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Assessment and Perception of Renewable Energy Awareness and Potential in Jordan

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Abstract

The global fossil fuel crisis has generated the need to find alternative solutions through renewable energy sources. Since Jordan has a distinctive location, the potential for using renewable energy such as solar, wind, or other available sources has been studied extensively by researchers. The main objective of this study is to investigate the awareness level about the renewable energy in the Jordanian society. The research study group of people consisted of six hundred and sixty six surveys. The data showed that Jordanians have a high awareness and knowledge about renewable energy and its sources. More than 90% of the surveyed know about renewable energy's merits, and the environmental effect of fossil fuels. This paper also provides a comprehensive overview of the renewable energy technologies and projects established in Jordan, including their distribution, advantages and disadvantages and the challenges encountered by each project.

Keywords: Wind energy, Solar energy, Renewable Energy, Jordan, Energy Assessment.

1. Introduction

Fossil fuels, including oil, gas, and coal, are the primary non-renewable energy sources used worldwide for all technological and industrial development sectors. About 80% of the world's total energy consumption is generated from fossil fuels [1]. According to the International Energy Agency (IEA), the total world demand for primary energy sources will dramatically increase by 2040. In addition, experts estimate that the oil price for the next 22 years will reach $215/barrel [2].

Jordan is one of the countries that suffers from limited fossil fuel resources (i.e. oil and gas). In 2011, around 98% of the total energy consumed was imported from neighboring countries such as Iraq, Egypt, and the Arab Gulf countries to meet the energy demands. Jordan's commercial, industrial and domestic sectors consume around 15.08%, 22.07%, and 46.12% of the total energy, respectively, [3, 4, 5]. Many issues prevent Jordan from securely covering its energy requirements, such as the unsteady state of production in Iraq, the insufficient natural gas supply from Egypt, the rapid growth of commercial and industrial sectors, the high refugee influx, and the rapid increase in population which is expected to exceed 10 million in 2020. In addition to these local issues, the global climate change crisis has come about through the continuous increase of greenhouse gas emissions. The percentage of CO_2 is about 76% of total greenhouse gasses, most of which is released by non-renewable energy consumption in industrial or agricultural fields [6]. Therefore, the government of Jordan started to direct its attention toward renewable energy resources, including Biomass, Geothermal, Solar, and Wind energy [7]. The government passed a new law in 2012 titled "Renewable Energy and Energy Efficiency" that vigorously promotes, diversifies, and regulates the use of renewable energy across all industries. The law aims to:

1. Reduce greenhouse gas (GHG) emissions.
2. Accomplish 10% energy mix projects by 2020, along with the allocation of $15 billion.
3. Motivate investments in renewable energy, especially in the private sector [3, 8].

The 2018 annual report of the national electricity company in Jordan shows that the total electricity generated and imported in the Kingdom reached 20692 GWhs, with renewable energy resources contributing only 10.7% of the total electricity generated that year[9]. In 2019, the renewable energy resources' contribution reached 15.1% of the total electricity generated in Jordan, which is expected to reach 31% by 2030 [5]. It is essential to mention that Zarqa city in Jordan contains the Al-Hussain power plant and the Jordanian petrol refinery that contributes 70% of the overall contamination from fossil fuel combustion in Jordan. This paper investigates the level of awareness in the Jordanian society of renewable energy and its technologies. It also provides a comprehensive overview of planning and existing projects for renewable energy in Jordan. Such research helps government decision-makers develop instructions and laws that encourage the use and regulation of renewable energy projects. It also helps companies understand the reasons

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for the turnout or shift away from using renewable energy sources instead of conventional energy resources. The paper is organized as follows; the main energy technologies and projects in Jordan are covered in section 2. The developments in the Jordanian industry's renewable energy use are discussed in section 3. The methodology and survey are in section 4. The conclusions are summarized in section 5.

2. Energy Technologies in Jordan

With the limited fossil fuel resources, Jordan has called attention to the local energy resources to bring down the high-cost energy bill. Jordan spared no effort to encourage investments in different renewable energy technologies and projects. In 2019, renewable energy contributed 15.1% of the total energy generated in Jordan. Solar energy contributed 10.4%, wind energy supplied 4.4% of the total energy generated, and other sources contributed only 0.3%.

2.1. Wind energy utilization in Jordan

Jordan has a considerable wind energy potential, estimated to be more than 250MW [10]. This energy could be utilized for power generation with an annual average wind speed between 7m/s and 9m/s above ground level. In Jordan, there are currently eight operational wind power plant stations in different regions: Hoffa, and Al-Ibrahimyya in Irbid city, Ras Muneef in Ajloun, Shammakh, Safawey, Umari, Twaneh, and Al-Jafr station. Only AlIbrahimyya and Hoffa stations (north region) are connected to the primary power grid. In 1988, Al-Ibrahimyya power plant (pilot wind farm) was built in cooperation with a Danish firm. Its capacity is 320KW, and its average annual energy production is around 650MWhs. Hoffa was constructed in 1996 with 1.2MW capacity in cooperation with the German government. Al-Khamshah and AlFujeij are two wind projects in progress with capacities of 30 – 40MW and 80 – 90MW, respectively. There are many benefits to using wind energy to generate electricity, including the fact that it is a free, renewable, clean, and abundant source of energy that does not pollute the atmosphere or produce atmospheric emissions, in contrast to the burning of fossil fuels, which releases nitrogen oxides (NO_X) and sulfur dioxide (SO_2), contributing to the greenhouse effect. Therefore, using wind energy may reduce fossil fuel consumption and environmentalpollution [10,11]

2.2. Solar energy utilization and distribution in Jordan

Jordan is one of the sun-belt countries with an annual average of global energy equaling 1800kWh/m^2/year [11]. Also, Jordan has more than 300 sunny days per year with solar radiation ranges between 5 – 7kWh/(m^2d); these significant facts make using solar energy in Jordan attractive.

The solar radiation in Jordan distributes as follows[3]:

- Southern region: 6-6.5 kWh/(m²d).
- Eastern region: 5.5-6 kWh/(m²d).
- Northern region: 5 -5.5 kWh/(m²d).
- Middle region: 4.5-5 kWh/(m²d).
- Eastern region: 4-4.5 kWh/(m²d).

According to the 2019 annual report [5] of the Jordanian National Electric Power Company (NEPCO), many solar energy projects with large and small capacities are distributed in Jordan. For example, Mafraq development projects at the north-east of Jordan have a 153MW capacity, whereas Safawi projects in the east of Jordan have 51 MW. Also, the Quwireh. PV project in the south of Jordan has 95MW. Different universities have large projects with more than 40 MW capacity. Also, large industries such as Lafarge company has projects with 15MW, and many others. Simultaneously, the small projects with less than 5MW capacity are estimated at around 250MW. Even though the advantages of using photovoltaic technology are prominent, solar energy systems have major drawbacks making it challenging to rely on this source:

- Solar Energy storage systems are expensive due to the high cost of batteries [12].
- The efficiency is below expectations. However, research and development works are still active, thriving towards achieving higher operational efficiency [12].
- It occupies more space than non-renewable systems, reducing the cultivation area [13].
- Soiling has a significant impact on the efficiency of solar panels. Any dirt, snow, dust, or bird droppings may reduce the panel's performance by decreasing the output power [14].
- The dust distribution was investigated by Sanaz Ghazi in 2014, revealing that the Middle East and North Africa are the places with the highest dust accumulation[15]. Therefore, manual or automated cleaning mechanisms are essential and must be applied periodically [16]. However, the cleaning process is expensive in Jordan, especially in arid regions such as in Ma'an Governorate. A study was conducted on the cleaning process's effect, concluding an average power degradation of 2.22% per month [17].

2.3. Biomass energy and its potential Use in Jordan

Biomass is a renewable energy source where carbon is derived from different organisms or their biological activities. Biomass includes plants (trees, crops, forests, and forest residues), animals, humans, and biological wastes (human, animal, and food waste). As a result, there is a wide variety of biomass types and classifications. Thus, Biomass can be classified as wood, and wood residues biomass, agriculture, herbs biomass, human and animal waste biomass, aquatic Biomass, and industrial biomass [18]. The Jordanian government aims to increase renewable energy use in general; however, most of the execution is concentrated on solar and wind energy. The focus on biomass is relatively scarce but has recently increased because biomass can compete with fossil fuels as another source of electricity generation [19].

2.3.1. Agricultural residues:

Jordan's production of crops is estimated at 188,000tons. In contrast, its fruit production is estimated at 426.6tons and 1928.6thousandtons of vegetables [20]. The residue amounts of agriculture are calculated as the ratio

between the residue's amount to the production amount (RPR) [21]. The RPR of wheat's estimated value is between 0.7and0.8 [22]. The estimated value of the RPR of maize is between 2.0 and 2.3. However, the value of PRP estimated for millet is between 1.75 and 2.0 [21, 23]. PRP value estimated for the olive tree is between 0.5 and 2.6 [23]. The estimated value of RPR for each barley, dentil, and clover trefoil is between 1.75 and 2 [21]. The total residues of the agricultural section were estimated at 997.25 thousand tons in 2011. The solid matter of this value contains 7.954Pj as energy content. This value covers about 2.48% of Jordan's energy consumption in the same year [21].

2.3.2. Olive cake:

The olive tree is considered a natural and essential source for olive oil in Jordan. Jordan's total number of olive trees in 2011 was approximately 17million [21]. Jordan's olive fruit production equals one-third of the total fruit production [20]. The olive cake is dried after its production as a byproduct of the oil extraction process. However, olive cake mass is considered as 35 to 45% of olive fruit mass. Moreover, the dried olive cake mass is 60 to 70% of this percentage [24]. In other words, each 100kg of olive fruit produces 26kg of dried olive cake[21]. The computed amount of olive cake in 2011 was 34,268 tons [20], with a maximum ash content of 3.27% and a calorific value of 24.5MJ/kg.

2.3.3. Animals' Manure:

Jordan depends on specific livestock and poultry species. In 2011, there were 6700 cows, 9210 horses and donkeys, 3017 sheep and goats, 13000 camels, and 37700 chickens. The total number estimated for livestock and poultry in 2011 was 3,106,710 [21]. The estimated amount of waste for these animals was 36000tons. This amount covers about 3.97% of the total energy consumption in Jordan in 2011 [21].

2.3.4. Municipal Sludge:

In Jordan, municipals collect sludge from slaughterhouses, vegetable markets, industrial organic waste, hotels, kitchens, and restaurants. The total amount of municipal sludge collected in the year 2011 was 1,960,000 tons[25]. The collected sludge's heating value from the mentioned places equals 11.49MJ/kg. This value covers 7.03% of Jordan's energy consumption in 2011 [21]. This good percentage makes animal waste an auspicious renewable energy source in the industrial section [21].

2.3.5. Medical Waste:

Medical waste is all solid, liquid, or gas waste produced from different healthcare centers. It also includes pharmaceutical industries, hospitals, laboratories, health centers, veterinary clinics, and the produced waste from the kitchens and offices of such buildings [26]. The total estimated amount of the medical section waste from these buildings is 9ton/day, which equals 3285ton/year [25]. Its average heating value is 14.2MJ/kg [21].

2.3.6. Industrial SectionWaste:

The total waste produced in Jordan's industrial section was 15,000 tons in 2007. However, this value is expected to increase and reach 59,000 tons by 2027 [21].

2.3.7. Wastewater:

In Jordan, there are only twenty-three wastewater treatment plants. The total flow rate daily is 216,412 m^3/day [27].Wastewater volume is increasing and is expected to reach 237MCM/year by 2020 [21]. The treatment plants only produce two million cubic meters of sewage yearly from Wastewater. This huge amount of sewage is a sufficient potential biogas energy source[28]. The dry solids of this sludge are 85,000tons, and the combustible material's heating value in the dry solid part of the sludge is 27.93MJ/kg. Hence, the amount of its potential energy is 2.52PJ [21].

Advantages and disadvantages of utilizing biomass and biomass fuel advantages:

- It is a renewable energy source.
- Natural production of CO_2 and climate benefits. It is a frugal renewable energy source with low carbon emission.
- It uses a non-edible material as a source of fuel.
- It helps in reducing fossil fuel consumption.
- Biomass energy has a low content of harmful elements.
- It riches of volatile matter.
- Its use does not need a high temperature in the degradable process.
- Biomass produces a large and continuous amount of energy due to its availability and continuous production.
- It helps in reducing SOx and NOx emissions, as well as waste reduction.
- Providing more jobs and extra incomes.
- Resuscitate degraded lands using digestate material rich in N_2[29].

Biomass and biomass fuel disadvantages:

- They are not always considered renewable energy sources due to their long-life cycle.
- There is a priority competition between the energy source and the edible source.
- It changes land use, which affects the natural ecosystem.
- Its use may lead to losing the controllability of feedstock supply.
- Some of the feedstock sources are unsustainable.
- There is an omission of production control and certification.
- There is limited knowledge about the validity of the technology. Also, there are few experiments and experiences of biofuel production.
- Relatively, it has a high initial cost.
- There is a low developing rate in biomass markets.
- Biomass production depends on the season, region, and time.
- There is a need for investment for harvesting, collection, storing.
- It has a high content of trace elements.
- Low pH and temperature [29].

2.3.8. Biomass Energy Projects in Jordan

The Ghabawi landfill was designed and constructed between 2001 and early 2003. The landfill depicts 9 excavated areas (called "cells") [30], each cell covers 120,000 to 200,000m^2. The first three cells produce around 4.8MWh. The landfill is fed with solid waste from Amman, the municipality of Zarqaa, AlMuaqqar, Alrusaifeh, and the small surrounding municipalities, with around 4300tons/day. They expect to cover and close the landfill by 2035.

2.4. Geothermal Energy Utilization in Jordan

The geothermal activities in Jordan can be expressed exclusively in two forms; direct usage of (thermal springs and hot deep wells) and using the earth's heat at the shallow ground for heating and cooling the buildings. Thermal springs form the primary source of geothermal energy in Jordan, with a temperature range between 20◦C and 63◦C [31]. The highest temperature of thermal springs reaches 63◦C. Zarqa Ma'in and Zara at the Dead sea are the primary geothermal manifestation in Jordan. In contrast, other springs have temperatures below 45 °C [32]. Table 1 shows the thermal springs and hot thermal deep wells' flow rates and temperatures. Thermal springs have been used as curative water for medical purposes through hotels' spas constructed in the area [32]. Also, in Jordan, geothermal energy is used as a Ground Source Heat Pump (GSHP) for heating and cooling buildings. There are two operation projects, the first at the American University of Madaba (AUM) and another at The Higher Council for Science and Technology (HCST). Geothermal Energy systems are the most environmentally friendly, cost-effective, and energy-efficient heating and cooling technology. The United States Environmental Protection Agency (USEPA) reported that geothermal energy is the least polluting energy [34]. Installing a single geothermal unit is equivalent to planting 750 trees [35]. For district heating systems and GHPs, CO_2 equivalent emission is from 14 to 202g/kWht, lower than the modest land footprints [36].

Ground heat pumps used in geothermal systems need lower energy (electricity), a lower amount of refrigerant fluid, and a more straightforward design for air pumps. On the other hand, the earth is a more stable energy source than the air [38]. The most perceptible effect on the environment is that of drilling. Its operation for boreholes modifies the area's surface morphology and could damage local plants and wildlife, aside from the drilling's irritating noise. In the case of blowouts of fluids from the wells, fluids can pollute surface water and air. Also, the withdrawal of geothermal fluids may trigger the frequency of seismic events in tectonically active areas. Deep hot water often contains gases, such as carbon dioxide (CO_2), hydrogen sulfide (H_2S), ammonia (NH_3), methane (CH_4), and trace amounts of other gases. In addition to the dissolved chemicals whose concentrations usually increase with temperature, all of which are a source of pollution if discharged into the environment [34].

Table 1. Thermal springs and hot thermal deep wells in Jordan [33]

Spring/Well	Temperature range(°C)	Flow Rate(m^3/h)
Himmeh springs	38-44	300-3000
Mukheibeh wells	30-41	200-6000
North Shuneh well	57	700
Queen Alia airport	30-45	30-100
Zara springs	34-55	1-255
Zarqa Ma'in springs	30-63	1-350
Wadi Ibn Hammad springs	35-41	1-25
TS-1D thermal well	50	400
Burbeitta spring	39	315
Afra springs	45-47	376
Smeika thermal well	57	50
Himmeh springs	38-44	300-3000
Mukheibeh wells	30-41	200-6000
North Shuneh well	57	700

2.4.1. Geothermal Projects in Jordan

Project at American University of Madaba (AUM) The largest geothermal project in the Middle East is the American University of Madaba (AUM) project. The AUM's geothermal project was started in July 2011 and completed in August 2012. The project's goal was to utilize the earth heat for cooling and heating by ground source heat pump (GSHP). The system covers a 660kW cooling load and 470kW heating load with 420 boreholes 100m depth [37]. The system eliminates carbon dioxide emissions by approximately 300tons per year (saving 47%compared to other conventional systems) [37].

Project at Higher Council for Science and Technology (HCST). The Higher Council for Science and Technology (HCST) is within El-Hassan Science City Campus in Amman, Jordan. The HCST aims to achieve international standards and recognition in bright sciences and technologies and maximize the benefits of their applications for Jordan's sustainable socio-economic development. In other words, since most of the renewable energy (RE) sources are sustainable, and positively affect the economy of Jordan, HCST utilized all state-of-the-art energy efficiency (EE) measures and renewable energy (RE) technologies to transfer the main building into an Eco-green building. The HCST geothermal project was set in June 2016 as a model or a pilot demonstration plant, and it was completed in August 2017. Now, it continues to be operational in excellent conditions. Hence, the project confirmed the proposed technologies and systems' functionality, efficiency, and economics. The Eco-Building project consists of three parts: 1. Geothermal system heat pump (GSHP) for heating and cooling. 2. LED lighting. 3. Photo-Voltaic (PV) electricity generating of 52kW. The chosen building consists of six floors (two

basement floors with a total area of 883m^2 and four floors with a total area of 3,427m^2). The Geothermal system is a type of Ground Source Heat Pump (GSHP) installed to cover 228kW cooling load and 262kWheating load and domestic hot water for the building.

The Ground Source Heat Pump (GSHP) incorporates 30 boreholes, each of which has dimensions (145mm diameter,130m deep and arranged in a 6m × 6m grid). It contains a double U probe pipe of 32mm (outer diameter). 60kW NIBE heat pumps, one master and five slaves, were installed to cover the building heating, cooling loads, and hot water demands. The GSHP can save 40% of the cooling system's energy and 46% of the heating system's energy compared with conventional cooling and heating systems. Therefore, it annually saves 19,784JD around 28,000USD, with a payback period of 14 years as calculated. Also, installing the GSHP system reduces the environmental pollution of burning diesel and the associated spilling of diesel tanks and reduces the amount of fossil fuel used before.

3. Industrial Sector

This section discusses Jordanian industry's use of renewable energy (RE) and its evolution from the early years of installing and operating projects to future projects. Several research studies have been performed to study the industrial sector in Jordan [38-43], focusing on each renewable energy source's efficiency. Several companies are advocating for the use of renewable energy, particularly solar and wind energy.These companies are under the Energy and Minerals Regulatory Commission (EMRC) instructions.

EMRC is the governmental commission regulating and monitoring the Kingdom's energy sector, natural resources, minerals, radio, and nuclear work .The total potential of electricity production in Jordan equals 18% of renewable energy (RE) at the end of the year 2018 with a total capacity of (855kW) which is a doubled value of 2017 [9, 5]. Table 2 shows the capacities of projects connected in 2021.

Due to the rapid increase in the Jordan population, energy consumption and demands are very high for both home and industrial use. Also, fossil fuel price is mounting continuously. As a result, the Jordanian government encourages and supports sectors to use renewable energy sources for electricity production, heating, cooling, pumping, and other general use. Many sectors develop their energy sources to utilize renewable energy for different user types. Figure 1 shows the sectors' usage of renewable energy units (The Capacity for each sector) in Jordan.

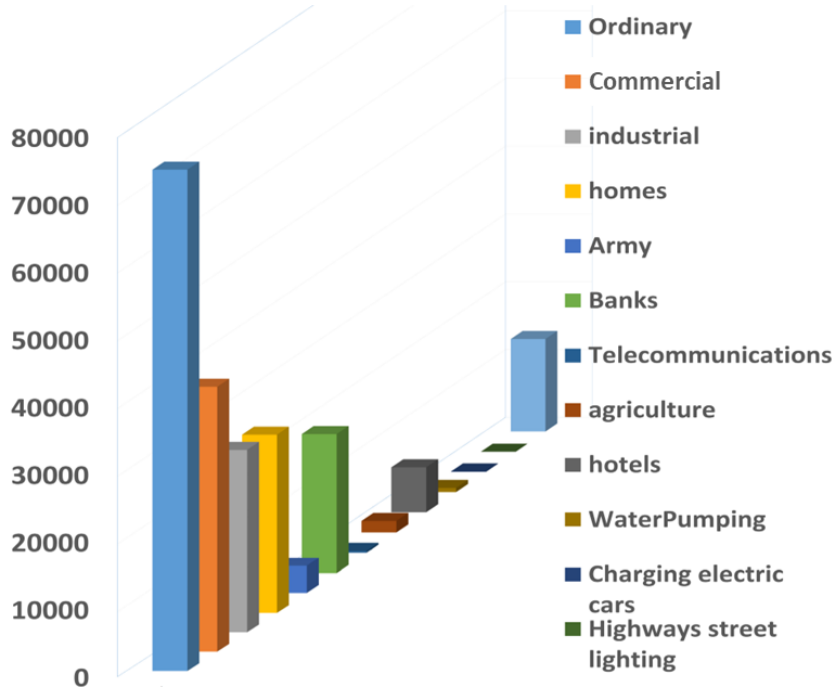


Figure 1. Capacity (kW) of connected renewable energy units for different sectors in Jordan

Table 2. The renewable energy project's status and capacity (PV and wind) in Jordan from 2018-2021.

Status	Capacity(MW)
Operated Project	630
Expected connected projects at the end of 2018	225
Expected connected projects at the end of 2019	196
Expected connected projects at in 2019 after the end of the green corridor	195
Expected connected projects in 2019/2020	100
Expected connected projects at in 2020 after the end of the green corridor	350
The total capacity of expected connected projects in 2021	50

It is obvious from figure 1 that most sectors that depend on renewable energy are the ordinary sectors, followed by the commercial and industrial sectors with capacities of 74382, 39360, and 27071MW, respectively. Also, the agriculture sector utilizes renewable energy with a capacity of 1698MW. In contrast, the lowest sector utilized RE is highway street lighting with a capacity of 2MW. The number of homes that utilized renewable energy is 2,845 with a capacity of 26339MW, indicating that the most significant contribution sectors are homes and domestic use. Hence, categorically, the public uses the most renewable energy sources.

4. Methodology

This paper sheds new light on the level of awareness and knowledge of Jordanian Citizens regarding renewable energy resources. Of the study population, 666 subjects completed and returned the questionnaire. The questionnaire consists of three sections: The questionnaire's first section investigates the general information regarding age, gender, and the participants' educational level. In the second section, several simple questions have been established to verify the participants' knowledge and awareness of renewable energy. Also, the third section concentrated on individuals who have their shops or residential groups. Finally, the survey ended with a question to determine the approval range from Jordanians to increase the reliance on renewable energy systems.

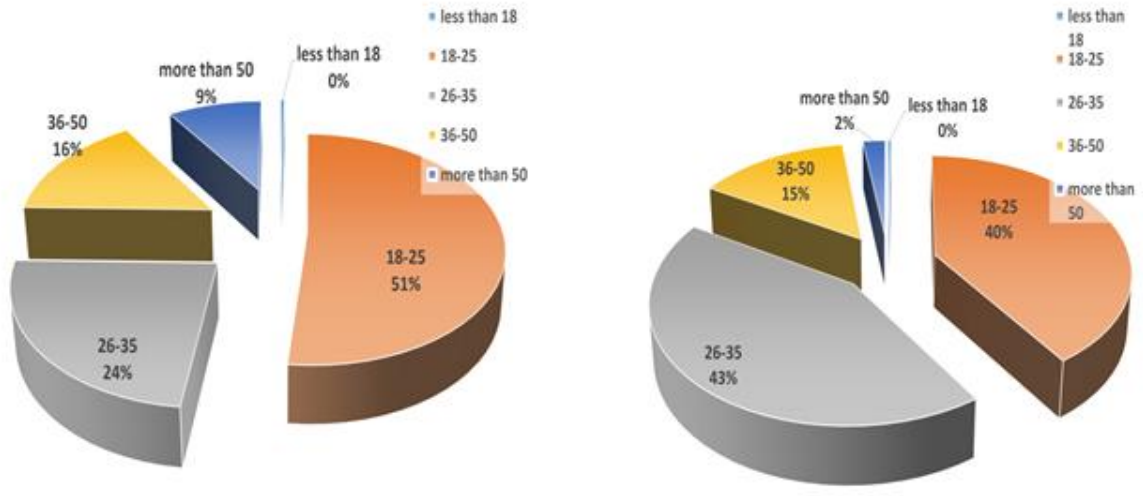
4.1. Part A: Public people awareness survey

A questionnaire was conducted based on closed format questions (Closed-ended Questions) of 15 questions using Google Survey. The closed-format questions include Dichotomous questions, Likert Scaling, Leading, Bipolar, and Rating. Only the Dichotomous, Likert, and multiple-choice questions have been used in this questionnaire to construct the survey structure. Four questions with the type of Dichotomous questions were answered with either "yes" or "no." While in five questions of Likert Scaling, the respondents answered with either agree, disagree, and strongly agree, and disagree, in addition to neutral.

A public survey was conducted for Jordanian citizens of all ages and educational levels and distributed randomly. Also, the draft survey was sent to experts in renewable energy to detect, delete, and correct unclear and improperly written questions. Additionally, we implemented the survey in Arabic and English to make it easier for the participants to choose the preferred language and increase the collected data's quality and quantity. This study gathered information from various sources, including the industrial and public sectors, the Jordanian Renewable Energy Society, and the Ministry of Energy and Minerals. In addition, interviews with experts and decision-makers were conducted.

4.1.1. Analysis and Results

Section I: The first section of the survey discusses the general information regarding age, gender (Male and Female), and the educational level of the 666 recipients. As seen in figure 2, 56% of the participants were female, with ages ranging from less than 18 to above 50. Furthermore, about 43% of the female participants were between the age of 26 − 35. On the other hand, 43.8% of the total responses were from males, and 51% were from aged 25 to 35. The educational level distribution is also an essential factor in this survey. Figure 3 shows that the majority of the respondents hold bachelor's degrees. In comparison, only 5% of the respondents hold high school diplomas or below.



(a) (b)

Figure 2. Gender Age distribution a) male and b) female

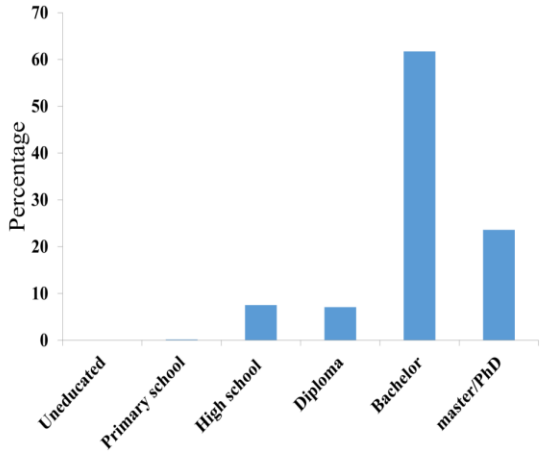


Figure 3. Educational Level Distribution

Section II : We primarily focused on testing (verifying) the level of awareness and knowledge of renewable energy in this section. For this purpose, we use Dichotomous questions shown in table 3, and Likert Scaling questions in Table 5. Interestingly, 98.9% answered that they have background knowledge of global warming, 90.80% of those surveyed indicated that they know the effect of burning fossil fuels on climate change. The terms of ”Renewable Energy” and its resources were impressively known by 99.4% of the total respondents. Further testing questions were conducted, as shown in Table 5. In Table 3, more than 73% of the respondents strongly agree (or agree) that the RE’s price will be much lower than conventional energy and will gradually become cheaper. On the other hand, less than 13% disagree (or strongly disagree), while 13.7% were neutral in response to this question. In response to the question: ’Compared to fossil fuel, do you think renewable energy-based technologies have a much lesser impact on the environment?’, the majority,approximately 95% replied by either strongly agree or agree. While less than 5% of those surveyed were neutral or disagreed that renewable energy has less impact than the conventional fossil fuel source of energy on the environment. When the participants were asked if they think investing in renewable energy is financially sustainable in the long run, the overall response to this question was very positive. Finally, respondents were asked to indicate whether they agree that renewable energy technologies are reliable or not. In response to this question, 55% agree, and37.2% strongly agree. A minority of participants (less than 4%) disagree or strongly disagree.

Section III: This questionnaire section required respondents to give information about the reliance on renewable energy at the shop markets and residential buildings. As shown in figure 4, when the participants were asked about support and increased reliance on Renewable energy resources, the majority (60%) of both genders (Male and Female) strongly agreed. A total of 73 shop or residential building owners were asked whether or not they installed a solar PV system and why they did not install it (if they do not use it). The results are divided into a category I of people who did not install the system and reasons for not installing. In contrast, category II refers to people who have the system and whether it meets their demand or not. Category I results show that most of the respondents (around 70%) do not have a PV system for several reasons shown in figure 6. These reasons can be summarized by the high costof installing these systems (around 65% agree on this), and 29% answered with the area’s limitation. Others replied that installing the system will not reduce the electricity bill. Simultaneously, only one participant responded that he does not care about environmental issues, and another did not answer. On the other hand, category II, shown in figure 5, shows that around 25% of the respondents installed the system and met their demands. At the same time, less than 10% did not meet their demand.

Table3. Jordanian Citizen level of knowledge of Renewable energy

		N=666				
		Scale				
	Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	Do you think renewable energy will match the price of conventional energy and will eventually become cheaper?	31.70%	42%	13.70%	9.20%	3.40%
2	Compared to fossil fuel do you think renewable energy based technologies have much lesser impact on the environment?	59.60%	34.80%	3%	1.8%	0.8%
3	Do you think investing in renewable energy is financially sustainable in the long run?	41%	44%	9.90%	4.2%	0.9%
4	Do you think renewable energy technologies are reliable	37.20%	55%	4.2%	2.6%	1.1%

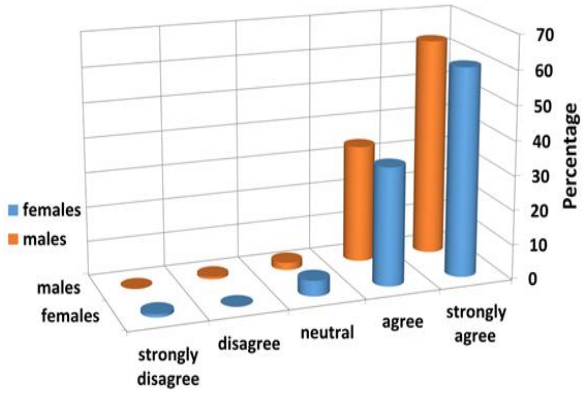


Figure 4. Support Renewable Energy

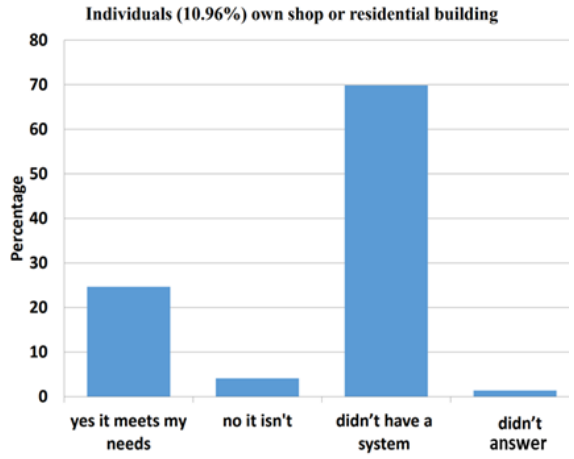


Figure 5. Individuals own shop or residential building.

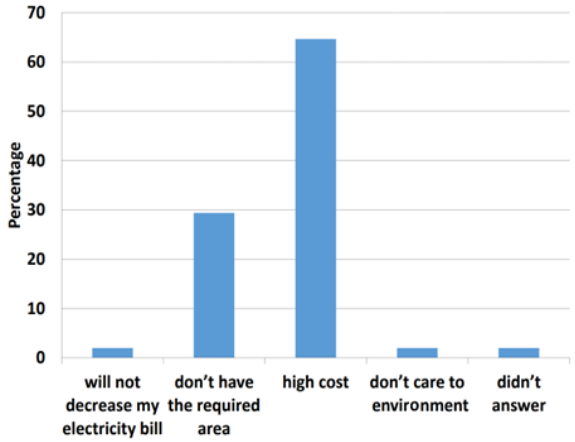


Figure 6. Reasons for not installing PV system

4.2. Part B: Mosques Gathering information

The mosque is a worship house sponsored by the Ministry of Awqaf Islamic Affairs and Holy Places. The mosque's geometric shape is characterized by the dome's existence on the roof and the minaret. The distribution and number of mosques in the Jordanian governorates and suburbs, as well as the mosques that utilize renewable energy systems, vary, with the majority implementing a renewable energy project. In the capital Amman, they reached 392 projects with a total capacity of 6576,715 kWp. Irbid is in second place where the number of renewable energy projects implemented by the end of 2017 in mosques is about 215 projects with the capacity of 3618.052 kWp. The rest of the executed projects are distributed in the other regions and the Jordanian governorates. See table 4 and figure 7. Due to the large increase in the electricity bill and the increase in the number of mosques in Jordan, the Jordanian Ministry of Awqaf Islamic Affairs and Holy Places has formed a Renewable Energy Committee that supervised 803 renewable energy projects on mosques with a total capacity of 13646.93 kWp at the end of 2017, that saved approximately 150,000 JD (around 210000 USD) per month. There are 141 renewable energy projects in the mosques around Jordan, with a total capacity of 2364kW. After implementing these projects, it is estimated that they will save 30000JD (42000 USD) per month. Also, due to Aqaba city's hot weather, the only coastal city in Jordan (located on the Red Sea's), Aqaba Governorate plans to support the implementation of 34 projects due to high electricity consumption in mosques especially in the summer semester. The total capacity of these 34 projects is 1568 kWp, with an almost year saving of 265000 JD (380000 USD). All these renewable energy systems projects implemented and planned to be implemented in mosques in Jordan, their capacities, and financialsavings are illustrated in table 6.

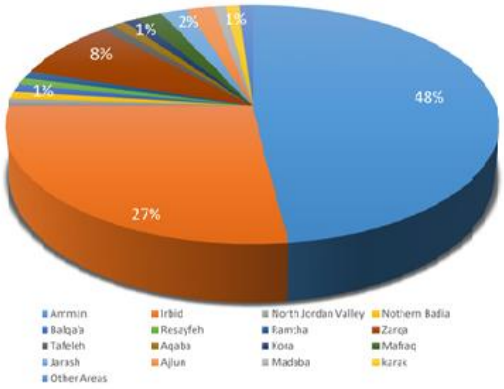


Figure 7. Distribution rates of renewable energy projects around Jordan at the end of 2017.

Table 4. The distribution of renewable energy projects in the mosques around Jordan that were implemented at the end of 2017.

Jordanian governorates	Number of projects	Project capacity (KWP)	Distribution rates (%)
Amman	392	6576.715	48.19
Irbid	215	3618.052	26.5
Northern Jordan Valley	8	145	1.06
Northern Badia	2	20.3	0.15
Balqa'a	23	360.5	2.6
Resayfeh	8	180.2	1.32
Ramtha	12	195.82	1.43
Zarqa'a	63	1134.45	8.31
Tafeleh	11	144.68	1.06
Aqaba	5	130.8	0.96
Kora	11	188.375	1.38
Mafraq	16	272.06	1.99
Jarash	11	179.535	1.31
Ajlun	15	332.463	2.44
Madaba	5	90.98	0.67
Karak	6	77	0.56

Table 5. Jordanian citizens' level of climate change knowledge and renewable energy

		N=666	
		Percentage (%)	
	Question	**Yes**	**No**
1	Have you heard of global warming or sometimes called climate change?	98.90%	1.10%
2	Do you think that burning fossil fuels is the cause of climate change?	90.80%	9.60%
3	Do you know the meaning of renewable energy?	98.80%	1.40%
4	Are you familiar with renewable energy resources such as solar, wind, and hydro?	99.40%	0.60%

4.3. Questionnaire survey analysis

All data were collected from the mosques' Imams (Imam is the one who leads Muslim worshippers in

prayers and manages the mosque), where we distributed our survey to the mosques' sample in Jordan-Irbid. The main questions are about investigating the challenges and barriers faced by mosques that utilize renewable energy systems and their benefits. In our study, most mosques installed PV systems that use solar energy at a rate of 88%. On the other hand, only 8% of them utilize biofuels as alternative and renewable energy sources. However, none of the mosques in our survey utilizes wind energy. See figure 8. The capacity of the PV systems utilized in the mosques we studied ranges from 4.55 to 20.4kWp. Therefore, 56% of mosques are able to satisfy their total energy consumption with renewable energy. However, PV systems covered most of the electricity consumption for 44% of the mosques. All agreed on the benefit of using the solar system to generate electricity and a good positive that none of the mosques (0%) claimed that the system is no longer useful. The reasons for installing renewable energy systems in the mosques and encouraging Imams to request utilizing them to generate the electricity are:

- Increase electric tariff.
- Large consumption of the mosque of electricity.
- Renewable and not threatened with depletion.
- Environmentally friendly.

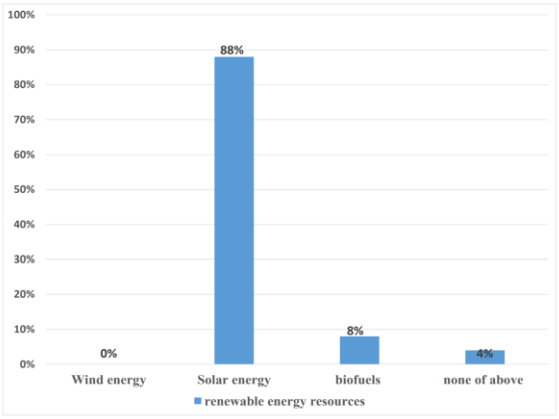


Figure 8. renewable energy resources that are utilized in the mosques

The increase in electricity tariffs in 28% of mosques is the main motive for using renewable energy systems. In comparison, 18% of mosques are directed to using renewable energy systems due to the high electricity consumption by the mosque. See figure 9. Based on experience in renewable energy systems, 52% plan to expand the system installed for the mosque, while 48% of mosques do not intend to expand the system. As for the benefits of such systems, the most important factor was the coverage of electricity consumption from the economic point of view. However, the managers of mosques face many obstacles after the installation and the use of the system; 40% complained of periodic maintenance required by the system and, therefore, the additional costs.

In comparison, 20% of mosques consider insufficient space a challenge. This may have led to 16% of mosques that did not cover the productivity of the renewable energy system required. 4% of them found the problem with the system's cost and its high structure, 12% did not face any obstacle. See figure 10.

Table 6. Summary of the economic feasibility of renewable energy projects in the Hashemite Kingdom of Jordan mosques until the end of December 2017.

Renewable energy projects	Projects number	Project capacity (KWP)	Financial saving (JD)
Implemented projects	803	13,646.93	150,000
Projects under construction	141	2,364.14	30,000
Planed projects to implement in Aqaba	34	1,568	22,000

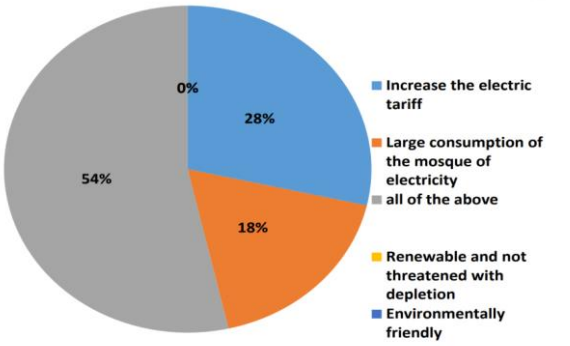


Figure 9. Reasons that the mosques install renewable energy systems

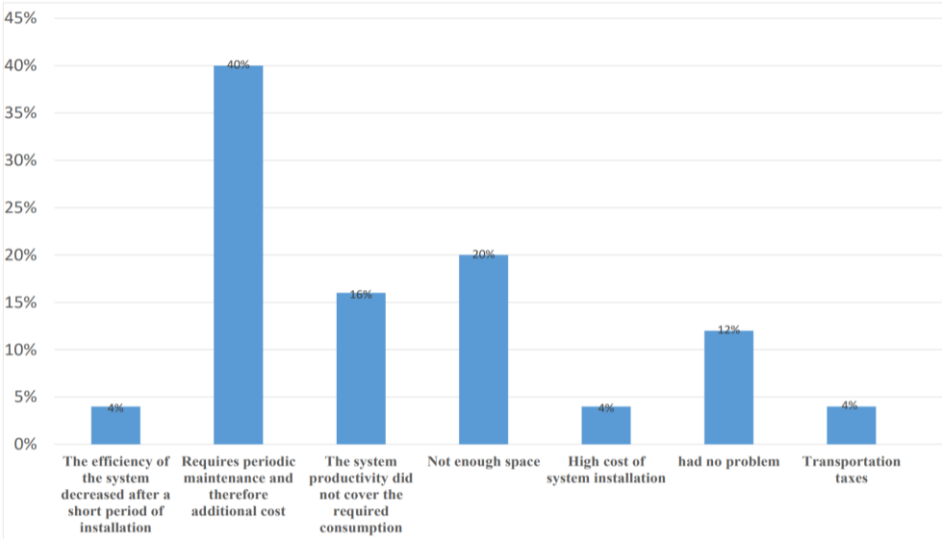


Figure 10. Problems and challenges while using the renewable energy system.

5. CONCLUSIONS

This paper studied an overview of renewable energy technologies used in Jordan regarding the installed projects' distribution, advantages, and disadvantages. It has been found that using PV systems for power generation and other applications through industries and in other sectors is dominant over all other technologies. Special attention regarding wind technology should be employed to enhance such potential benefits, especially on farms. Furthermore, the level of awareness of Jordanians to renewable energy was conducted by constructing a questionnaire. The data was then collected and analyzed for 666 respondents of different ages and educational levels for both genders. The results showed that the level of awareness in Jordanian society is high. More than 90% of the surveyed know about renewable energy, its merits, and the environmental effect of fossil fuels. Even though 70% of those who have a shop or a residential building did not install a PV system, the main cause was the high cost.

Regarding the high increase in renewable energy projects installed for mosques in Jordan, Amman has the highest number of projects (392) at the end of 2017. Irbid follows with 215 projects. All Imams of the mosques utilizing renewable energy systems are satisfied because of the reduction in the electricity bills. Finally, the number of people supporting renewable energy was high; therefore, the government should encourage people to install PV systems at their homes or facilities by providing continuous and necessary support.

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