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Prospects and Obstacles Associated with Community Solar and Wind Farms in Jordan's Suburban Areas

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Abstract: Jordan faces significant, immediate challenges of enhancing energy security while mitigating greenhouse gas emissions. One of the most promising approaches to achieve sustainable development, energy security, and environmental conservation is to increase the integration of renewable energy into electricity generation. To this end, the Jordanian government aims to expand investments in the green energy sector, with solar and wind energy expected to play a crucial role in meeting energy demands and promoting environmental sustainability. This paper aims to examine the distinct dynamics, challenges, obstacles, and potential solutions related to establishing community solar and wind farms in suburban areas of Jordan. It seeks to highlight the opportunities and barriers influencing the adoption of sustainable energy in the country. Evaluation results from engaging 320 key stakeholders were obtained through a questionnaire, and after comprehensive analysis, it became evident that the benefits and positive aspects of solar and wind farms outweigh their drawbacks and obstacles. These insights can be useful in guiding policies and practices to make renewable energy community projects a reality within Jordan's suburban areas. Additionally, the findings may serve as a valuable benchmark for other regions facing similar challenges in their pursuit of a sustainable energy future.

Keywords: community solar and wind farms; Jordan; suburban areas

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1. Introduction

1.1. Renewables in Jordan

In an era marked by escalating environmental concerns and the pursuit of sustainable energy solutions, the role of solar and wind renewables has emerged as a pivotal force in mitigating environmental damage and curbing energy costs. Countries worldwide are increasingly turning to these renewable sources, recognizing their potential to address both environmental and economic challenges [1]. A compelling case in point is Jordan, a nation grappling with a scarcity of fossil and other resources and economic constraints, where the integration of community solar and wind farms presents a promising avenue for achieving environmental targets and alleviating the burden of soaring energy bills [2].

The Jordan National Energy Strategy for the period 2020–2030 is centered on enhancing energy security by improving energy efficiency, diversifying the energy mix, increasing the proportion of renewable energy in the overall energy composition, reducing carbon emissions, and lowering energy costs. Moreover, the strategy is geared toward diminishing dependence on imported oil fuels for electricity generation. The overarching goal is to achieve, by the end of 2030, the goal of 48.5 percent of the country's electricity generation being sourced from local energy outlets [3].

Jordan's enduring potential for additional renewable energy is underscored by factors such as an annual average of 316 sunny days, wind speeds ranging between 7 and 8.5 m per second, and vast desert areas with sparse populations. Furthermore, aligning with Jordan's commitment to the Paris Agreement, the government updated its 2016 Nationally Determined Contribution (NDC) goal in October 2021. This revision entails a commitment to reduce greenhouse gas emissions from 14% to 31% by the year 2030, emphasizing the nation's dedication to advancing sustainability and addressing climate change concerns [4].

The imperatives of transitioning toward renewable energy sources are underscored by the pressing need to reduce environmental damage and curtail the adverse effects of climate change. Solar and wind renewables, with their inherently clean and sustainable nature, offer a viable alternative to traditional energy sources that contribute significantly to carbon emissions. By harnessing the power of these renewables, nations can take substantial strides toward meeting their environmental commitments and fostering a greener, more sustainable future [5].

For countries facing the dual challenge of limited fossil resources and economic constraints, the adoption of solar and wind renewables becomes not only an environmental imperative but also a strategic economic decision. The prospect of reducing dependency on expensive imported fuels and mitigating the impacts of volatile global energy markets positions renewables as a prudent choice for developing countries like Jordan. By investing in sustainable energy solutions, nations can not only contribute to global environmental goals but also insulate themselves from the economic shocks caused by fluctuating energy prices [6].

However, the journey toward embracing solar and wind energy is not without its challenges, particularly for individual households in Jordan. The upfront costs associated with the installation of solar and wind generator systems can be prohibitively expensive, posing a significant barrier for many households. Despite the long-term potential for substantial energy savings, the initial investment required often deters widespread adoption, thereby limiting the immediate benefits that these technologies can offer to the average consumer [7].

Therefore, it is imperative to explore alternative models that not only make renewable energy more accessible to households but also ensure a reasonable return on investment. Community solar and wind farms emerge as a solution that addresses the economic challenges faced by individual households in Jordan. By pooling resources and sharing the costs of installation and maintenance, communities can collectively harness the benefits of renewable energy, making it a more economically viable option for all [8].

As we delve into the specific case of Jordan, it becomes evident that unlocking the potentials for green energy is not merely a theoretical exercise but a practical necessity [7]. This paper seeks to explore the unique dynamics and challenges associated with community solar and wind farms in Jordan, shedding light on the opportunities and barriers that shape the trajectory of sustainable energy adoption in the country. By examining the case of Jordan, we aim to derive insights that can inform policies and practices, not only in the context of this nation but also serving as a valuable reference for other regions facing similar challenges on their journey toward a sustainable energy future.

1.2. Potential for Green Energy in Jordan

Jordan, situated in a region with abundant sunlight and steady wind patterns, holds immense potential for harnessing green energy, particularly from solar and wind sources. The country's geographical location provides it with substantial solar energy potential. Jordan experiences high levels of solar irradiance throughout the year, making it an ideal candidate for solar power generation [9]. The implementation of solar photovoltaic (PV) systems holds the promise of tapping into this abundant resource, offering an environmentally friendly alternative to conventional energy sources. Large-scale solar projects, like the Shams Ma'an Solar Power Plant, underscore the viability and success of solar energy initiatives in Jordan [10].

Moreover, Jordan's topography and wind patterns make it conducive to the development of wind energy projects. The country's northern and southern regions exhibit favorable wind speeds, presenting opportunities for the establishment of wind farms [11]. The Tafila Wind Farm, a pioneering venture in the Middle East, stands as a testament to Jordan's commitment to wind energy [12]. With advancements in wind turbine technology, there is growing potential for expanding wind energy capacity and contributing significantly to the national energy grid [13].

1.3. Sunlight per Day in Jordan

As shown in Figure 1, Amman, the capital city of Jordan, experiences varying durations of sunlight throughout the year, with mean hours ranging from 6:32 in February and December to 13:07 in July. The longest single span of direct solar radiation is in July, spanning 14:05 h, while the shortest duration of 9:54 h is in December, resulting in a difference of 4:11 between them. These sunlight patterns highlight the dynamic solar conditions in Amman. The city receives an average of 3602 h of sunlight annually, out of a possible 4383, translating to an average of 9:51 of sunlight per day and more than 300 sunny days a year, providing approximately 3125 h/year of sunshine. Notably, this abundant sunlight presents a substantial latent opportunity for power generation from solar panels.

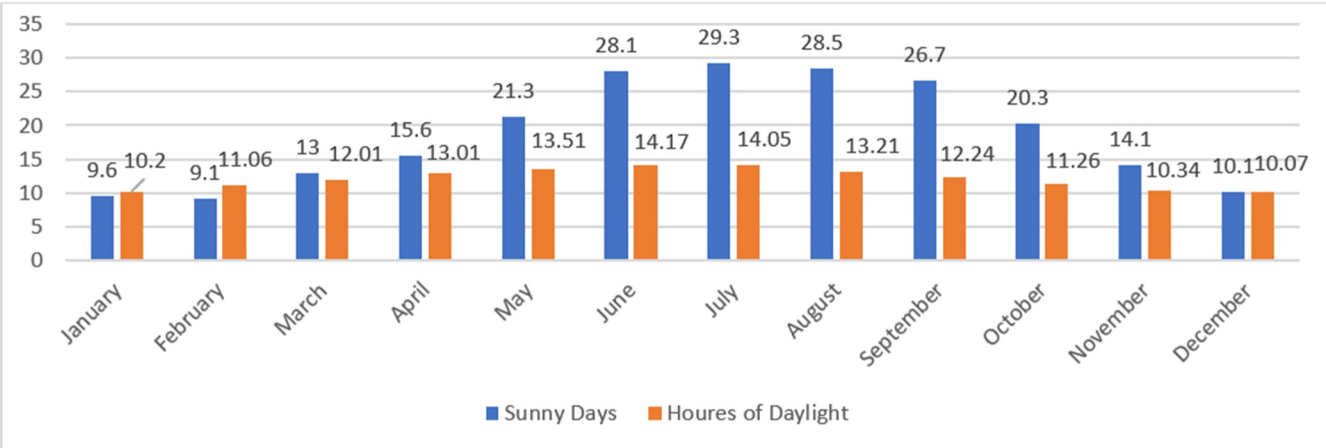

Figure 1. Number of sunshine days and hours of daylight in Amman city [14].

With an average of 82.2% sunny daylight hours, the remaining 17.8% may experience conditions such as cloud cover, shade, haze, or low sun intensity. The midday sun at its zenith is typically 58.4° above the horizon. This specific angle further emphasizes the favorable solar conditions, making Amman and other cities in Jordan an ideal location for harnessing solar energy through the installation of solar panels [14].

Moreover, Jordan lies on the solar belt of the world, where the Global Horizontal Irradiation (GHI) as well as the Direct Normal Irradiation (DNI) are very high [10]. This is mainly due to the high altitude and the low humidity. The irradiation on the horizontal plane for all of Jordan's governorates shows promising figures. The Average Annual Global Horizontal Irradiation (AAGHI) for Jordan is about 2327 kWh/m^2, while the Average Annual Direct Normal Irradiation (AADNI) is around 2798 kWh/m^2.

For the governorate of Ma'an, reference [10] presents plots for each month of the year for the Direct Normal Irradiation (DNI), Global Horizontal Irradiation (GHI), and Diffuse Horizontal Irradiation (DHI). It reveals the average monthly sum of the GHI and the DHI for the governorate of Mafraq. The highest irradiation on the horizontal plane occurs during June with an average irradiation of around 260 kWh/m^2, while the lowest irradiation occurs during December with an average of about 90 kWh/m^2. This confirms that for all of Jordan's governorates, the highest irradiation occurs during June, while the lowest irradiation arises during December.

1.4. Wind in Jordan

Jordan possesses designated regions in its northern, central, and southern territories where wind speeds consistently reach up to 8 m/s all year round. This circumstance renders the prospect of investing in these areas and harnessing their wind potential for electricity generation highly advantageous [15]. Figure 2 shows the mean monthly wind speed at a height of 10 m for Jordan governorates; the average wind speed varies from the lowest average of 2.34 m/s in Ajluon to the highest of 6.71 m/s in Aqaba, showing that some areas in Jordan are generally considered to be within the range suitable for energy generation from wind farms. The energy output of a wind turbine is proportional to the cube of the wind speed, so even a moderate increase in wind speed can result in a significant boost in power production [16]. In the context of wind energy, wind speed is often classified into different classes, ranging from Class 1 (low wind speed) to Class 7 (high wind speed). For instance, Maan has an average wind speed of 6.01 m/s, which would fall within the range of Class 3, which is considered moderate and is suitable for low-cost wind power generation [17].

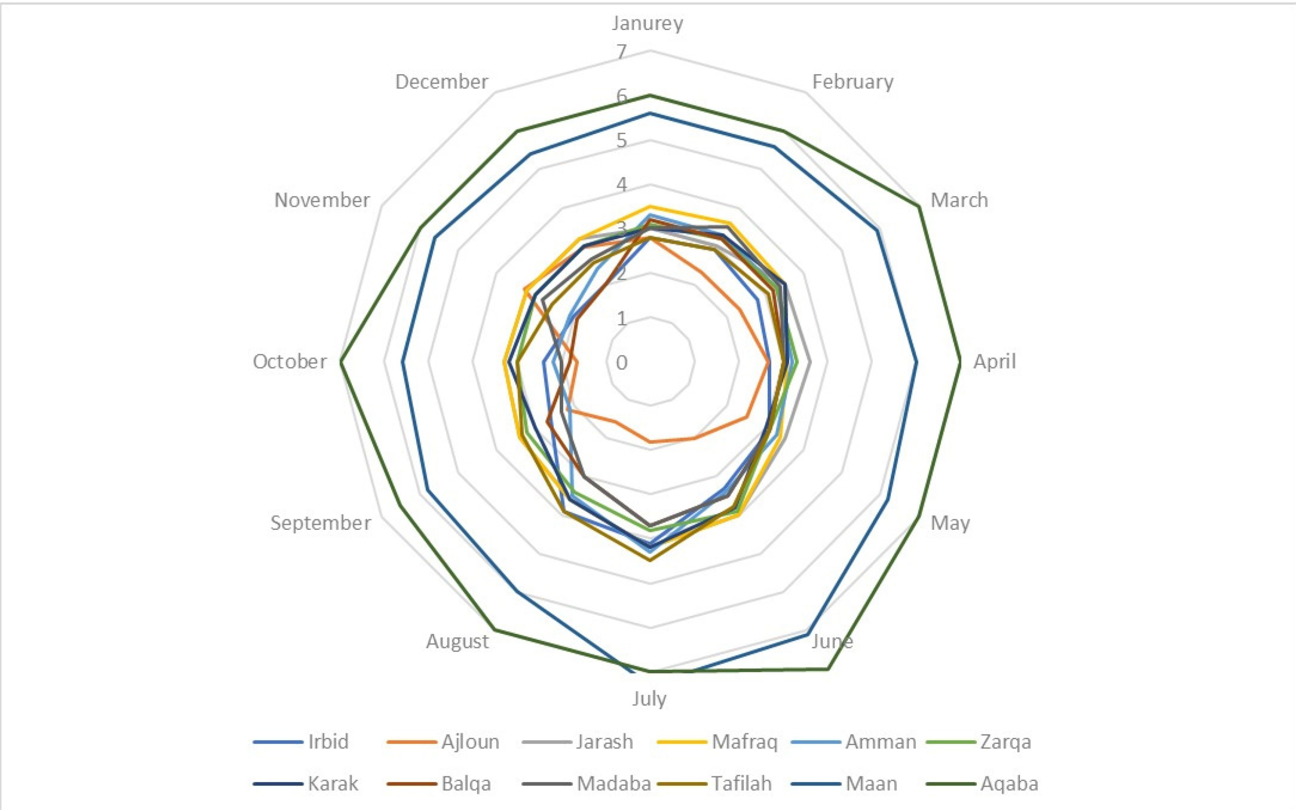

Figure 2. Mean monthly wind speed at height of 10 m for Jordan Governorates [16].

For governorates where the average wind speed is less than 5 m/s, the wind still can generate a substantial amount of energy in winter when the wind speed increases significantly. Furthermore, in these governorates, solar farms can be the main source of energy. It is feasible to have solar/wind hybrid power systems for all Jordan governorates, where in the windy seasons wind power would be the main source of energy, while in other seasons solar energy would be the prime source.

1.5. Distribution of Electric Vehicle Charging Stations in Jordan

While Jordan has taken steps to promote e-mobility, resulting in a noticeable increase in the number of electric vehicles, this progress faces a significant hurdle due to the scarcity of electric charging points [18]. This limitation restricts the usage of electric vehicles to the vicinity of home charging points or regions with available public charging infrastructure. As shown in Figure 3, as of April 2024, the total number of public electric charging stations is limited to 46, with most concentrated in the capital and nearby areas [19]. The scarcity of charging points outside the capital poses a risk for electric vehicle owners, as they may face the possibility of running out of charge during long-distance journeys. This disparity also discourages residents in suburban areas from transitioning to electric vehicles. Furthermore, the growing number of electric vehicles will strain the electricity supply from the main grid. Therefore, it is essential to establish community charging points that can directly harness energy from wind and solar sources, or feed generated energy back into the main grid [20]. This approach would not only address the challenge of charging point availability but also help mitigate the strain on the national grid and encourage the use of e-mobility means in Jordan's suburban areas.

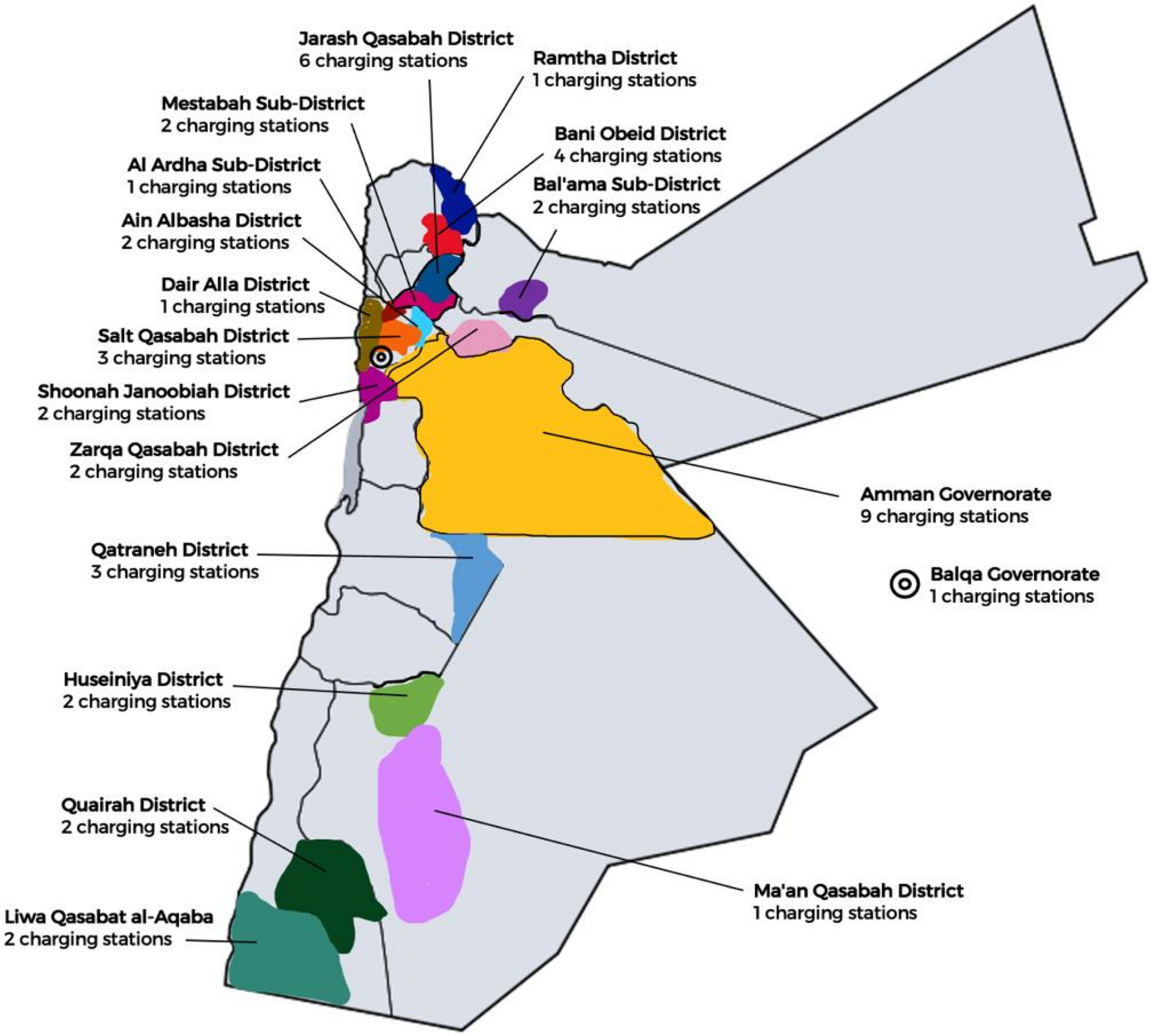

Figure 3. Distribution of electric vehicle charging stations in Jordan [18].

1.6. Challenges for Wind and Solar Energy Deployment

In general, Jordan faces challenges in deploying wind and solar energy [18]. The following points are related to deployment within rural communities.

- Initial investment costs: the substantial upfront costs associated with acquiring and installing solar panels or wind turbines can be a significant obstacle for rural communities, as they often have limited financial resources to allocate to such projects [18].
- Technology accessibility: Limited access to the latest and most efficient solar and wind technologies may impede the effectiveness of renewable energy systems in rural areas. Accessibility to cutting-edge technologies is crucial for optimizing energy production and efficiency [18].
- Storage solutions: The intermittent nature of wind and solar resources necessitates reliable and cost-effective energy storage solutions to store excess energy for times when these resources are not available. This becomes particularly challenging in remote areas where grid connectivity is limited [6].
- Grid connectivity: Establishing grid connections in remote rural locations is often challenging due to logistical complexities and high costs. Lack of grid connectivity can hinder the integration of renewable energy into the existing power infrastructure [18].
- Maintenance and repairs: limited technical expertise and resources for the ongoing maintenance and repair of solar panels and wind turbines may lead to system inefficiencies and downtime, impacting the overall reliability of the renewable energy systems [21].
- Community engagement: Limited awareness and understanding of the benefits of wind and solar energy within rural communities may result in skepticism or resistance. Effective community engagement is essential for building support and encouraging widespread adoption [21].
- Policy and regulatory support: The absence of clear policies and supportive regulatory frameworks can discourage investment in and hinder the integration of solar and wind technologies. A conducive regulatory environment is crucial for fostering renewable energy development [21].
- Site suitability: Identifying suitable locations for wind and solar installations involves considering ecological impacts and ensuring compatibility with existing land uses. Conducting thorough assessments of site suitability is vital for minimizing environmental consequences and optimizing energy production [22].

1.7. Community-Based Wind and Solar Energy Systems

Communities across rural areas are embracing a movement that not only champions environmental sustainability but also holds the promise of substantial reductions in energy bills—the advent of community-owned wind and solar power projects. This collective approach to energy generation not only aligns with the global imperative to reduce carbon emissions but also presents a compelling economic model that fosters community resilience and empowerment [23].

The significance of community-owned energy systems lies not only in their ability to contribute to the reduction in the country's carbon footprint but also in their potential to alleviate the financial burden of energy costs on community members. By actively participating in and investing in these projects, community members stand to benefit from shared ownership, enjoying reduced energy bills as a result of generating their own electricity [24]. This financial incentive not only encourages active community involvement but also ensures that the economic advantages of renewable energy are distributed locally [25].

Beyond the direct economic benefits, community-based energy projects have a ripple effect on the local economy. These initiatives create job opportunities, attracting skilled professionals and fostering the development of expertise within the community [26]. Additionally, the infusion of investment into these projects stimulates economic growth, injecting vitality into local businesses and services [27]. As community-owned energy projects gain momentum, they become catalysts for positive change, enhancing the overall economic landscape of the regions they serve [28].

Furthermore, these projects serve as inspirational beacons, motivating communities to address additional local challenges. The success of a community-owned energy initiative often sparks a sense of collective efficacy, prompting communities to tackle other pertinent issues such as improving transportation infrastructure or enhancing access to essential services [29]. In this way, community-based renewable energy projects become not just sources of power but also catalysts for holistic community development [30].

The income generated by these community-owned projects can be strategically reinvested to fund more local initiatives. Whether supporting education, healthcare, or cultural programs, the surplus funds generated from renewable energy endeavors can be channeled back into the community [31]. This self-sustaining cycle of investment not only strengthens community bonds but also ensures that the benefits of renewable energy extend far beyond the immediate scope of reduced energy bills [32].

Hence, community-owned wind and solar power projects represent a transformative force in the landscape of sustainable energy. Beyond the obvious environmental advantages, these initiatives empower communities economically, socially, and culturally [33]. By fostering shared ownership, creating jobs, attracting investments, and inspiring community engagement, these projects emerge as beacons of positive change, demonstrating that a sustainable future is not only possible but also economically viable at the grassroots level [34]. As communities continue to embrace the potential of renewable energy, they not only contribute to a cleaner planet but also carve out a more resilient and empowered future for themselves [35].

2. Materials and Methods

2.1. Theoretical Foundation

The research methodology was structured on the foundation of the theory of change, a concept dating back to the 1930s [36]. This theory elucidates how activities generate a series of outcomes contributing to the realization of intended impacts. Widely applied in interventions, events, policies, strategies, and programs, the theory of change aids in establishing concrete plans by accurately identifying objectives and activities. This facilitates informed decision-making among diverse stakeholders, allowing them to respond effectively to emerging issues. The theory of change, also referred to as a "logical framework" (or "logframe"), is characterized by its process-level analysis, encompassing inputs, outputs, outcomes, and impacts [37].

Employing the theory of change as a methodology for constructing the framework could enhance the future adaptation and implementation of community solar and wind farms in Jordanian rural areas. A systematic analysis of the causal relationships between stakeholder engagement in the planning process and the identification and attainment of long-term goals can reveal potential challenges in achieving those objectives [38]. Moreover, leveraging the theory of change to formulate a causal relationship-based roadmap can simplify intricate issues, thereby instigating change. This is particularly crucial for community solar and wind farm projects, which necessitate collaboration among stakeholders from diverse organizations within complex environments and contexts [39].

Before constructing the research design logframe, as illustrated in Figure 4, it was crucial to identify the fundamental purpose of the framework. This purpose was determined to be the creation of a solution and success roadmap for the deployment of community solar and wind farms in Jordanian rural areas, with the aim of ensuring clear comprehension by various stakeholders [40]. This approach is envisioned to facilitate the future deployment of solar and wind farms by effectively addressing the existing challenges.

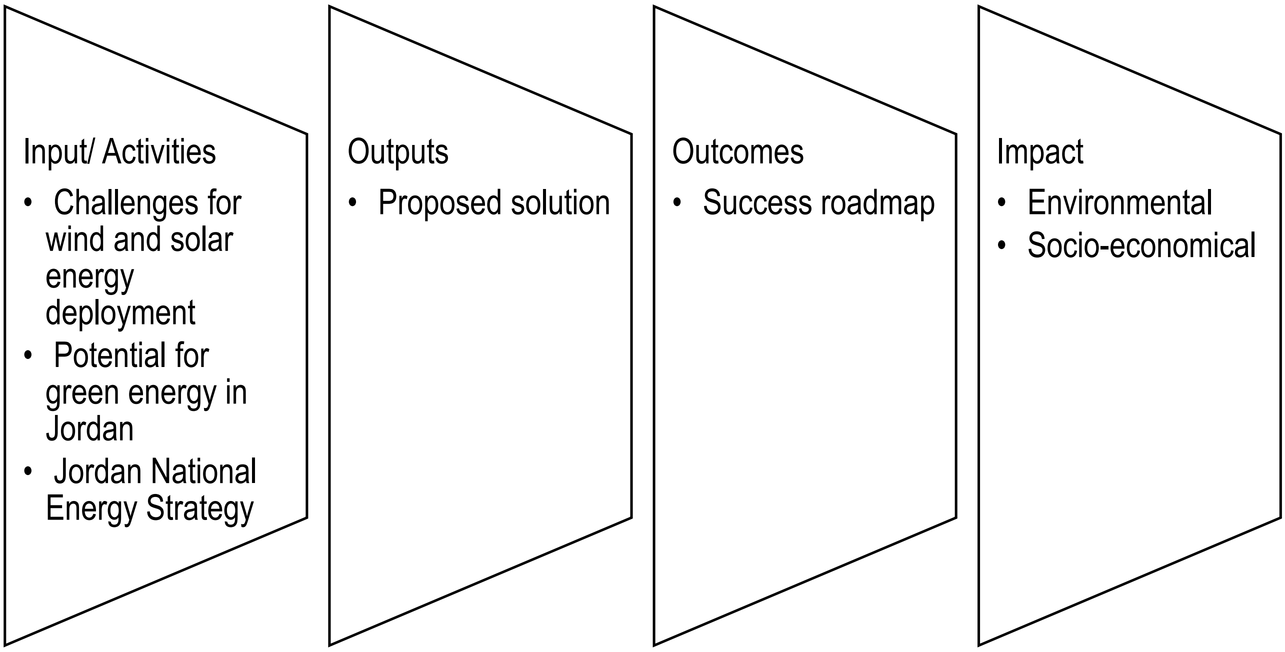

Figure 4. Logframe.

2.2. Stakeholder Evaluation

Effective community and stakeholder engagement plays a crucial role in the success of renewable energy community projects. This engagement should commence early in the project development process and involve the broader community and stakeholders as the project progresses. It goes beyond meeting the consultation requirements of the planning application process: it involves ensuring that all relevant project stakeholders are fully informed and given opportunities to express their opinions. Since not all stakeholders and community members will be directly involved in the projects, it is essential to keep them adequately informed [41]. To achieve this, the two primary stakeholders, rural community homeowners and electrical engineers, were engaged in evaluating the challenges, benefits, proposed solutions, and success plans as part of this research.

A Likert-scale questionnaire was utilized to gather the opinions of these stakeholders on listed challenges for wind and solar energy deployment, community solar and wind farms' potential benefits in addressing challenges for wind and solar energy deployment, community solar and wind farms' additional benefits, and the success roadmap. The items of the questionnaire are detailed in the following section and analysis. This enabled data to be analyzed using IBM SPSS-27 statistical software, including reliability tests to ensure the adequacy of responses, provide descriptive analysis to gain a general understanding of their feedback, and perform comparative tests to compare responses from different participants [42].

2.3. Proposed Solution for Community Solar and Wind Farms

As illustrated in Figure 5, homes in rural communities can be equipped with solar panel systems with complete integration into conventional power grids (as well as functioning as standalone systems). These systems allow for the sharing of generated energy, which can be directed to a centralized storage station. Subsequently, this stored energy can be transmitted through the main grid to power other homes or cater to the energy needs of commercial consumers within urban areas. On the other hand, the generated energy can also be utilized to support local community centers. This includes the provision of electric vehicle charging stations that contribute to the charging infrastructure for electric vehicles within the community, benefiting both local residents and other road users in Jordan [43].

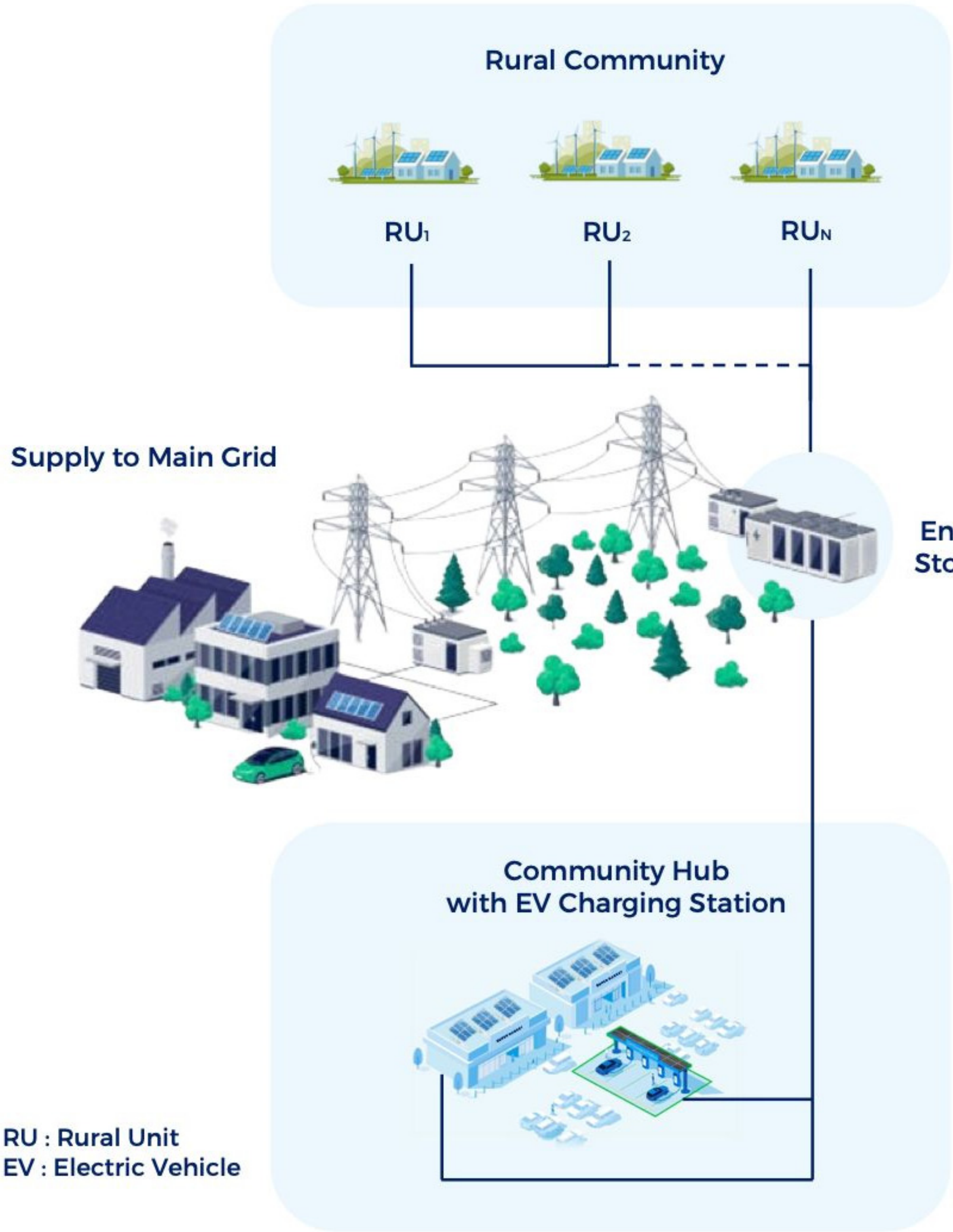

Figure 5. Illustration of the proposed solution for community solar and wind farms.

2.4. Expected Outcomes from Community Solar and Wind Farms

It is expected that the proposed community solar and wind farm solutions will result in direct benefits that can contribute to overcoming the previously listed challenges [44]. In addition, they can bring other environmental and socioeconomic benefits, including addressing the abovementioned challenges to wind and solar energy deployment and other extra benefits, as discussed below.

- Tackling initial investment costs: Community-based initiatives can pool financial resources, making it more feasible for rural households to collectively invest in solar and wind projects. Shared financing can significantly reduce the financial burden on individual community members [45].

- Technology accessibility: Community-led projects can facilitate the adoption of technology by providing training and technical support to residents. Collaborative efforts can ensure that communities have access to the latest and most efficient solar and wind technologies [45].
- Offering storage solutions: Community projects can invest in centralized energy storage solutions, such as community battery systems. This ensures efficient storage and distribution of energy, addressing the intermittency challenge and enhancing the reliability of the local power supply [46].
- Addressing grid connectivity: Community-based projects can create microgrids that operate independently or in conjunction with the main grid. Microgrid systems offer a decentralized approach, providing energy resilience and reducing reliance on extensive grid connectivity [47].
- Maintenance and repairs: Establishing community-owned maintenance teams or outsourcing maintenance to local technicians can address technical challenges efficiently. This not only ensures timely repairs but also creates job opportunities within the community [48].
- Avoiding land-use and space constraints: Community solar and wind projects can be designed to share space with existing land uses, such as agriculture. Innovative land-use planning can optimize the use of available space, making it a win-win for both energy production and local activities [49].
- Improving intermittency and reliability: Community projects can leverage a mix of renewable sources, combining solar and wind energy to mitigate intermittency. Diversifying the energy sources enhances reliability and ensures a more consistent power supply [50].
- Enhancing community engagement: Engaging the community in decision-making processes and project planning builds a sense of ownership and democratization. Community members become advocates for renewable energy, fostering a positive attitude and encouraging widespread adoption [51].
- Fostering policy and regulatory support: Community-led initiatives can work collaboratively with local authorities to advocate for favorable policies and regulatory frameworks. Strong community support can influence policymakers to create an environment conducive to renewable energy development [52].
- Better assurance of site suitability: In community-based projects, the community can actively participate in site selection processes. This ensures that projects are developed with consideration for local ecosystems and minimize environmental impact, turning potential challenges into an opportunity for sustainable development [53].
- Facilitating urban–suburban integration with space-efficient solutions: By addressing space constraints in urban homes, where rooftop availability is limited due to the proliferation of flats and multi-story structures, community solar and wind projects serve as a crucial bridge. By capitalizing on the comparatively larger roof spaces in suburban homes, these projects harmonize urban and suburban areas, ensuring efficient and equitable utilization of available space for sustainable energy generation [54].
- Mitigating rural-to-urban migration: By creating new economic opportunities and empowering local communities, these projects act as catalysts for reducing migration from suburban to urban areas. This not only sustains rural populations but also contributes to overall economic growth [55].
- Contributing to national and global green strategy goals: aligned with national objectives, community solar and wind projects actively contribute to achieving national and global green energy goals, promoting sustainability and environmental stewardship [56].
- Facilitating electric vehicle charging beyond cities: Recognizing the increasing demand for electric vehicle infrastructure beyond city limits, these projects strategically establish charging points, fostering the nation's shift toward sustainable transportation. This initiative not only encourages suburban areas to adopt electric vehicles but also

empowers urban dwellers to extend their electric car usage beyond local commuting, contributing to a broader and more sustainable transportation ecosystem [57].

- Creating a methodology for incentivizing community green transformation and attracting international funding: introducing mechanisms to the Jordanian government that incentivize and reward community-led efforts toward green transformation encourages proactive participation and commitment to environmentally friendly practices, along with practical indicators to attract international funding [58].
- Empowering women in rural communities: The proposed solution can create opportunities for women within rural communities, empowering them economically and socially. Participation in the renewable energy sector enables women to actively contribute to community development, particularly as women in Jordan are highly educated in various subjects, including engineering, but often lack employment opportunities [59].
- Paving the way for green energy exports: Community solar and wind projects position Jordan for future opportunities in green energy exports. By developing a robust renewable energy sector, the country can contribute to the global green energy market [60].
- Raising awareness and competition between communities: Implementing strategies for raising awareness and fostering healthy competition between communities, as well as utilizing promotional campaigns, educational initiatives, and recognition programs, encourage proactive engagement and showcase the positive impact of green initiatives. This approach raises awareness and motivates communities to excel in sustainable practices [61].

2.5. Success Roadmap

The success for community solar and wind projects in rural Jordan depends on having the right success roadmap, which is paramount for community solar and wind projects, serving as the guiding compass toward sustainable energy achievements. Such a roadmap, as shown in Figure 6 and described below, outlines strategic milestones, ensuring efficient project execution and fostering community engagement [62].

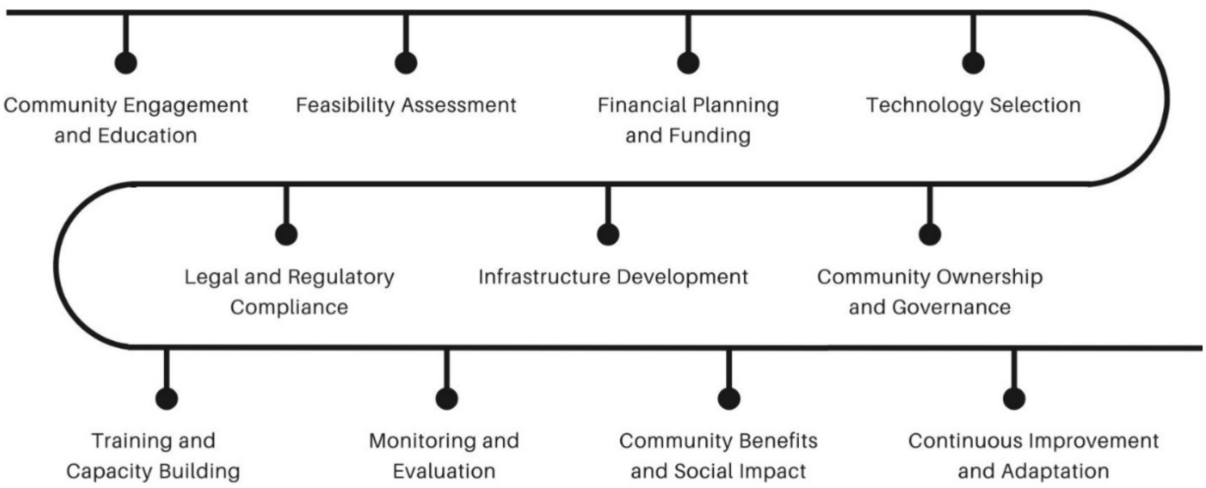

Figure 6. Success roadmap for community solar and wind farms.

- Engagement and education: Engaging the community from the beginning is crucial. Workshops and information sessions help build awareness about the benefits of renewable energy. Establishing community committees ensures ongoing involvement in decision-making processes, fostering a sense of ownership [63].
- Feasibility assessment: Conducting thorough site assessments is essential to understand solar and wind potential. Collaboration with experts helps in evaluating economic feasibility, considering factors such as available resources, energy demand, and potential revenue streams [64].

- Financial planning and funding: Developing a sound financial plan involves exploring various funding sources. This may include government incentives, grants, and community contributions. Creating a detailed financial model helps in understanding the project's economic viability [65].
- Technology selection: Collaborating with experts helps in selecting the most suitable and cost-effective technologies. Considering the latest advancements ensures optimal energy production and efficiency, aligning with the project's long-term sustainability [66].
- Legal and regulatory compliance: Working closely with regulatory authorities is essential for obtaining the necessary approvals and permits. Ensuring compliance with local regulations minimizes legal challenges and facilitates a smoother project implementation process [67].
- Infrastructure development: Coordinating with local contractors for the physical installation of solar panels, wind turbines, and grid connections is a key step. Establishing maintenance protocols ensures the ongoing reliability of the infrastructure [68].
- Community ownership and governance: Establishing a community-based governance structure promotes a sense of ownership and responsibility. Encouraging community participation in decision-making processes ensures that the project aligns with the community's needs and values [69].
- Training and capacity building: Providing training sessions for community members on maintenance and troubleshooting enhances local capacity. Creating opportunities for skill development and job creation within the community fosters a sustainable and empowered workforce [70].
- Monitoring and evaluation: Implementing monitoring systems to track energy production and system health is crucial. Regular feedback collection from the community helps in assessing satisfaction and identifying areas for improvement, ensuring the project's continuous success [71].
- Community benefits and social impact: Ensuring tangible benefits for the community, such as revenue-sharing or community funds from energy sales, creates a positive impact. Implementing social programs funded by the project contributes to broader community development and well-being [72].
- Continuous improvement and adaptation: Regularly reviewing project performance allows for continuous improvement. Staying informed about emerging technologies ensures that the project remains adaptable to changes, enhancing efficiency and long-term success [73].

By focusing on these elements and providing detailed explanations, the roadmap for community solar and wind projects in rural Jordan becomes a strategic guide for successful planning, implementation, and sustainable energy solutions.

3. Evaluation Analysis

As mentioned earlier, to gain better insight into the challenges and benefits of the proposed solution for community solar and wind farms, as well as the success roadmap, evaluation questionnaires have been conducted with two key stakeholders, electrical engineers and homeowners in rural areas in Jordan, during the first quarter of 2024. Findings from the analysis are discussed in this section.

3.1. Statistical Methods Used

With help of IBM SPSS-27 statistical software [74], statistical methods including mean, standard deviation, frequency, percentage, and degree values were calculated, with scores calculated based on the following:

$$Length\ of\ period = \frac{Upper\ bound - Lower\ bound}{Number\ of\ levels} = \frac{5-1}{3} = 1.33 \quad (1)$$

The period level was accordingly classified as low (1–2.33), medium (2.34–3.67), or high (3.68–). Cronbach's alpha coefficient was used to determine internal consistency, and an independent sample *t*-test to determine the statistical significance of hypothesized relationships (as discussed below).

3.2. Reliability

Cronbach's alpha coefficients, a statistical measure used to assess the internal consistency of the questionnaire, ensured the stability of the study tool, with results shown in Table 1, ranging between 0.84 and 0.91. It is noteworthy that all values surpass the threshold of 0.6, indicating the stability of the study tool and the reliability of the data for analysis [75].

Table 1. Cronbach's alpha coefficients for testing the stability of the study tool.

	Cronbach Alpha Coefficients	# of Paragraphs
Challenges for wind and solar energy deployment	0.87	7
Community solar and wind farms can lead to benefits, addressing early listed challenges for wind and solar energy deployment	0.84	7
Community solar and wind farm benefit	0.91	8
Success roadmap	0.84	11

3.3. Normal Distribution Test

Skewness and Kurtosis coefficients were extracted to test the normal distribution of the study data, where if the Skewness and Kurtosis coefficient values are less than (1), then the data are normally distributed [76]. Table 2 shows that all the values of the Skewness and Kurtosis coefficients are less than 1, which indicates that the data are distributed normally. According to the central limit theorem, if we choose all the possible samples from a particular population and calculate the arithmetic mean for each sample, all the arithmetic means of the samples are distributed close to the normal distribution, even if the distribution of the original population is not close to the normal distribution, provided that the number of observations in each sample exceeds 30 observations [77].

Table 2. Normal distribution of the data based on the Skewness and Kurtosis coefficients.

Variable	Mean	Std. Deviation	Kurtosis	Skewness
Challenges for wind and solar energy deployment	3.6897	0.98044	−0.317	−0.697
Community solar and wind farm benefits can lead to addressing early listed challenges for wind and solar energy deployment	3.6629	1.03708	−0.294	−0.727
Community solar and wind farm benefit	3.6906	1.06857	−0.056	−0.847
Success roadmap	3.7658	1.11971	0.084	−0.993

3.4. Sociodemographic Characteristics

The results appearing in Table 3 show that the percentage of engineers who participated in the study sample amounted to 85.9% (n = 275), while the percentage of residents of rural areas was 14.1% (n = 45).

Table 3. Demographic information.

Variable		N	%
Gender	Engineer	275	85.9
	Rural resident	45	14.1
	Total	320	100

3.5. Answering Research Questions

The research questions adumbrated below were answered using the mean and standard deviation scores for each paragraph (all items were measured using a five-point Likert scale).

3.5.1. What Are the Challenges Related to Wind and Solar Energy Deployment in Jordan's Rural Communities?

Table 4 shows the mean scores of all the paragraphs representing challenges related to wind and solar energy deployment in Jordan's rural communities. The challenges are discussed below.

Table 4. Challenges related to wind and solar energy deployment in Jordan's rural communities.

Challenges	Mean	Std. Deviation	Degree	%
Storage solutions	3.73	1.266	High	74.6
Initial investment costs	3.72	1.197	High	74.4
Policy and regulatory support	3.71	1.232	High	74.1
Technology accessibility	3.70	1.211	High	73.9
Grid connectivity	3.68	1.214	High	73.6
Maintenance and repairs	3.65	1.287	Medium	73.1
Community engagement	3.65	1.281	Medium	72.9
Overall	3.69	0.980	High	73.8

Storage solutions: the intermittent nature of wind and solar resources necessitates reliable and cost-effective energy storage solutions to store excess energy for times when these resources are not available, which become particularly challenging in remote areas where grid connectivity is limited.

Initial investment costs: the substantial upfront costs associated with acquiring and installing solar panels or wind turbines can be a significant obstacle for rural communities, as they often have limited financial resources to allocate to such projects.

Policy and regulatory support: The absence of clear policies and supportive regulatory frameworks can discourage investment in and hinder the integration of solar and wind technologies. A conducive regulatory environment is crucial for fostering renewable energy development.

Technology accessibility: Limited access to the latest and most efficient solar and wind technologies may impede the effectiveness of renewable energy systems in rural areas. Accessibility to cutting-edge technologies is crucial for optimizing energy production and efficiency.

Grid connectivity: Establishing grid connections in remote rural locations is often challenging due to logistical complexities and high costs. "Lack of grid connectivity can hinder the integration of renewable energy into the existing power infrastructure" had a high mean score (ranging between 3.68 and 3.73).

Maintenance and repairs: Limited technical expertise and resources for the ongoing maintenance and repair of solar panels and wind turbines may lead to system inefficiencies and downtime, impacting the overall reliability of renewable energy systems.

Community engagement: Limited awareness and understanding of the benefits of wind and solar energy within rural communities may result in skepticism or resistance. "Effective community engagement is essential for building support and encouraging widespread adoption" obtained a medium mean score (3.65).

The overall average was high (3.69), which means that the degree of challenges related to wind and solar energy deployment in Jordan's rural communities are formidable.

3.5.2. What Community Solar and Wind Farm Benefits Can Address the Identified Challenges for Wind and Solar Energy Deployment?

Table 5 shows the mean scores of all the paragraphs that represent community solar and wind farm benefits addressing the identified challenges.

Table 5. Community solar and wind farm benefits can address the identified challenges for wind and solar energy deployment.

	Mean	Std. Deviation	Degree	%
Maintenance and repairs	3.76	1.258	High	75.1
Offering storage solutions	3.72	1.225	High	74.4
Enhance community engagement	3.71	1.286	High	74.3
Fostering policy and regulatory support	3.66	1.301	Medium	73.3
Addressing grid connectivity	3.63	1.267	Medium	72.7
Tacking initial investment costs	3.61	1.167	Medium	72.2
Technology accessibility	3.55	1.256	Medium	70.9
Overall	3.66	1.037	Medium	73.3

Maintenance and repairs: Establishing community-owned maintenance teams or outsourcing maintenance to local technicians can address technical challenges efficiently. This not only ensures timely repairs but also creates job opportunities within the community.

Offering storage solutions: Community projects can invest in centralized energy storage solutions, such as community battery systems. This ensures the efficient storage and distribution of energy, addressing the intermittency challenge and enhancing the reliability of the local power supply.

Enhance community engagement: Engaging the community in decision-making processes and project planning builds a sense of ownership. "Community members become advocates for renewable energy, fostering a positive attitude and encouraging widespread adoption" had a high mean score (ranging between 3.68 and 3.76).

Fostering policy and regulatory support: Community-led initiatives can work collaboratively with local authorities to advocate for favorable policies and regulatory frameworks. Strong community support can influence policymakers to create an environment conducive to renewable energy development.

Addressing grid connectivity: Community-based projects can create microgrids that operate independently or in conjunction with the main grid. Microgrid systems offer a decentralized approach, providing energy resilience and reducing reliance on extensive grid connectivity.

Tacking initial investment costs: Community-based initiatives can pool financial resources, making it more feasible for rural households to collectively invest in solar and wind projects. Shared financing can significantly reduce the financial burden on individual community members.

Technology accessibility opportunity: Community-led projects can facilitate the adoption of technology by providing training and technical support to residents. "Collaborative efforts can ensure that communities have access to the latest and most efficient solar and wind technologies" had a medium mean score (ranging between 3.55 and 3.66).

The overall average was high (3.66), indicating that perceptions that community solar and wind farm benefits can address the identified challenges for wind and solar energy deployment are demonstrated to a medium degree.

3.5.3. What Extra Benefits Can Community Solar and Wind Farms Lead To?

Table 6 shows the mean scores of all the paragraphs concerning the perceived benefits community solar and wind farms can lead to, and participants responded as described below.

Table 6. The extra benefits that community solar and wind farms can lead to.

	Mean	Std. Deviation	Degree	%
Approach for raising awareness and competition between communities	3.75	1.212	High	74.9
Facilitate electric vehicle charging beyond cities	3.74	1.258	High	74.9
Pave the way for green energy exports.	3.74	1.295	High	74.9
Contribute to national green strategy goals	3.71	1.259	High	74.3
Create a methodology for incentivizing community green transformation and attracting international funding	3.68	1.285	High	73.7
Mitigate rural-to-urban migration	3.64	1.308	Medium	72.8
Approach for empowering women in rural communities	3.63	1.306	Medium	72.6
Facilitate urban–suburban integration with space-efficient solutions	3.62	1.271	Medium	72.4
Overall	3.69	1.069	High	73.8

Competition between communities: implementing strategies for raising awareness and fostering healthy competition between communities, as well as utilizing promotional campaigns, educational initiatives, and recognition programs to encourage proactive engagement and showcase the positive impact of green initiatives, can raise awareness and motivate communities to excel in sustainable practices.

Facilitate electric vehicle charging beyond cities: By recognizing the increasing demand for electric vehicle infrastructure beyond city limits, these projects strategically establish charging points, fostering the nation's shift toward sustainable transportation. This initiative not only encourages suburban areas to adopt electric vehicles but also empowers urban dwellers to extend their electric car usage beyond local commuting, contributing to a broader and more sustainable transportation ecosystem.

Pave the way for green energy exports: community solar and wind projects position Jordan for future opportunities in green energy exports. By developing a robust renewable energy sector, the country can contribute to the global green energy market.

Contribute to national green strategy goals: aligned with national objectives, community solar and wind projects actively contribute to achieving the country's green energy goals, promoting sustainability and environmental stewardship.

Create a methodology for incentivizing community green transformation and attracting international funding: Introduce mechanisms to the Jordanian government that incentivize and reward community-led efforts toward green transformation. "This encourages proactive participation and commitment to environmentally friendly practices, along with practical indicators to attract international funding" had a high mean score (ranging between 3.68 and 3.75).

Mitigate rural-to-urban migration: By creating new economic opportunities and empowering local communities, these projects act as catalysts for reducing migration from suburban to urban areas. This not only sustains rural populations but also contributes to overall economic growth.

Approach for empowering women in rural communities: Creating opportunities for women within rural communities empowers them economically and socially. Participation in the renewable energy sector enables women to actively contribute to community development, particularly as women in Jordan are highly educated in various subjects, including engineering, with a lack of employment opportunities.

Facilitate urban–suburban integration with space-efficient solutions: By addressing space constraints in urban homes, where rooftop availability is limited due to the proliferation of flats and multi-story structures, community solar and wind projects serve as a crucial bridge. "By capitalizing on the comparatively larger roof spaces in suburban homes, these projects harmonize urban and suburban areas, ensuring efficient and equitable utilization of available space for sustainable energy generation" had a medium mean score (ranging between 3.62 and 3.64).

The overall average was high (3.69) concerning the perceived degree of the extra benefits that community solar and wind farms can lead to.

3.5.4. What Elements Included in the Community Solar and Wind Farm Projects in Jordanian Rural Areas Depend on Having the Right Roadmap?

Table 7 shows the mean scores of all the paragraphs representing elements included in the community solar and wind farm projects in Jordanian rural areas depending on having the right roadmap. All elements have a high mean score (ranging between 3.72–3.87), except the paragraph "Community ownership and governance: Establishing a community-based governance structure promotes a sense of ownership and responsibility. Encouraging community participation in decision-making processes ensures that the project aligns with the community's needs and values", which has a medium mean score (3.66).

Table 7. What elements included in the community solar and wind farm projects in Jordanian rural areas depend on having the right roadmap.

	Mean	Std. Deviation	Degree	%
Technology selection	3.87	1.269	High	77.4
Training and capacity building	3.81	1.302	High	76.3
Feasibility assessment.	3.80	1.267	High	75.9
Infrastructure development	3.79	1.271	High	75.8
Continuous improvement and adaptation	3.79	1.313	High	75.8
Monitoring and evaluation	3.77	1.276	High	75.3
Financial planning and funding	3.76	1.315	High	75.3
Legal and regulatory compliance	3.75	1.340	High	74.9
Community engagement and education	3.72	1.265	High	74.4
Community benefits and social impact	3.72	1.288	High	74.3
Community ownership and governance	3.66	1.303	Medium	73.3
Overall	3.77	1.120	High	75.3

The overall average was high on average (3.77), indicating that the elements included in community solar and wind farm projects in Jordanian rural areas depend to a large degree on having the right roadmap.

3.6. Hypothesis Test Results

The four hypotheses adumbrated below were tested using an independent sample *T*-test.

H01: *Member Type Does Not Significantly Affect Perspective about Challenges Related to Wind and Solar Energy Deployment in Jordan's Rural Areas at ($\alpha \leq 0.05$).*

From Table 8, we note that the (T) value was not statistically significant at ($\alpha \leq 0.05$), so we conclude that there is no difference due to the participant type (engineer or rural resident) with regard to their point of view about challenges related to wind and solar energy deployment in Jordan's rural communities at ($\alpha \leq 0.05$).

Table 8. Independent sample *T*-test to test the first hypothesis.

Participant Type	N	Mean	Std. Deviation	T	Df	Sig. (2-Tailed)
Engineer	275	3.69	0.969	−0.158	318	0.875
Rural resident	45	3.71	1.057			

H02: *Member Type Does Not Significantly Affect Perspective about Challenges Related to Wind and Solar Energy Benefits That Can Lead to Addressing Early Listed Challenges for Wind and Solar Energy Deployment at ($\alpha \leq 0.05$).*

From the results shown in Table 9, we note that the (T) value not statistically significant at ($\alpha \leq 0.05$), so we conclude that member type does not significantly affect perspective about challenges related to wind and solar energy benefits that can lead to addressing the identified challenges to wind and solar energy deployment at ($\alpha \leq 0.05$).

Table 9. Independent sample *T*-test to test the second hypothesis.

Participant Type	N	Mean	Std. Deviation	T	Df	Sig. (2-Tailed)
Engineer	275	3.67	1.018	0.217	318	0.828
Rural resident	45	3.63	1.158			

H03: *Member Type Does Not Significantly Affect Perspective about Challenges Related to Wind and Solar Energy Extra Benefits at ($\alpha \leq 0.05$).*

From the results shown in Table 10, we note that the (T) value was not statistically significant at ($\alpha \leq 0.05$), so we conclude that member type does not significantly affect perspective about challenges related to wind and solar energy extra benefits ($\alpha \leq 0.05$).

Table 10. Independent sample *T*-test to test the third hypothesis.

Participant Type	N	Mean	Std. Deviation	T	Df	Sig. (2-Tailed)
Engineer	275	3.70	1.065	0.200	318	0.842
Rural resident	45	3.66	1.104			

H04: *Participant Type Does Not Significantly Affect Perspective about Elements of Community Solar and Wind Farm Projects in Jordanian Rural Areas Depending on Having the Right Roadmap at ($\alpha \leq 0.05$).*

From the results shown in Table 11, we note that the (T) value was not statistically significant at ($\alpha \leq 0.05$), so we conclude that there is no difference due to the participant type in terms of their point of view about elements of community solar and wind farm projects in Jordanian rural areas depending on having the right roadmap ($\alpha \leq 0.05$).

Table 11. Independent sample *T*-test to test the fourth hypothesis.

Participant Type	N	Mean	Std. Deviation	T	Df	Sig. (2-Tailed)
Engineer	275	3.78	1.118	0.504	318	0.614
Rural resident	45	3.69	1.142			

The cost of solar farms, wind farms, and hybrid systems (wind and solar) would depend on various factors: space availability, selection of optimum sites, local technological availability, environment factors, local expertise, social acceptance, and governing regulations and policies. In view of these factors, the capital cost of each case and type of energy source would be assessed based on the expected benefit/cost ratio, the convenience of grid connection, the possible installation capacity of the appropriate type of energy farm, and so on.

4. Conclusions

This study aimed to investigate the distinct dynamics, challenges, obstacles, and potential solutions related to establishing community solar and wind farms in suburban areas of Jordan. This study revealed that Jordan holds untapped potential for clean energy generation from wind and solar sources, which has yet to be fully exploited. However, a number of challenges have been reported hindering its realization. Therefore, the concept of establishing community solar and wind farms emerges as a key solution to address these challenges while also offering several benefits to local communities. This includes resolving issues such as the scarcity of electric vehicle charging stations.

The evaluation results from engaging key stakeholders were obtained through a questionnaire, and after comprehensive analysis, it became clear that the benefits and positive aspects of solar and wind farms outweigh their drawbacks and obstacles. Consequently, this study strongly advocates for the implementation, expansion, and advancement of solar and wind energy technologies and associated community projects in suburban areas to promote a sustainable future in Jordan.

While the results of this investigation are specific to suburban areas of Jordan, they can generally apply to surrounding countries as well, as the strengths, weaknesses, and opportunities identified are commonly shared attributes. It is anticipated that these findings can assist policymakers in making informed decisions, enabling them to formulate robust policies and guidelines aimed at efficiently fostering development and ensuring sustainability through improved planning for clean energy provision. It is also strongly believed that the findings may serve as a valuable benchmark for other regions facing similar challenges in their pursuit of a sustainable energy future.

The cost of solar farms, wind farms, and hybrid systems (wind and solar) depends on various factors: space availability, the selection of optimum sites, local technological availability, environmental factors, local expertise, social acceptance, and governing regulations and policies. Considering these factors, the capital cost of each case and type of energy source should be assessed based on the expected benefit/cost ratio, the convenience of grid connection, the potential installation capacity of the appropriate type of energy farm, and so forth. Moreover, this can be achieved through government initiatives to support the startup of pilot community solar and wind farms in Jordan's suburban areas, fostering renewable energy adoption, as well as demonstrating real challenges and benefits, before full deployment across Jordan.

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