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MANAGEMENT AND DEVELOPMENT OF A RESIDENTIAL ENERGY STORAGE SYSTEM: A CASE STUDY JORDAN

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The use of renewable energy generation (REG) and energy storage systems (ESSs) strategies have a considerable possibility in delivering resilience for renewable energy sources (RESs). Thus, combining REG and ESSs strategies to fix operational, economic, ecological, and power-concerning governmental issues have been received particular concern from power system (PS) operators and planners globally. In this concern, developing countries (Jordan), which are poor in traditional energy resources, have proposed different supportive issues and experiences for the common use of ESSs strategies in the situation of distribution PSs. Therefore, this article performs a universal solution to this problem possessed to construct the infrastructure substantially to achieve high penetration of RE in the PS. Based on this, the article firstly studies the necessity of using REG and ESSs strategies in RE-based distribution PS. So, the current approaches and motivation programs used in various countries for the growth of RERs in optimum composition with ESSs and REG strategies are offered. The results of this study suggest that the use of an ESS is very important for the management and development of residential Solar Energy (SE) applications. Most respondents (85.3%) said that the use of a domestic ESS is critical to the management and growth of demand and supply for RE. To improve main grid efficiency and reduce demand for conventional power supplies, Jordanian engineers and experts recommend that consumers should install ES devices in their homes.

Keywords: renewable energy resources (RERs), energy storage systems (ESSs), questionnaire, Jordan

1 INTRODUCTION

The change in the environment is a worldwide crisis that suddenly appears behind the structure of state economic policy. The Paris Convention, which was held with the participation of 196 parties at the "annual Conference of the Parties (COP21) in Paris", is the most significant worldwide activity to solve environmental problems[1]. In line with these strategic goals stipulated in the Paris Climate Agreement, the participants annually recommend a series of projects to raise the penetration rate of "renewable energy sources (RESs) in the electrical power systems"[2]. And to that end, important motivation and policies have been thought-out by governments to develop RESs and support investors. Despite the climate benefits and sustainability of the RESs, PS control operators faced two primary constraints when combining the large-power RESs into the PS. The first one, the output power of RESs highly depends on surrounding environmental circumstances and is not controlled [3-7]. The second one, the existent infrastructure of the PSs is not suitable for raising the penetration of RESs, which imposes the PS control operators to decrease a significant percentage of RESs. For instance, the reduction of wind and solar power in Germany's PS from 2009 to 2018 is shown in Fig.1 [8]. As shown in the figure, the rate of solar and wind reduction in Germany's power grid hit a record of 5.37 TWh in 2018.

One of the poorest countries in terms of traditional energy resources is Jordan, but at the same time it is an ideal place for renewable energy sources; for example, sun and wind; because there are more than 300 sunny days a year, and the wind is available daily in many different places. To ensure the safety of human health and the environment, the effective sustainable management of solid waste is of great importance. Rapid urbanization and scarcity of financial resources and the rapidly growing population of Jordan are always big, worrying, and serious problems facing the local government [9 - 14].

The primary energy sources for Jordan in 2018 are shown in Fig. 2. Imported natural gas and Crude oil contain the largest share at 89% of the total energy need, while local resources account for 9% of the energy supply, including 7% obtained from RE [15].

Over the past century, the whole world relied solely on a unified system of electricity: electricity was supplied through huge transmission and distribution networks from large central generating stations to all kinds of consumers in their homes, offices, and factories [16 - 18].

However, a parallel trend has emerged in recent years, where smaller generating units are connected at the distribution level. This technology is called a distributed generation (DG) [18]. The most important of these DG technologies in Jordan are solar heat, wind turbines, and solar photovoltaic (PV) cells. Most recent studies indicate

that in the long and medium-term, PV energy will become an important source on a commercial level so that it can be seen in most parts of the world [19 - 21].

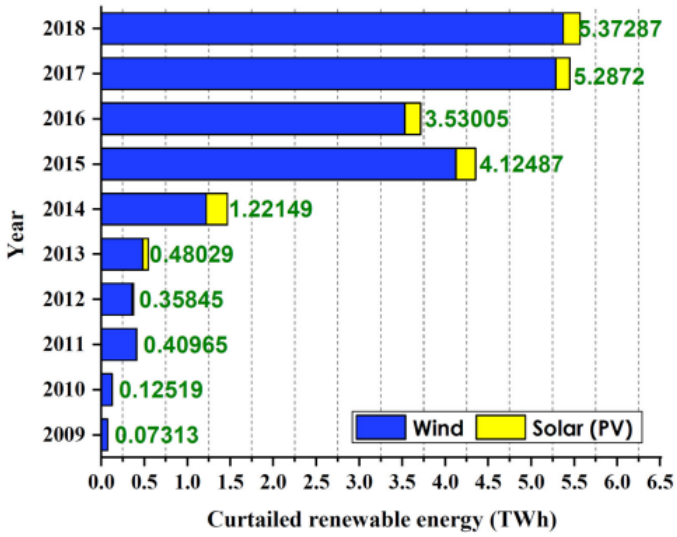

Fig. 1. Curtailed wind and solar energy from 2009 to 2018 in Germany [4].

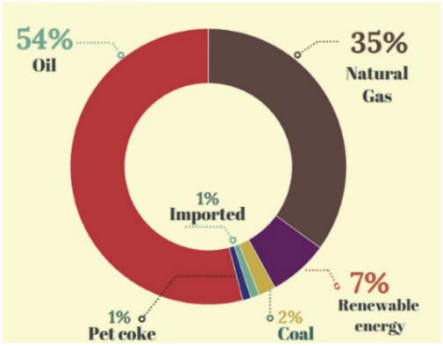

Fig. 2. Structure of primary energy sources in Jordan in 2018 (9,712 ktoe) [11].

Jordan is very rich in RE resources, the most important of which are solar, and wind energy [22]. The 2011 report of the Arab Forum for Environment and Development (AFED) stated that the Arab region has an installed hydroelectric capacity of about 10.7 megawatts, and there are large hydroelectric stations in Egypt and Iraq, and stations of different capacities in Algeria, Jordan, Lebanon, Mauritania, Morocco, Sudan, Syria, and Tunisia [23].

By investigating the conducted studies can be seen that an efficient settling to find a solution for the above-mentioned challenges, is to use flexible options, such as demand-side management strategies and energy storage systems (ESSs).The system can be optimized based on the availability of the ESSs, particularly for energy conversion efficiency.

At present, the exploitation of ESSs by consumers in the Arab world is limited to water heating applications and garden lighting, in addition to the initiation of large governmental plans and projects to generate electricity from ESSs for commercial and industrial use, as is the case in Egypt, the United Arab Emirates, and Bahrain.

However, RE generation systems rely heavily on the use of ESSs (Batteries, flywheel ES, fuel cell storage, compressed air ES, pumped hydropower storage systems) that are available in various locations to store energy for use during interruptions and disruptions in PG from the main source or the grid [24 - 28].

Many Arab countries are also eligible to benefit from wind energy, especially Egypt and Jordan, where the average wind speed is 11.8 meters / second in the Gulf of Suez in Egypt, and 7.5 meters / second in Jordan, which makes these two countries qualified to generate electricity from wind as well as can be generated in many locations in Morocco, Syria, and some other Arab countries [29 - 32].

This document aimed to use energy efficiently where it is feasible to improve the management and control of the workload of residential buildings and distributed energy resources while improving their efficiency. Additionally, this research highlights significant leverage points to integrate battery storage systems while promoting battery application more effectively in the country. A more environmentally friendly, low-emission power distribution system will benefit in the long term from the findings of this study.

The methodology of this study has been based on a structured way of collecting relevant data and information. It can also be described as a process in which the researcher can solve some unsolved problems and learn how to

carry out the study. Epistemology and procedure are closely related to each other. Epistemology contains theory, and study methods related to the perception of the cosmos, while methodology includes the practice of different research methods.

In this study, a questionnaire survey is performed to define Arab countries' actual perspectives and attitudes towards the management and development of ESSs and their economical and time benefits. The questionnaire consists of four parts. Specifically, section one is used to evaluate the characteristics of the samples, which includes a variety of measures, such as gender, age, governance, characteristics of the dwelling, the type of dwelling, the total area of the dwelling, the number of family members in the household and the family income in Jordanian dinars. Consequently, Section Two is used to assess social perspective attitudes towards the value of managing the residential ESSs. Section three is used to waive management of the residential ESSs. In addition, Solutions for the management and development of residential solar ESSs in Arab countries. A five-point Likert-style scale is used to determine the degree of identification of Jordan's social point of view with each predictor. The questionnaire is tested with 429 respondents from 12 provinces and the necessary modifications are made. The questionnaire was designed to achieve and satisfy the objectives of the study.

Statistical information and data were collected and distributed through Google form and sent to respondents through social media applications. The study's collected data were analyzed using both descriptive and inferential statistics using reliability tests, descriptive statistics, and linear regression models. The data were then organized and categorized according to specific goals.

2 MATERIALS, AND METHODS

The materials included were natural sand, coarse aggregate, recycled coarse aggregate, crumb rubber, ordinary Portland cement (OPC) with a specific gravity of 3.15, super-plasticizer to attain the required workability and normal tap water.

With the use of photovoltaic panels, green energy can be supplied to residential structures, regardless of the energy efficiency level of the building. SE is often stored in batteries and then discharged as needed, which is a common strategy to address short-term shortfalls produced by solar radiation that is not always available. The best long-term use and storage of solar resources can be achieved by using suitable storage technology, such as hydrogen derived from electrolytic solar electricity. The management and development of residential solar battery storage are critical to its success. Fig. 3 depicts the research approach used in the current study.

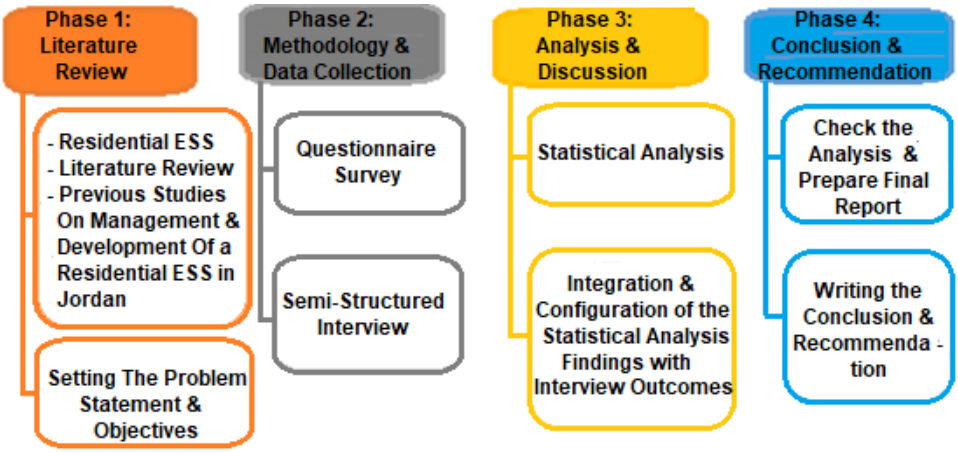

Fig. 3. Flowchart of research methodology.

Research has identified the study approach to acquire essential data and information. A researcher's approach to solving specific unsolved problems can also be viewed as an examination of the most effective strategies for undertaking future research. Based on actual Jordanian views and attitudes, the questionnaire survey attempts to identify the role of home ESSs in saving time, effort, and money. The design of the questionnaire is the initial phase of this study. Four sections are included in the questionnaire. This part assesses the characteristics of the samples, such as their gender, age, level of government, type of dwelling, size of residence, and the number of family members living there, as well as their income in Jordanian dinars. Section two is intended to assess the social point of view on the value of managing home ESSs, consisting of 13 questions.

Additionally, Jordanian home ESS development and management solutions are available. Likert-style scales from 1 to 5 were used to measure the level of agreement or disagreement between the point of view of Jordanian society and each of the predictors. Pilot tests of the questionnaire are carried out with 429 participants from 12 provinces. The objectives of the study were approved through a questionnaire consisting of three main items: Importance of Residential ESS Management in the World, Effects of not applying residential ESS management, and solutions for management and development of residential ESS in Jordan as a case study.

Analysis of the issue was done using quantitative data collecting methods. A total of 429 people took part in the poll, which was administered via Google Forms, social networking apps, and questionnaires. A confidence level of 95% and a margin of error of 5% should be achieved by adopting appropriate management [33 - 36]. In this paper, The Statistical Package for the Social Sciences (SPSS software package version 20) was used for the statistical analysis of this research. Reliability tests, descriptive statistics, and linear regression models were used to examine the data acquired for the research. The raw data gathered via surveys has been revised to remove any errors or omissions that may have occurred. The socioeconomic characteristics of the respondents were considered. The most important traits in the sample, including age, sex, government, dwelling characteristics, dwelling type, total dwelling area, number of family members, and family income in Jordanian dinars, are summarized in Table 1.

When it comes to qualitative research, semi-structured interviews are the method of choice. The Jordanian engineering industry is trying to use solar ES as a study for academics, however, this has yet to be implemented. A minimum of more than 5 years of experience working within the solar or RE sectors was required for each of the participants questioned in this research.

3 RESEARCHQUESTIONSANDHYPOTHESIS

The hypotheses of this research are presented as follows:

- **Null Hypothesis, H_0:** "Jordanian engineers lack knowledge and experience related to the management and development of a residential solar system and ESS within the meaning of its regulations, directions, and policies."
- **First Hypothesis, H_1:** "Jordanian engineers and experts have rich experience and knowledge in development and management of residential ESS with its regulations, directions, and policies."
- **Second Hypothesis, H_2:** "Jordanian engineers and experts will not encounter any form of trouble in the future with their household ESS".
- **Third Hypothesis, H_3:** "Jordanian engineers can protect their users from any problems in the future related to negligence issues and design flaws, and they can do so because they have used residential ESSs that have achieved this performance level and functionality".

Table 12. Respondents' socio-economic characteristics.

Variable	Category
Gender	The number of study samples that were collected from males was 249 samples, or 57.9%, compared to 180 females, or 42.1%.
Age	Approximately 137 of the respondents in Jordan, (31.9%), were (20-30) years old and 33 of the respondents, (7.7%), were under 20 years of age.
Governate	The majority of those who responded to the items, (38.7%), lived in Amman compared to the lowest percentage, (2.8%), in Ajloun.
Characteristic of housing	Most of those who responded to the items, (51.7%), have their own house compared to the lowest percentage of them, (20.3%), who live as a renter's home.
Type of housing	The majority of those who responded to the items, (47.1%), live in a separate home while the lowest percentage of them, (13.8%), live on a farm.
The total area of the dwelling	The majority of those who responded to items, (46.6 %), have a house area from [100-200 m^2] as compared to the lowest percentage, (10.3 %), who live in a house ofarea less than 100 m^2.
The number of family members	Approximately 246 (57.3 %) of respondents in Jordan have family members (More than four people)
The family's income in Jordanian dinars	Most respondents (49.9%) have an income of more than 500 dinars per month and less than a thousand dinars.

4 RESULTS AND DISCUSSION

Participants in Jordan were asked whether they attempted to insure or use domestic solar ES as part of the first research target, which was achieved. Given that there is a wide range of views on how important it is to manage a residential ESS, this approach and management style have been used. Most users are concerned about expected future limits in private practice, growth, corporate governance, and learning about the ESS.

Residential solar ES management in Arab countries is seen as important by many Jordanians to ensure energy production and gauge the views of those who rely on renewable sources of energy.

Fig. 4 shows the average results, which reveal that local ESSs account for 85.3% of the 364 respondents, according to the users studied, and are needed to expand and improve residential ESSs. Most participants seem to agree on the need to protect both the reputation of the renewable energy sector and the impact of unsustainable energy supplies. It was explained to the respondent that (a) solar panels without ES are inefficient, (b) solar panels do not work at night, (c) solar panels do not work in cold, cloudy, or foggy climates, and (d) solar panels are initially expensive, (e) the solar cell is made of polluting materials and (f) the solar is weather dependent.

Fig. 5 also presents typical user views on the implications of not trying to use a residential ESS, which shows that approximately 71 percent disagree and demonstrates that there is a risk of continuing to use SE in dwellings and not using ES solution. To achieve the most frightening results that lead to optimal and most efficient ES production, the operation and improvement of RE must be managed based on how significant the limits on their impact are, and whether they are acceptable or not.

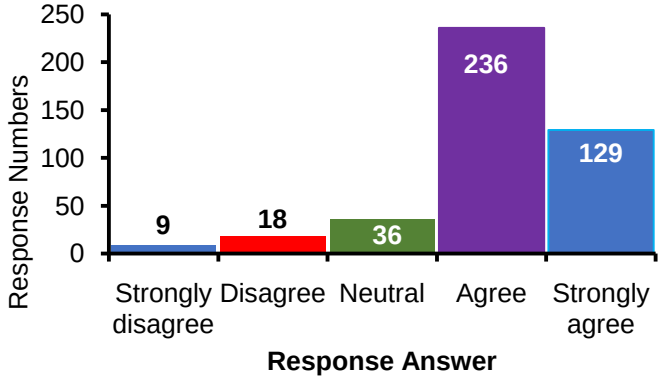

Fig. 4. Users' perceptions of the Importance of managing a domestic ESS.

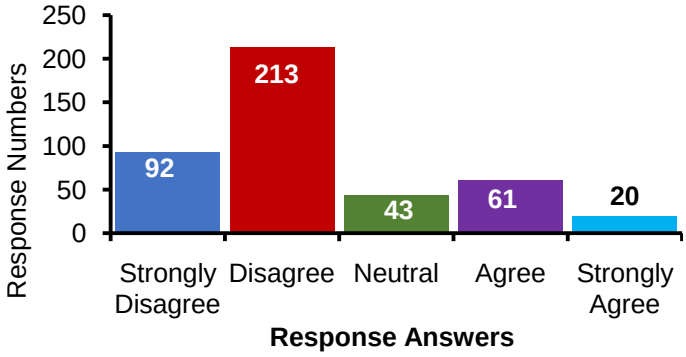

Fig. 5. Users' perceptions of the Effects of not applying residential ESS management in Jordan.

After balancing energy demand and supply, reducing energy prices, and increasing efficiency, the second research goal was achieved in this study. There are no problems highlighted by respondents, such as unfair neglect by the government. After averaging the responses, we came up with a solution to Jordan's solar storage problems, as shown in Fig. 6.

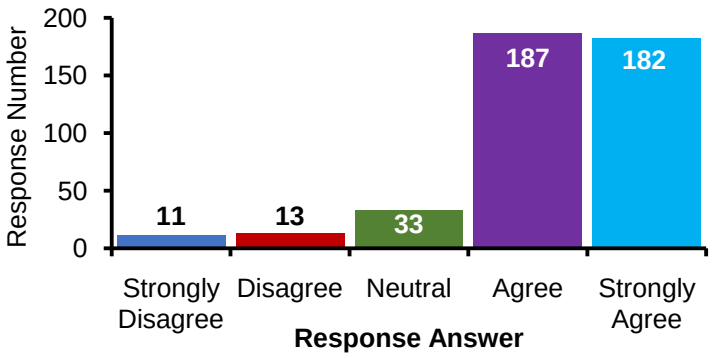

Fig. 6. Solutions for management and development of residential ESS in Jordan use energy-generating respondents.

More than half of the respondents supported all the solutions offered due to the value of the investment and the improvement of land use and quality. At first glance, this may seem like a clear matter, but the severity of the problem and the potential danger should not be underestimated.

As an example, trends may be derived from data by using descriptive statistics to characterize, present or sum up data. Summary statistics are shown in Table 2. The mean or average of all data is a center pattern, which means a number that includes everything else. The standard deviation is the average distance measured from the mean of the variables. There is a significant difference between data points with low normal divergence and data points with a high dependent variable in terms of their distance from the data collection average.

Table 2. The summary descriptive statistics analysis for data.

Variable	Average Mean	Average Std. Deviation
Importance	4.25	0.629
Effects	3.00	0.753
Solutions	4.26	0.770

According to the item's importance rate, respondents were asked if noise pollution had been reduced or limited and if they had any appliances in their homes that were running without interruption to guarantee the importance of ecological sustainability, management, and development of residential ES. Most respondents thought that sustainable ES management was of vital importance for decreasing noise pollution. Based on the average (4.25) and variance (0.629) of the average item importance, the results are clear. According to the participants, the issue of rapid climate change (b1) is one of the main significant impacts on the Jordanian ESS, and therefore ES management is unsustainable, as evidenced by the average (3.00) and standard error (0.753). This is an indication of average items' Effects. Approximately 86% of respondents said that all findings (solutions) suggest that the management of residential ESSs in Jordan is very important, and thereby it should be improved. The management of a residential ESS in Jordan also includes elements such as reduced customer bills, increased security of supply, reduced peak energy purchases, seminars, and marketing to promote public awareness. There is no doubt that all of these are viable options for managing Jordan's domestic ESS.

Regarding the reliability analysis, Cronbach's coefficient alpha is used to overcome the limitation in the reliability of the study. As a general guide, if Cronbach alpha is at least 0.70, that's great. If it is 0.80 or higher, it is better. Table 3 shows that the significance, effect, and solution have strong retest correlations, which makes sense since the examined construct is expected to be stable over time.

Table 3. Study reliability analysis results.

Variable	Cronbach alpha
Importance	0.970
Effects	0.835
Solutions	0.940
Average	**0.915**

The effect of solutions on the efficiency of solar ES management was predicted using regression analysis. These comments reveal that the recommended solutions for developing a domestic ESS in Jordan (section C) have had a significant impact on the importance of managing this system (section A).

Table 4 shows the information needed to predict income prices and determine whether income contributes significantly and statistically to the model (by looking at the "Sig." column). As a last option, we may use the values of column B, as "non-standard coefficients". The regression equation can be expressed as (significance = 1.355 + 0.682 (solution)) as shown in Table 5 which presents the regression equation coefficients.

Table 4. Regression analysis coefficients.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta	B	Std. Error
(Constant)	1.355	.146	0.698	9.267	0.000
Importance of Residential Solar	0.682	0.034		20.052	0.000

4.1 The average security of ES management in residential buildings:

As part of the third purpose of the study, participants were asked whether solar ES technologies in the sustainable energy industry are secure. ES because of these inconsistencies has been discussed in the construction industry.

The majority (73%) of interview participants are confident that ES technology will be used in residential construction, while only 27% of respondents claimed that ES technology is not necessary which is shown in Table 5. While some participants had no plans to use ES at home, large organizations such as factories and power plants believe they should use it in their institutes.

When it comes to reducing carbon dioxide emissions while also conserving time and money on PG commitments, ES technology, they say, plays an important role in the field. Based on their assertions that ES could allow for flexible production and steady energy supply to meet consumer needs, the result was that ES technology could be relied upon. In addition, energy consumption fluctuates greatly throughout the year and within a single day, making it difficult to predict how much energy is required. Peak and off-peak demands of energy are generated by a combination of individual orders and weather conditions. This necessitates the application of an ESS.

Table 5. Current perspective on the implementation of residential SE Technology in Jordan.

Current perspective on the implementation of residential SE technology in Jordan.	N	Percentage (%)
Yes	8	73
No	3	27
Total	**11**	**100**

4.2 The advantages of using ES in residential buildings:

Table 6 illustrates the descriptions and the characteristics derived based on the responses from the respondents:

Table 6: Descriptions that are given by respondents (advantages of ES management).

Respondent No.	Descriptions (advantages of ES management)
AE01	The criteria have the potential to both save money and help the environment.
AE02	Only if end-users are pleased can the system be considered sustainable in terms of both work environments and society.
AE03	As long as the RE sector's job market is unaffected by ES.
AE04	To better express the government's view on current and upcoming energy-generating projects, fresh perspectives should be developed in the field of ES.
AE05	Solar panels and battery storage systems, unlike generators, do not produce noise pollution that will annoy your neighbors.
AE06	Solar battery systems enable your home to be more energy resilient.
AE07	ES can reduce grid powering costs while also saving electricity users money if they install it in their residences or places of business.
AE08	Possibly. I'm not an expert on this topic, but ES makes it feasible to store energy. Even if the sun is now not blazing or the wind doesn't blow, ES is still important.
AE09	Wind and solar power, which are notoriously unpredictable, can be smoothed out with the use of ES.
AE010	In the event of a power outage, ES can step in to supply backup power.
AE011	Long-duration ES, in particular, offers significant advantages to energy-conscious brands. Incorporating renewables and ES into company activities promotes more sustainable and economically viable business strategies.

4.3 Factors that will encourage the use of ES management in Jordanian homes

Respondents noted that a limited supply of raw materials and sophistication of production procedures are two of the main constraints limiting manufacturing flexibility as a result of COVID 19. ES is a state-of-the-art technology that can be used in a variety of environments. When it comes to getting the most benefits, facility managers and executives need to be well versed on the subject. Financial and investment problems can arise, as not all facilities pay service fees that allow them to take advantage of these benefits. However, many warehousing organizations provide industrial and commercial customers with no-down-payment warehousing options so this can be resolved with the proper information. Respondents' descriptions of ES application restrictions are found in Table 7.

Table 7: Energy storing limitations respondents.

Respondent No.	Descriptions (limitations of ESS application)
AE01	Design Inaccuracies
AE02	As a result of outdated ES laws and standards, interconnection and permitting procedures have become increasingly complex, expensive, and time-consuming.
AE03	As a copyright holder, I think the procedure is too complicated and there are too many requirements that need to be met.
AE04	The energy lost in “round trip” inefficiencies.
AE05	A disadvantage of implementing battery storage systems is the initial cost.
AE06	None. Everything is just fine
AE07	Batteries have a finite lifespan; hence proper disposal must be practiced to avoid harming the environment.
AE08	There is now only a limited criterion for the application of SE stored in Jordan.
AE09	High Initial Cost.
AE010	Solar ES is Expensive.
AE011	There is a scarcity of information on the many ES technologies available today, including their capabilities, costs, and financing options.

5 CONCLUSION

Connecting RE sources to the main grid of the electrical system is one of the problems that Jordan has faced in recent decades. As a result, it will be difficult for them to rely entirely on electricity generated from renewable sources at present due to the possibility of continuous power outages, especially in weather conditions that are not suitable for generating energy from SE systems. Therefore, the use of ESSs is an ideal solution to this problem, as it allows more energy to be stored from emerging sources of RE, such as photovoltaic systems with batteries, and delivered to consumers on demand.

This paper and its methodology focus on the basic concepts of quantitative and qualitative analysis of the application of ESSs and their impact on the energy market in Jordan, rather than just imagining the risks and possibilities associated with the imminent transition from reliance on PG using fossil fuels to RE systems without finding solutions to the problem of power outages associated with this transformation. A wide range of stakeholders and experienced people were engaged through personal interviews and questionnaires to help build the final model and complete visualization of a solution to the ES problem in Jordan. The idea is that governments and companies interested in this topic may use it to test and evaluate a variety of scenarios so that they can better understand how photovoltaic and battery ES technologies are revolutionizing the energy sector and industry.

According to the comments and responses of the Jordanian respondents, engineers and specialist groups in developed countries have extensive knowledge in the management and development of domestic ESSs by the legislation, instructions, and policies adopted in the world. Also, customers do not have to worry about neglecting their needs and unsatisfying their electricity demands.

A potential solution to this problem could also be achieved by encouraging customers to efficiently use household appliances that rely on ESSs, such as photovoltaic energy with batteries to help modern energy supply networks become more incentivizing to consumers and less polluting. Furthermore, customer needs can be met while reducing the cost of energy production through the use of energy demand-side management. As a result, consumers are rewarded for efficient use of electricity resulting in the most popular incentive-based system.

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