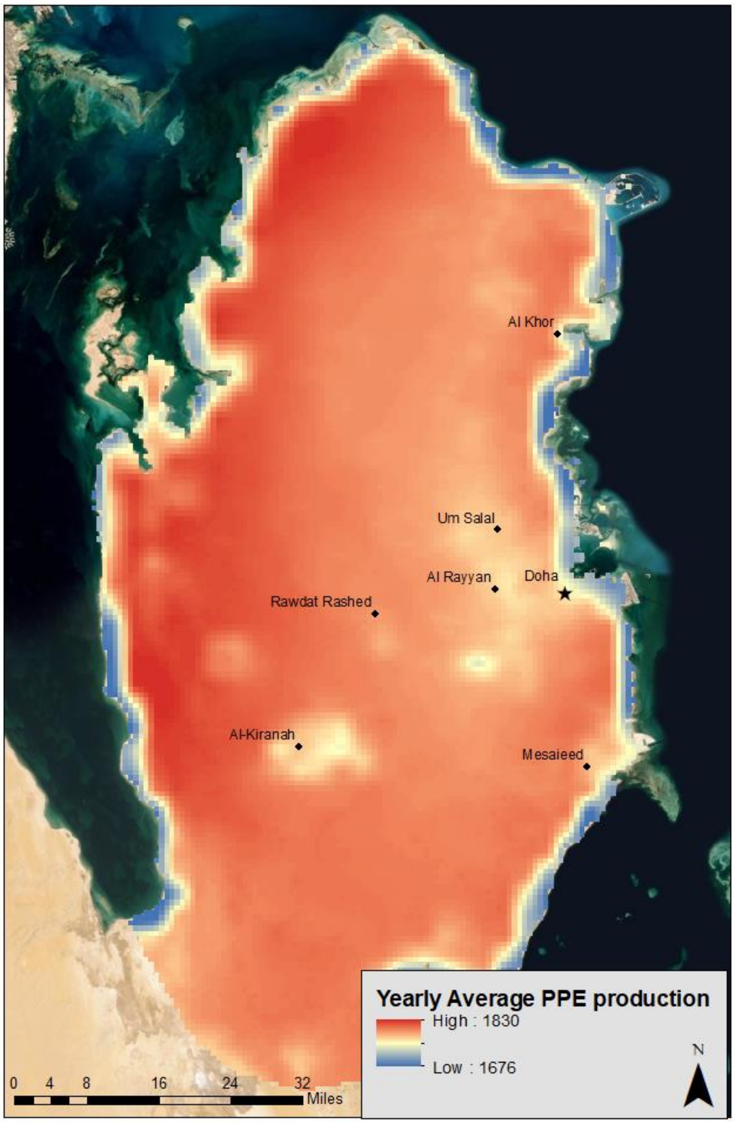

Figure 4. Long-term yearly average of potential photovoltaic electricity (PPE) production covering the period 1999–2018. The Map also shows the capital and major cities in Qatar. Data from [59].

Several factors may explain why unknowledgeable participants prefer natural gas to wind energy. In contrast to the solar energy source, Qatar has not been advocating wind energy although several studies have been conducted to examine the wind energy potential and the economic feasibility in Qatar (See Figure 5). Based on these studies, the country is suitable for small- to medium-size wind turbines, since the mean annual wind speed over land is between 4.3 to 5.1 m/s and 5.7 to 6.6 m/s over offshore [60–62]. Approximately 3 million US dollars can be saved per year by using wind turbines of these sizes, and 6 tons of carbon dioxide emissions can be avoided every year [61]. In addition, the unknowledgeable group decision may reflect the perception amongst citizens that Qatar's natural gas resource is a major economic engine and source of government funding so it should be preferable over other resources. A number of recent studies have also highlighted the potential of natural gas to reduce anthropogenic carbon dioxide in the near term and to act as a transitional fuel to renewable fuels [63,64]. However, a long-term dependence on this form of energy may stymie the transition to green energy sources [65].

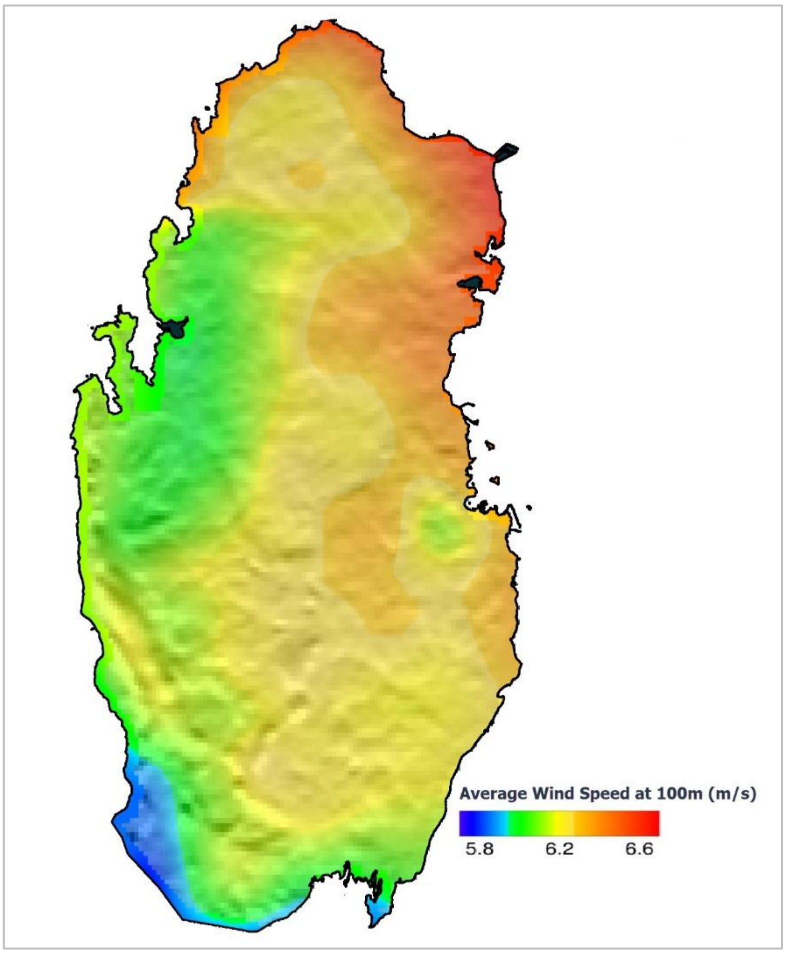

Figure 5. Map of distribution wind energy in Qatar [66].

Despite its drought-sensitivity and impracticality, hydropower source was still preferred by participants over coal, nuclear, bioenergy and geothermal, despite not being used in Qatar or the GCC countries. The findings are in line with a study conducted in Turkey [55] and another conducted in the US [56] where hydropower ranked third in the national public's preference, following solar and wind. However, the difference is that hydropower is one of the main sources of electricity generation in Turkey and the United States compared to Qatar. Several factors may explain participants' preference for hydropower in our study. First, as of 2020, hydropower plants globally have a 4300 TWh annual generating capacity. This accounts for around 17% of global annual electricity output, making it the single most important source of electricity from REs [67]. Second, there is also the possibility that the participants might have been exposed to the controversy over the Grand Ethiopian Renaissance Dam in the GCC media. In contrast to other renewable energy projects, hydropower projects have international significance because they generate controversy worldwide because they affect so many countries simultaneously [68]. Taking the Grand Ethiopian Renaissance Dam being built on the Blue Nile River as an example, the dam will greatly benefit Ethiopia while affecting the flow of the Nile, and hence Egypt and Sudan are concerned about a possible reduction in the amount of water that could negatively affect their economies [69].

In our study, we found that bioenergy and geothermal had lower rankings than other REs, which is also consistent with a study conducted in Europe [70]. Despite the fact that geothermal and bioenergy technologies in the GCC countries are largely unexplored [71], studies have investigated their potential to generate power in these countries [12,72]. Our analysis revealed, however, that knowledgeable individuals preferred bioenergy and geothermal sources in all remaining comparisons. In contrast, the unknowledgeable group preferred bioenergy over coal and nuclear sources, which is consistent with findings from a study conducted in China, which found that the public was highly supportive of bioenergy and willing to pay an additional premium for electricity produced with bioenergy instead of coal [24]. However, the opposition to geothermal energy in comparison with oil, coal, and nuclear power implies that most unknowledgeable individuals have limited or no knowledge about this renewable resource. Indeed, according to a study conducted in five European and American countries where geothermal energy has been already exploited, this source was widely accepted particularly by the educated sectors of the population [23]. Despite the fact that bioenergy and geothermal energy systems still have a significantly lower impact on the environment than fossil fuels [73], no technology is without adverse environmental effects. The mixed views we found in our study about the use of bioenergy and geothermal energy sources are similar to those in other studies [74–76].

As Qataris have a good understanding of oil since it represents an important revenue source for their countries, most of the sample preferred oil over coal. There was, however, a surprising difference between the preference for oil and natural gas, with the former ranking fifth. Qatar may indeed be considered a special case in comparison to other GCC countries, including Saudi Arabia and the UAE, since oil is a secondary source of government revenue in Qatar. Additionally, several studies and media reports have recommended natural gas as being more environmentally friendly than oil [77].

Despite studies showing that nuclear energy can contribute to a significant reduction in carbon emissions [78], coal was preferred over nuclear energy in this study. Many countries have reduced the number of nuclear power plants following the Chernobyl and Fukushima incidents, as well as the shifting global policy towards renewable energy [79]. In addition, there are many factors that make nuclear energy highly uncertain in the future. These include rising costs and historical difficulties, such as spent nuclear fuel disposal and security concerns at nuclear power plants [80]. Among the biggest fears facing citizens of the GCC countries is the possibility of nuclear energy being linked to proliferation of nuclear weapons and terrorism, especially since the Gulf region has been experiencing the consequences of the invasion of Iraq under the pretext of nuclear weapons and Iran's relentless pursuit of nuclear weapons. The reasons above have a negative impact on public opinion in the Gulf region towards this type of energy. In many countries, public support for nuclear energy is highly intertwined and divided, with some countries opposing nuclear energy due to environmental and energy security concerns [55]. However, at other times the public is supportive whenever other better energy sources alternatives have been exhausted and as long as it is used to help address climate change [81–84].

4. Conclusions and Policy Implications

The transition from fossil fuels to renewable energy is a social restructuring act, and it requires community participation and local support to facilitate the transition [85]. It is therefore the first attempt to understand Qatari preferences for a wide range of energy sources in one of the world's most hydrocarbon-rich nations with ambitious energy transition plans. In this study, participants were asked to prioritize energy sources based on their environmental impact, price, benefits to Qatar's economy (economic security), support of energy security, and ability to create jobs.

It is necessary to study the societal interactions in the development of renewable energy in Qatar since the development of renewable energy is still in an immature stage and it is proposed that a large expansion will be undertaken in the upcoming years. This represents the first study reporting high levels of general public acceptance of REs. The development of successful policies can be aided by understanding the expectations people have regarding the future sources of energy.

A research questionnaire was selected as the means of investigation through one-sample binomial and two-way chi-square tests. According to the findings, most of the sample preferred REs, particularly solar, over non-REs. This study revealed that REs were preferred more by those with a broader knowledge of energy sources than those with a limited knowledge. Except for solar energy, which was ranked first in terms of preference and was highly supported by both groups. Natural gas and wind energy were both ranked second in terms of preference. The study revealed that citizens with limited knowledge of energy sources favored natural gas primarily, whereas citizens with good knowledge of energy sources favored wind energy mainly for its minimal environmental impact. Nonetheless, the rationale for supporting natural gas may reflect citizens' appreciation for Qatar's main source of revenue as Qatar has the world's largest reserves, production, and exports of natural gas. In fact, this preference is in line with the country's commitment to increase LNG production by 42% over the next five years as part of its local energy strategy [86]. Other REs held the lower positions in terms of preference, namely hydropower, bioenergy, and geothermal energy. However, nuclear energy was not ranked which may be due to political, security and environmental concerns associated with this type of energy, especially in the Gulf region. Throughout history, this type of energy has been exposed to many shocks, including the nuclear disasters of Fukushima and Chernobyl, or for political reasons, including the Iraq war under the pretext of weapons of mass destruction and nuclear problems with Iran at the present time.

Qatar and its Gulf neighbors are actively working to reduce their reliance on fossil fuels and to protect the environment through the gradual transition to REs. What gives a strong impetus towards energy transition is the tremendous potential for utilizing and growing renewable energy in these hydrocarbon-rich countries, particularly solar energy sources. Consequently, these countries have introduced renewable energy and mitigation initiatives through their 2030 and 2050 visions in order to reduce emissions and eventually achieve zero-carbon emissions, which ultimately benefit everyone's health and well-being.

GCC countries are active members of global coalitions aimed at decarbonization and averting global warming, so careful policymaking will be needed to ensure that their economies can adapt to this shift away from fossil fuels. As a result, countries that export hydrocarbons will have time to reform their economies, but they will need to do so in a systematic and coordinated manner. Indeed, Qatar aims to reduce its carbon footprint and greenhouse gas emissions by 25% each between now and 2030 following the 2021 COP26 climate change summit in Glasgow. Therefore, GCC countries may be able to become less reliant on oil and gas production. It is worth noting that during the writing of this research, the European Union voted to consider natural gas as a green energy under certain conditions [87], which will give a greater impetus to support this energy in the State of Qatar in particular, and other Gulf countries in general. However, this might hinder the momentum of renewable energy investment.

5. Limitations of the Study and Directions for Further Research

As with many other types of research, this paper has a number of limitations that should be acknowledged. A generalization of the research findings was made based on opinions expressed by the 354 participants during specific global and local events occurring at the time of data collection (including the COVID-19 pandemic and the Russian invasion of Ukraine, which greatly influenced perceptions and policies regarding energy). These factors may psychologically affect participants' awareness of their crystallized energy preferences. Consequently, future research should examine different factors that influence participant preferences and respondents should compare their preferences based on individual factors. Additionally, there is a possibility that the study's findings may favor solar power and natural gas as energy sources. These sources may be preferred by the participants for a number of reasons, including the specific factors mentioned in the discussion, as well as their bias toward natural gas, which is the primary energy source for their country, as well as the fact that the government supports and invests in solar energy. The research currently being conducted focuses on participants aged 18 and above, regardless of gender. The research could therefore be extended to include different demographic compositions, age groups, and social and geospatial categories in the future.

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