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A STUDY ON MAKING SOLAR-POWERED IRRIGATION SYSTEM ECONOMICALLY VIABLE AND SOCIALLY ACCEPTABLE IN BANGLADESH

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Abstract:
Solar power is at the forefront of sustainable development discussions due to the global movement toward renewable energy. In Bangladesh, where agriculture is vital to the economy, sustainable irrigation is crucial. This thesis investigates the economic viability and socio-economic acceptability of solar-powered irrigation systems (SPIS) in Bogra, Bangladesh. Several approaches have been proposed to make solar power irrigation in Bangladesh more profitable. High-value crops like summer tomatoes and hybrid vegetables highlight the economic benefits and increased profitability of solar-powered irrigation systems. Furthermore, it is imperative to decrease the expenses associated with these systems. Partnering with government agencies to make vital equipment affordable and accessible can achieve this goal. Researching new methods and localized production can also lower solar panel prices. A collaborative technique between marginal and large-scale farmers can help small-scale farmers afford solar power irrigation by distributing costs fairly. Government backing, expanded R&D, localized manufacture, training, and subsidies can also help solar-powered irrigation become economically sustainable. To improve socio-economic acceptability, solar power irrigation benefits must be promoted and communicated. Training, informed advertising, and successful case studies help build faith in the technology and motivate farmers to employ it. Community involvement and practical examples in Bogra can boost social approval as farmers see the benefits of solar-powered irrigation. Sharecroppers, a large part of Bangladesh's agricultural community, need subsidies or reasonable financing. This paper examines the economic viability and socio-economic acceptability of solar-powered irrigation systems in Bangladesh, specifically in Bogra. The goal is to sustainably enhance agriculture in the region by examining many options and strategic methods. This field addresses the critical need for environmentally friendly and sustainable irrigation solutions.

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Keywords: solar power irrigation system (Bogra district), economic viability analysis & socio-economic acceptability analysis.

1. Introduction

Solar power has become a significant topic in discussions about sustainable development, as the world increasingly shifts towards renewable energy sources (Hossain, 2019). In countries like Bangladesh, where agriculture is the backbone of the economy, it is crucial to implement sustainable irrigation systems. Currently, the nation faces power shortages and escalating environmental issues, making it necessary to explore alternatives to traditional energy sources. One potential alternative is solar-powered irrigation systems (SPIS), although concerns remain about their economic feasibility and social acceptance. This thesis focuses on addressing these concerns.

Implementing SPIS offers a potentially effective solution to the challenges faced by Bangladesh. These systems utilize solar energy to extract water from various sources, such as rivers, ponds, and groundwater, primarily for irrigation purposes. According to IRENA (2016), SPIS not only reduces reliance on fossil fuels but also eliminates harmful emissions associated with their use.

In Bangladesh, the agriculture sector heavily relies on irrigation, with irrigation accounting for 4.58% of the country's overall electricity production (Bangladesh Power Development Board, 2021). Given the existing power limitations, relying on conventional energy sources for irrigation is unsustainable. Moreover, the combustion of fossil fuels for electricity generation contributes to air pollution and climate change, exacerbating environmental challenges in Bangladesh (Hossain, 2019). SPIS can address these challenges by providing a sustainable and environmentally friendly energy solution for irrigation.

However, the high initial costs of implementing SPIS and the lack of sufficient financial assistance have hindered widespread adoption in Bangladesh (Kabir *et al.*, 2018). This thesis aims to explore strategies to enhance the economic feasibility of solar-powered irrigation systems in Bangladesh. This includes identifying potential sources of financing, evaluating the cost-effectiveness of different SPIS technologies, and formulating policy recommendations to improve their economic viability.

In addition to economic feasibility, the social and economic acceptance of SPIS is crucial. Solar-powered irrigation has the potential to transform traditional farming practices in Bangladesh. However, it is essential to approach its adoption with caution and ensure widespread societal approval. This requires understanding the opinions and attitudes of farmers, local communities, and other stakeholders towards SPIS. It is also necessary to explore approaches that promote the acceptance of SPIS, such as community involvement, educational campaigns, and capacity-building activities. Therefore, the secondary aim of this thesis is to investigate strategies for enhancing the socio-economic viability of solar-powered irrigation in Bangladesh.

To summarize, adopting sustainable irrigation practices in Bangladesh is imperative. The potential solution offered by SPIS requires a thorough examination of its economic viability and socio-economic acceptance. This thesis aims to contribute to the research field by fostering a more sustainable and resilient agriculture sector in Bangladesh.

1.2 Rational of the Study

Farmers who are using solar-powered pumps for irrigation purposes need or use solar pumps for irrigation a maximum of 3 to 4 months. But there is no use of it for the rest of the month. That's why we should find other possible options to make solar power irrigation economically viable & socioeconomically acceptable.

We know that Nationally Determinant Contribution (NDC) targets of Bangladesh promised to generate 10% power from renewable energy, but we could not meet the target. Besides, the Bangladesh government promised renewable energy issues in the perspective plan, sustainable development goal, eight five-year plan, 100 delta plan, and Mujib perspective plan.

So, to make it happen, we need to ensure full use of solar power wherever we install it. In that regard, efficient use of solar power irrigation comes first.

1.3 Goal of the Study

The goal of this study is to develop a comprehensive understanding of the factors influencing the economic viability and socio-economic acceptance of solar-powered irrigation systems in Bangladesh. The study aims to identify feasible financial mechanisms, assess the cost-effectiveness of various solar technologies for irrigation, and propose policy measures to enhance their economic feasibility.

1.4 Specific Objectives of the Study

1) To find options to make solar power irrigation economically viable in Bangladesh.
2) To find a way to make solar power irrigation socially acceptable.

1.5 Scope of the Study

This study will examine various critical areas of solar-powered irrigation system installation and acceptance in Bangladesh.

- **Geographical Focus:** Bangladesh, a large agricultural economy, might benefit from sustainable irrigation systems. Bangladeshi agricultural regions may be chosen for thorough case studies.
- **Technological Evaluation:** The study will evaluate Bangladeshi irrigation-suitable solar technologies. This entails testing solar panels, pumps, and other equipment for efficiency and suitability in local conditions.
- **Economic Analysis:** Solar-powered irrigation systems' economic viability will be a major focus of this study. This comprises original investment, operation and

maintenance costs, savings, and ROI. We'll also look into subsidies, grants, and loans to help implement these systems.

- **Socioeconomic Acceptability:** The study will examine local people, farmers, and other stakeholders' social and cultural acceptability of solar-powered irrigation systems. This includes assessing their thoughts, ideas, and attitudes toward these systems, their desire to switch to solar-powered irrigation, and the potential societal benefits or problems.
- **Policy Analysis:** The study will examine Bangladeshi renewable energy, irrigation, and agriculture policies and recommend solar-powered irrigation system adoption strategies

1.6 Limitations of the Study

The present study seeks to offer a full comprehension of solar-powered irrigation systems in Bangladesh; nonetheless, it is important to acknowledge that certain limitations will necessarily influence the extent of its investigation. The primary methodology employed in this study was a qualitative survey. Limitations in the study may arise due to various factors, including temporal constraints, resource limitations, and data availability, which could potentially restrict the extent or scope of some aspects of the research. For instance, the research conducted may exhibit limitations in terms of its coverage of various regions within Bangladesh, as well as its inclusion of all relevant stakeholder groups. Likewise, the comprehensive examination of specific policy initiatives' feasibility may be hindered by the intricate nature of the policy landscape and the methodological constraints inherent in the study.

1.7 Orientation of the Field Work

Introduction: *Chapter One* provides the background, aims and objectives, limitations and scopes, and also the rationale of the present study. A logical rationale for the necessity of conducting the present study along with its possible benefits has also been chalked out in this chapter as a backdrop of the study.

Literature Review: *Chapter Two* provides a brief description of the review of relevant literature, including policies, documents, articles, reports, and books, on related topics on solar-powered irrigation which are thought to be relevant to the current research works.

Methodology: *Chapter Three* briefly describes the study area and details the research methodology, sample, and data collection methods employed in this study. Finally, data analysis and presentation are planned. The chapter also describes the study's methodology. The sample, sampling strategy, data collection, fieldwork procedure, and questionnaire design are detailed.

Data Analysis: In C*hapter Four*, after the collection of relevant information from the respondents, data were analyzed mostly by using descriptive analysis. The conversations were transcribed, and the data was meticulously organized into Microsoft Excel for further analysis.

Conclusion: Finally, the last chapter (*Chapter Five*), includes the conclusion of the study findings and also presents some possible recommendations, which were put forward before the policymakers to satisfy the research objectives.

2. Literature Review

The literature review is a crucial component of any research endeavors, as it serves to establish a strong foundation for designing a study. Additionally, it allows researchers to identify recurring patterns and observations found in existing literature pertaining to the topic at hand, while also highlighting areas that require further investigation or offer potential for future research.

2.1 Section I: Importance of making economically viable solar-powered irrigation system:

- **Understanding the Current State of Knowledge:** A literature study offers a thorough and inclusive examination of the existing body of knowledge pertaining to a specific subject matter. Gaining an understanding of previous studies, their conclusions, and the procedures employed therein might be beneficial. The aforementioned information plays a vital role in the identification of deficiencies within the current body of knowledge, as well as in guiding the development and implementation of novel research initiatives.
- **Identifying Gaps and Opportunities:** Through a literature review, one can identify areas that have not been sufficiently addressed in previous studies. For our focused work, solar-powered irrigation's economic effects on farmers, its capacity to lessen GHG emissions, and its place within the broader framework of Bangladesh's energy strategy and climate obligations are all possible topics for such an investigation (Gupta *et al.*, 2017).
- **Informing Policy and Practice:** The inclusion of a literature review in research can additionally contribute to informing policy and practice by the provision of insights that are grounded in evidence. For example, it has the capacity to provide insights into the most economically efficient approaches for promoting solar-powered irrigation, the possible advantages and disadvantages of various financing structures, or the manners in which solar-powered irrigation might contribute to the attainment of sustainable development objectives.
- **Basis for Further Research:** The literature review serves the purpose of identifying gaps in existing research, so assisting researchers, policymakers, and practitioners in determining the areas that require more investigation and allocating their resources accordingly.
- **Understanding the Local Context:** In a country-specific study like this one, a literature review can help figure out how local factors might affect how well solar-powered irrigation systems work and how they are put in place. These could be, for example, the geography and climate of Bangladesh, the way the agricultural

sector is set up, or the way green energy is regulated in the country (Papaioannou, Sutton, & Booth, 2016).

In essence, doing a comprehensive literature review on the economic viability of solar-powered irrigation in Bangladesh is an essential undertaking that facilitates comprehension of the feasibility, potential advantages, and limitations associated with implementing such systems within the specific local context. This can provide valuable guidance for future research endeavors, policy formulation, and the practical execution of initiatives in this particular domain.

In a country like Bangladesh, where farming is so important to the economy and the people's way of life, irrigation is more vital than ever. Nearly half of all jobs in Bangladesh are in the agricultural industry, so reliable irrigation systems are critical to the country's economic and food security (World Bank, 2016). Irrigation allows farmers to maintain consistent crop output despite the country's heavy reliance on monsoon rains for agriculture and helps mitigate the effects of seasonal variability and climate change (BBS, 2017). More food is needed to feed the country's rising population, Parvin and Rahman (2009) point out that irrigation can help boost agricultural production. As a result, the agricultural expansion and food security of Bangladesh depend critically on the establishment and administration of irrigation systems.

2.2 Section II: Significance of Irrigation and Solar Pumps

Irrigation plays a crucial role in agricultural production by facilitating the acquisition of energy and nutrients necessary for optimal crop growth. Conversely, regions in Sub-Saharan Africa and South Asia that lack access to irrigation have experienced significant challenges in crop production (FAO & GIZ, 2015).

Farmers rely on a range of sources for irrigation. Historically, rainfall has been one of the primary factors contributing to irrigation. However, with the advent of deep tube-wells, farmers have increasingly turned to this method for irrigation. Additionally, motorized tube-wells powered by diesel have also been utilized by farmers for irrigation purposes (Shah *et al.*, 2004; Agarwal & Jain, 2015). Solar-powered pumps have emerged as a significant innovation in the field of irrigation, with potential implications for crop output. Research conducted by Alofe *et al.* (2016) and Burney *et al.* (2014) has revealed that the utilization of solar-powered pumps can positively impact crop diversity and promote food security.

The utilization of solar module pumps appears to have witnessed a rise, potentially attributed to the government's implementation of greater subsidies for their adoption. These pumps are favored due to their environmentally benign nature and comparatively lower cost in comparison to alternative irrigation instruments (Bloomberg, 2016). According to a report by Grant View Research (2016), the solar pump market is currently seeing significant growth and is projected to reach an annual volume of 1.5 million units by the year 2022.

According to Suman (2018), the implementation of solar pumps in agricultural practices has been found to contribute to increased income for farmers. This is attributed

to the changes in crop production patterns, reduction in costs, and lower water wastage. According to a feasibility study conducted by Karim and Shankar (2017), solar pumps have been demonstrated to be more financially advantageous and less prone to danger.

2.3 Section III: Solar-Powered Irrigation System in the Agriculture Sector

Renewable energy, including solar power, can help farmers develop value-added agricultural goods and generate long-term revenue. Agriculture uses solar energy to reduce electricity and heating costs, facilitate crop drying, improve residential and livestock thermal conditions, provide hot water for dairy processes, and power farm activities and remote water pumps. Clean, low-risk, and environmentally friendly energy sources are needed to run agricultural facilities efficiently (Chikaire *et al.*, 2010).

Solar power has become a viable alternative to grid-powered and diesel-powered water pumping equipment in the Indian agricultural industry. Solar water pumping devices reduce diesel fuel use by providing irrigation water to small farmers. Considering the original investment, operational, and maintenance expenses, these systems are cheaper and greener than diesel engine pumping systems. In addition, solar water pump systems can generate power when irrigation is unnecessary (Kanna *et al.*, 2020). This technology is becoming crucial to Bangladesh's sustainable agricultural development. Due to its large and accurate energy supply, it is ideal for agricultural irrigation, especially in desert regions (Islam *et al.*, 2017). Direct solar electricity for irrigation is an efficient and sustainable way to alleviate Bangladesh's rice production issues. Solar panels and submersible pumps irrigated 15 acres without electricity or diesel fuel. The Benefit-Cost Ratio (BCR) and Internal Rate of Return (IRR) suggest that this method is economically viable (Khan *et al.*, 2015). Solar pumps for irrigation in Bangladesh are cheaper and greener than diesel pumps (Akter & Bari, 2022). However, solar pumps have a benefit-cost ratio of 0.277, suggesting that for particular families, their costs may outweigh their benefits over diesel pumps.

When growing traditional crops, Bangladeshi farmers choose fossil fuel-based pumping technology (Thapa *et al.*, 2019). Due to their low starting cost and efficient supply chain networks, such technologies are preferred. Solar pumps are being used as backups to traditional pumps, frequently with grants or subsidies. Diesel-electric pumps are still used, however, solar pumps have reduced their use, providing benefits. According to Hossain & Karim (2020), solar irrigation reduces air pollution and allows farmers to water more areas and use solar-generated electricity for other income. Market-based finance and gender inclusion can make solar irrigation projects economically viable for rural nations like Bangladesh.

Solar irrigation systems use less fertilizer than diesel systems. Inelastic irrigation demand means farmers use the same amount of water regardless of cost (Rana *et al.*, 2021). Sustainable agriculture requires a delicate balance between agricultural output, natural resource utilization, and environmental effects. Renewable energy technologies like solar, wind, biomass, and geothermal power can reduce agricultural fossil fuel use's environmental impact (Chel and Kaushik, 2011).

2.4 Section IV: Nexus between Solar Powered Irrigation System and Energy Savings

Khan, M. N. H., Khan, M. H., & Khan, M. F. H., (2015) propose that the utilization of direct solar-powered irrigation may present a viable alternative for distant regions situated in subtropical and low-latitude nations. This approach has the potential to diminish electricity expenses and facilitate energy conservation. Additionally, it underscores the possibility of mitigating carbon dioxide emissions by employing sustainable energy resources.

The global community has expressed significant concern regarding the management of energy consumption in the agricultural sector, primarily due to the detrimental impacts associated with carbon dioxide emissions stemming from the use of fossil fuels. Renewable energy systems play a crucial role in reducing fossil fuel consumption and mitigating CO2 emissions in the agriculture sector. The use of renewable energy technologies in agriculture is suitable for any location in the world and offers the additional benefit of earning carbon credits compared to conventional fossil fuel-based technologies. Efforts should be made to reduce fossil energy use in agriculture and promote green energies to mitigate climate change and its impact on human life and the environment (Chel and Kaushik, 2011).

According to the research (Guno & Agaton, 2022), we can say that solar irrigation systems have significant environmental benefits, including a reduction in greenhouse gas emissions and air pollutants, compared to diesel-powered pumps for irrigation. Solar irrigation systems, despite their relatively higher initial investment cost, exhibit reduced maintenance and operational expenses, thereby yielding substantial long-term fuel cost savings for agricultural practitioners. The adoption of solar irrigation systems has the potential to yield substantial energy conservation within the agricultural industry, specifically in the context of rice cultivation. Promoting the adoption of solar photovoltaic (PV) systems as the predominant energy source can effectively alleviate the strain on the grid power supply (Hossain & Rahman, 2021).

As emphasized by Muhammad Joni Iskandar *et al.* (2023), the utilization of solar-powered automatic drip irrigation systems offers several supplementary benefits, including the provision of endless renewable energy, environmental sustainability, and the ability to react to agricultural climate fluctuations. The research additionally examines the significance of optimizing water allocation in irrigation systems to enhance production outputs.

2.5 Section V: Global Scenario of Implementing Solar Power Irrigation System

Solar pumps in agricultural irrigation are affected by many elements. These determinants include household size, irrigation water sources, views of improved productivity, and yield estimates for the year. Solar pumps are less popular in houses with shared irrigation infrastructure (Khan, M. N. H., Khan, M. H., & Khan, M. F. H., 2015).

Khan, Sarkar, & Islam (2013) list many benefits of using locally-made solar water pumping systems. First, these systems are cheaper than imported ones. They also promote energy self-reliance by reducing diesel and grid electricity use. Local specialists

and farmers can install and replace them, and maintenance is much lower. Optimising solar panel efficiency and voltage can boost pump performance. Installation of solar water pumping systems may also generate carbon credits. Solar irrigation systems (SIF) can reduce agricultural energy use and boost food self-sufficiency and economic growth (Sunny *et al.*, 2022). Recent research shows that solar-powered irrigation systems (SPIS) increase wheat production technical efficiency (TE) by 6.657% in Balochistan, Pakistan (Ullah *et al.*, 2023). The analyzed farmers have a 13.7% solar technology adoption rate and a wheat production efficiency (TE) above 80%. Looking ahead, significantly subsidized investments in renewable energy technology adoption are justified. Such activities should speed up the distribution of renewable energy-powered machines, benefiting the targeted beneficiaries (Islam & Hossain, 2022).

Agrawal & Jain (2018) noted that solar irrigation pumps (SIPs) have great potential to increase irrigation in economically challenged nations. SIP sustainability depends on crop water requirements, water source depth, solar irradiation, farm scale, utilization efficiency, alternative costs, system quality, post-sale services, and technical knowledge. These varied aspects determine the sustainability of Structural Insulated Panels (SIPs); hence a thorough examination is needed before implementation.

Despite the benefits, local farming groups are slow to use solar pumps due to budgetary constraints. Current market conditions make it doubtful whether farmers can switch to solar power soon. However, public awareness campaigns and government financial incentives may boost solar pump popularity (Akter & Bari, 2022).

Awareness campaigns can encourage rural populations to embrace solar irrigation systems even without prior understanding. Small-scale solar irrigation systems are ideal for land irrigation because their pressure head is within subsurface water pressure limits. A solar irrigation system with a battery requires a longer ROI than a battery-free system, regardless of field size. In small-scale applications, a solar irrigation system with a battery takes five years to pay for itself (Kamruzzaman & Haque, 2022).

2.6 Section VI: Solar Powered Irrigation Scenario, Especially in the Case of Bangladesh

Solar-powered irrigation is improving in Bangladesh, especially in delivering drinkable water to communities and irrigation (Hossain *et al.*, 2015). Bangladesh's favorable location makes solar radiation a promising energy source (Hossain & Rahman, 2021). The country's cumulative solar power capacity reached 220 MW in 2018, a major step toward the government's 600 MW objective by 2021. This capability covers household systems, rooftop installations, mini-grids, and solar-diesel hybrids.

Abdullah-Al-Mahbub *et al.* (2022) note that Bangladesh is leading worldwide solar energy activities due to diminishing fossil fuel reserves. Solar parks, charging stations, irrigation systems, and water utilities are examples. Sustainable Drip Irrigation Systems (SDrOP) reduce life cycle costs (LCC) and make solar-powered drip irrigation more affordable for small farmers (Khan, Sarkar, & Islam, 2013).

Solar-powered irrigation practices (SIP) in Bangladesh are reliable, sustainable, and cost-effective. SIP ensures water supply reliability, accessibility, and cost, according

to Hossain & Karim (2020). SIP enhances yields in some agricultural sectors and seasons, but they warn that expenses must be reduced to boost future agricultural revenue.

Bangladesh will rely on solar energy for residential systems, irrigation, street lights, and drinking water pumps. This meets the country's power generation program's renewable energy goals (Abdullah-Al-Mahbub *et al.*, 2022). Sunny *et al.* (2022) found that northern farmers' solar irrigation facility use is influenced by agricultural competence, environmental awareness, land fertility, and irrigation apparatus ownership.

However, financial issues slow solar irrigation scheme implementation in Bangladesh. Islam *et al.* (2017) recommend considering local customers, societal hierarchy, discourse, and technological training for successful adoption. Biswas & Hossain (2013) worry about groundwater access owing to climate effect-caused water decline. Given Bangladesh's third-largest rice producer status and significant water demand, they suggest large-scale solar pumps.

2.7 Section VII: Cost Comparison for Economic Viability

The economic benefits of solar irrigation systems in Bangladesh have been thoroughly examined. As shown, solar irrigation is not beneficial for all crops. Onion, carrot, chili, and tomato crops are economically burdened by it (Pathik *et al.*, 2014). Solar-irrigated potato, cotton, soybean, and sunflower crops are more profitable (Pathik *et al.*, 2014).

Solar photovoltaic pumping, a potential energy solution in Bangladesh, is especially advantageous for Boro rice cultivation (Rana *et al.*, 2021). Farmers using sustainable irrigation strategies saw lower irrigation expenses and higher ROI (Rana *et al.*, 2021). The Bangladeshi government should invest in solar-powered irrigation systems for their long-term economic and environmental benefits (Rana *et al.*, 2021). Islam & Hossain (2022) revealed that tiny solar irrigation pumps have the largest investment potential, followed by large pumps. The "fees for ownership model" of solar irrigation pumps outperformed the "fees for service model" (Hossain *et al.*, 2015). Solar pumps are cheaper than diesel pumps over five years (Hossain *et al.*, 2015).

Solar-powered irrigation systems in Bangladesh have higher gross and net margins than diesel-powered systems despite higher startup costs (Rana *et al.*, 2020). Diesel systems emit a lot of CO2, therefore solar systems are better for the environment (Rana *et al.*, 2020). The economic and environmental benefits of solar irrigation systems and the need for financial aid for small farmers (Guno & Agaton, 2022).

2.8 Section VIII: Financial Barriers and Possible Collaborative Solutions

Recent research has focused on solar pumping systems as a sustainable irrigation approach, particularly in rural regions. Khan, Sarkar, and Islam (2013) found that the initial financial barrier to these systems prevents their wider adoption in distant places like Bangladesh. The authors advise that private companies, financial institutions, and governments work together to solve this problem. Together, these entities might adapt solutions to these communities' requirements.

Solar irrigation pumps (SPIPs) are promising. They boost irrigation access and encourage low-carbon agriculture, helping farmers adapt to climate change. The high cost and lack of farmer input prevent the widespread implementation of such technology (Bastakoti, Raut, & Thapa, 2020). To overcome obstacles, promote the technology's benefits and advancements.

Solar irrigation reduces greenhouse gas emissions and benefits farmers, solar pump providers, and governments. Solar irrigation has various obstacles to sustainable development. Data shortages, groundwater depletion, regulatory framework gaps, governance issues, and resource-poor farmer access are examples. Solar irrigation systems must address equal access for smallholder farmers, eco-friendly practises, and adequate planning and monitoring to be sustainable and accessible (Lefore, Closas, & Schmitter, 2021). Though solar-powered systems are expensive, they may become the favored choice for smallholder farmers in the future. By improving financing, technology, and assistance, this can be achieved (Thapa *et al.*, 2019). The research reveals that many rural communities can implement solar irrigation systems with collaboration and strategic planning.

2.9 Section IX: Sustainability of Solar-Powered Irrigation

Solar power is a possible solution for places with inconsistent electricity grid connectivity. This solution secures agricultural energy supply and reduces grid strain (Roblin, 2016). Since Sustainable Intensification of Farming (SIFs) has good effects, the government and stakeholders should prioritize the development of better ways through continual trial and iteration. This includes cheaper watering costs, higher ROI, and lower production costs. Regular monitoring of solar panel efficiency and regulatory support for updating low-efficiency solar panels are needed to sustain the solar energy sector. Field demonstration projects and campaigns are essential for SIF uptake and communication of their benefits and environmental impacts (Sunny *et al.*, 2022).

The environmental benefit of Structural Insulated Panels (SIPs) is comparable to their installation subsidy. Small solar installation projects (SIPs) have the largest net environmental benefit per kWp (Islam & Hossain, 2022). Governments must assess and mitigate groundwater extraction hazards while implementing Sustainable Public Infrastructure Projects (SPIPs). Groundwater quality must be understood as a whole, including geogenic and anthropogenic contaminants (Bastakoti, Raut, & Thapa, 2020).

Specific policies and initiatives that address environmental variables are essential to promote sustainability efficiently in a specific context. Strategies that improve at least one sustainability feature and prevent others from deteriorating are essential (Agrawal & Jain, 2018).

In Bangladesh, where diesel-based irrigation systems are common, solar irrigation pumps (SIPs) are financially viable. After irrigation, SIP operators can sell surplus electricity to the distribution grid with government support. Technologically, an 11kV 3-phase grid connection is suitable, but financial feasibility requires solar installation capacities beyond 20kWp (Alam, 2022). Bangladeshi solar irrigation systems at 70%-80%

of their potential are cost-effective compared to other approaches (Hoque *et al.*, 2016). However, Bangladesh needs government laws and funding to promote and expand solar irrigation systems.

2.10 Research Gaps Identified from the Literature Review

After reviewing the above writing, the three main limitations of diverse literatures are:

- **Lack of Detailed Technical Analysis:** Many studies do not analyze the technology's technical elements. This contains real-world performance and efficiency of solar water pumping systems, the technological problems of scaling them up, and their design and components. Without this information, these systems' potential and limitations are hard to assess.
- **Insufficient Consideration of Economic Factors:** The economic ramifications of the technology discussed are not fully analyzed in several studies. The technologies' cost-effectiveness compared to alternatives, long-term maintenance and operational costs, and financial feasibility are considered. The technology's viability and adoption potential depend on these economic factors.
- **Insufficient Exploration of Environmental and Sociocultural Consequences:** The studies generally ignore the technologies' environmental and sustainability consequences. The impact of social or cultural variables on technology adoption is often overlooked. These components are essential for understanding these technologies' wider ramifications and their potential for success in varied situations.

2.11 Concluding Remarks

Solar-powered agricultural irrigation in Bangladesh is reviewed. Solar irrigation boosts food security, efficiency, and sustainability. Solar irrigation reduces dependence on unpredictable energy sources and is renewable and cost-effective. Innovative irrigation methods like solar pumps diversify and secure agriculture. Solar pumps' low operational and maintenance costs make them commercially viable despite their high initial investment. Their use changes agricultural production patterns, lowers costs, and reduces water waste, increasing farmers' income. Many hurdles prevent widespread solar-powered irrigation. In poor countries, the initial financial barrier is high. Private firms, financial institutions, and governments must collaborate to meet these communities' needs. Crop water requirements, water source depth, sun irradiation, and farm-scale affect solar irrigation system sustainability and accessibility. Government financial incentives and awareness efforts may assist rural populations adopt solar irrigation systems. Potable water and irrigation from solar-powered irrigation are improving in Bangladesh. Lack of farmer input and funds limit technology deployment. Despite these challenges, solar irrigation systems offer larger gross and net margins than diesel systems.

Finally, solar-powered irrigation can encourage sustainable agriculture in energy-scarce and climate-change-affected areas. However, stakeholders must collaborate to

overcome adoption barriers and maximize advantages. Sustainable food security, economic growth, and environmental impact could be improved via solar-powered irrigation.

3. Methodology

The usefulness of research methodology is its systematic and structured framework for studying methodologies, tactics, and approaches. The role of a research framework is to guide the research process, improve the credibility and consistency of findings, align with the study's goals, facilitate replication and comparison, direct data collection and analysis, and ensure ethical research.

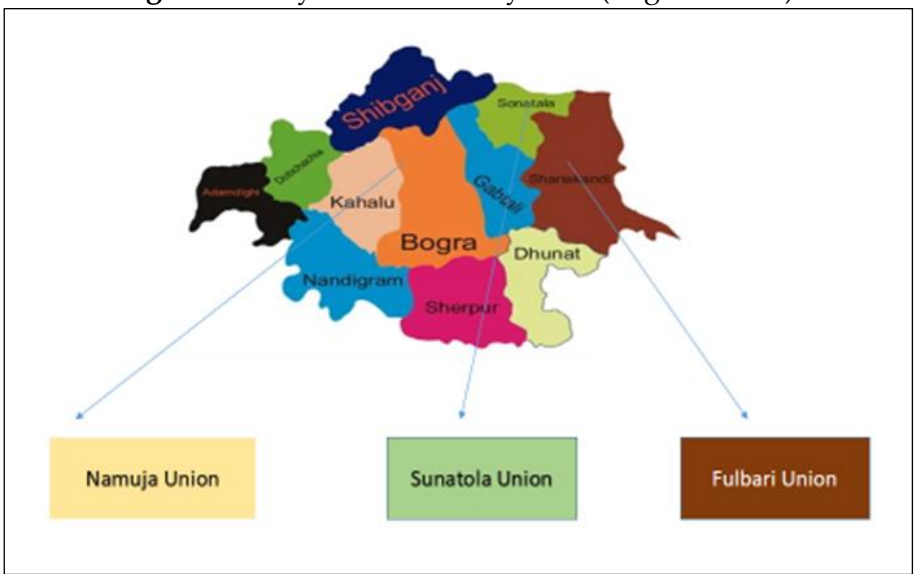
Key Informant Interviews were used. Pengxia, Li. (2022) states that key informant interviews (KIIs) are valuable data collection methods in qualitative social science research. Solar-powered irrigation difficulties were fully understood through in-depth talks and views from farmers, legislators, and relevant organization representatives using the KII survey methodology.

3.1 Study Area

The present study investigates solar-powered irrigation in Bogra, Bangladesh, to address the need for alternative and environmentally sustainable irrigation methods. This study examines the economic viability and socio-economic acceptability of solar-powered irrigation systems to identify potential opportunities and challenges.

Bogra, one of the northern districts of Bangladesh, is known for its agricultural productivity. The region has fertile land, good weather, and relies on agriculture for food. Solar-panel-based water pumps are popular with farmers in seven unions (Balua, Digdair, Zorgachha, Madhupur, Pakulla, Sonatala Sadar, and Tekani Chukainagar) of Sonatola *Upazila* in Bogura because they deliver cost-effective irrigation water. Over the past seven to eight years, the World Bank and the Infrastructure Development Company Limited (IDCOL), under the Ministry of Finance of Bangladesh, have supported solar-panel water pump implementation. These water pumps are built throughout the *Upazila* (Solar Water Pumps Get Popular in Bogura, n.d.).

Figure 3.1: Layout of the Study Area (Bogra district)



Source: Google

The economic viability of solar-powered irrigation systems in Bogra district is examined in this study. This area was chosen for solar pump use and farmer engagement in Sonatola, Namuja, and Fulbari unions. This article supports Bogra district as the study area.

- Bogra district was chosen due to high solar pump consumption in targeted unions. This provides solar irrigation infrastructure and information.
- Active Farmer Participation: Selected union farmers suggest using solar pump technology. These proactive farmers can teach us about solar irrigation system benefits and drawbacks.
- Bogra district's geography is ideal for research due to its ample sunlight and agricultural landscape. Results will guide solar energy integration into global agriculture.

3.2 Research Design

The selection of a research design is of utmost importance as it significantly influences the overall framework and approach employed in a study. A qualitative research design has been utilized to examine the economic feasibility and socio-economic acceptability of solar-powered irrigation systems in Bogra, Bangladesh. This design facilitates a comprehensive examination of the experiences, viewpoints, and expertise of primary stakeholders through the utilization of Key Informant Interviews (KIIs). The interviews, which were conducted on the field and then recorded, offer a valuable dataset that can be transcribed and subjected to analysis to avoid any inconveniences.

3.3 A brief Outline of the KII Survey Used for Data Collection

The KII survey was designed to gather comprehensive insights from various stakeholders, including farmers, engineers, Agriculture officers, energy department personnel, and stakeholders, regarding solar-powered irrigation systems in the Bogra district.

The survey began with a set of generalized questions, followed by specific questions tailored to each group.

I. Generalized Questions

1. General Information

- Collect basic demographic information about the respondents, including their name, age, and organization/institution.

2. Background and Context

- Assess the respondents' familiarity with solar-powered irrigation systems.
- Explore their understanding of the current challenges and barriers to adopting solar-powered irrigation in the Bogra district.
- Seek insights into the economic feasibility and potential benefits of solar-powered irrigation in the region.

3. Cost Analysis

- Discuss the initial costs involved in setting up a solar-powered irrigation system compared to traditional electric or diesel pumps.
- Explore the operational and maintenance costs of solar-powered irrigation systems compared to traditional pumps.
- Inquire about any additional costs or considerations specific to solar-powered irrigation systems.

4. Last Year's Information

- Ask the respondents if they have observed any trends or changes in the adoption of solar-powered irrigation systems in the Bogra district over the past year.
- Inquire about the factors that have influenced the adoption or non-adoption of solar-powered irrigation systems during this period.
- Seek information on any notable success stories or challenges related to the economic viability of solar-powered irrigation systems in the region.

5. Comparison with Electric and Diesel Pumps

- Discuss how the performance and cost-effectiveness of solar-powered irrigation systems compare to traditional electric and diesel pumps.
- Explore any specific advantages or disadvantages of solar-powered irrigation systems compared to electric and diesel pumps in the Bogra district.
- Inquire about the factors that farmers or other stakeholders consider when deciding between solar-powered and traditional pumps.

6. Market Viability

- Assess the current availability and accessibility of solar-powered irrigation systems in the Bogra district.

- Inquire about any government policies or incentives that support the adoption of solar-powered irrigation systems.
- Discuss potential barriers or challenges to the wider market penetration of solar-powered irrigation systems in the region.

7. Socio-economic Factors

- Explore how the adoption of solar-powered irrigation systems impacts the socio-economic conditions of farmers in the Bogra district.
- Inquire about any social or cultural factors that influence the acceptability of solar-powered irrigation systems in this region.
- Seek opinions on measures or strategies that could be implemented to enhance the socio-economic acceptability of solar-powered irrigation systems.

II. Specific Questions for Different Stakeholder Groups

- Tailor the questions based on the specific roles or areas of expertise of the respondents.
- For farmers, inquire about their current source of irrigation, awareness, and understanding of solar-powered irrigation systems, considerations for adoption or non-adoption, affordability assessment, challenges or barriers, support or incentives, government schemes, success stories, performance expectations, and socio-economic impact.
- Adapt the questions accordingly for Engineers, Agriculture department officers, Energy department personnel, and Stakeholders, focusing on their specific roles, perspectives, and experiences related to solar-powered irrigation systems.

The KII survey aimed to gather in-depth qualitative insights from the key informants to understand the current status, challenges, and potential solutions regarding solar-powered irrigation systems in the Bogra district. The gathered data will contribute to a comprehensive analysis and findings in the research.

3.4 Sampling Method

The research methodology incorporates purposive sampling as a method of participant selection, which aims to include persons from diverse backgrounds and professions within the agricultural industry. The individuals encompassed within this category consist of agricultural officers, engineers, farmers, researchers, and stakeholders. A number of total ten respondents have been selected to implement the survey.

3.5 Information of Respondents

The research methodology incorporates the selection of participants from various geographical regions to enable the inclusion of a varied array of perspectives and experiences. This approach aims to facilitate a full comprehension of solar-powered irrigation in the context of Bogra.

Table 3.1: Information of Respondents

Name	Designation	Type of respondents
Md. Humayun Kabir	Joint Director, BADC	Agriculture Sector
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector
Md. Rashedul Alam	Assistant Director (Solar), SREDA	Energy Sector
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business
Salek Rahman	CEO, Salek Solar Power	Solar Business
Sujaul Islam	Farmer	Farmer
Md Atikur Rahman Selim	Farmer	Farmer
Md Abul Kalam Azad	Farmer	Farmer

Source: Author's Completion.

3.6 Data Collection, Processing and Analysis

The researchers performed Key Informant Interviews (KIIs), which facilitated an easy and efficient method for collecting data. KII was employed as a means of a valuable avenue for collecting comprehensive and situational data from individuals who possess specialized expertise or experience in the specific field of study. Interviews provide researchers with the opportunity to delve into intricate subjects, comprehend many viewpoints, and acquire valuable insights that may be challenging to achieve using alternative means of data collecting. In addition, the act of recording conversations serves to guarantee reliability and preserve the integrity of the information collected.

3.7 Transcription

After conducting the interviews, the telephone conversations were transcribed. The process of transcription serves the purpose of creating written documentation of the interviews, so enabling a comprehensive examination and evaluation of the collected data. Through the process of transcribing interviews, researchers can carefully analyze the participants' comments, discern patterns that emerge repeatedly, and acquire a more profound comprehension of their viewpoints.

3.8 Data Analysis Technique

The research design employs thematic analysis as the primary method of data analysis. The thematic analysis involves identifying patterns, themes, and categories within the data. By closely examining the transcriptions, meaningful insights can be extracted and develop a comprehensive understanding of the economic viability and socio-economic acceptability of solar-powered irrigation systems in Bogra. The analysis process involves organizing the data, coding it for key themes, and interpreting the findings.

3.9 Ethical Consideration

Ethics are crucial throughout research design. Before the interviews, all participants gave informed consent, understanding the study's goal and their rights. To protect participants' privacy, data was anonymized for analysis and reporting. This secures participant names and personal information while sharing crucial study findings.

The research design uses qualitative methods including KIIs, in-depth interviews, and transcription to examine the economic viability and socio-economic acceptability of solar-powered irrigation systems in Bogra, Bangladesh. This design provides a comprehensive understanding of key stakeholders' perspectives and experiences, and thematic analysis of the transcribed data will inform future strategies and policies to promote and adopt solar-powered irrigation in the region.

Table 3.2: Methodological Framework

Objective	Indicator	Data Source	Stakeholder
To find options to make solar power irrigation economically viable in Bangladesh.	1. The cost-effectiveness 2. Potential financial incentives or support mechanisms for farmers 3. The long-term economic benefits, including energy savings and increased crop yield.	Key Informant Interviews (KIIs)	People engaged with solar system/ solar-powered irrigation
To find a way to make solar power irrigation socially acceptable.	1. The social and cultural factors that may influence the acceptance 2. The perceptions, attitudes, and knowledge of farmers 3. Strategies to promote awareness and encourage the adoption in the local community.	Key Informant Interviews (KIIs)	People engaged with solar system/ solar-powered irrigation

Source: Author's Completion.

3.10 Conclusion

Moreover, the selection of methodology plays a crucial role in determining the strategies employed for data gathering and analysis. Researchers ensure the relevance and efficacy of obtained data in addressing research such as 'Making solar-powered irrigation economically viable in Bangladesh' inquiries by carefully selecting acceptable methods and approaches. It ensures alignment with the study objectives, facilitates replication and comparison of results, guides the process of data collecting and analysis, and upholds ethical standards in research activities.

The economic viability and socio-economic acceptance of solar-powered irrigation systems in Bangladesh are examined in this chapter. The talks were transcribed and properly organized into Microsoft Excel for analysis.

To meet study goals, data analysis addresses three main components.

In Section I, responder acquaintance with Solar-Powered Irrigation System. Each respondent's Solar Powered Irrigation System expertise or experience. The responders may have different levels of comprehension or exposure to this system. The goal and implications of judging respondents' familiarity are unclear without context. Solar pump irrigation risks and benefits. The pros and cons of solar irrigation pumps are examined. It shows that we are weighing the pros and cons of this technology.

Section II: Options to make solar power irrigation economically viable in Bangladesh. To satisfy the section,

- Solar-powered irrigation systems were evaluated for cost-effectiveness, considering initial investment, maintenance costs, and potential savings over time. Solar irrigation systems for Bangladeshi farmers are economically viable, according to the research.
- Explore financial incentives and support systems for solar-powered irrigation uptake. By evaluating the responses, government subsidies and microfinance schemes were identified to help farmers financially.
- Solar-powered irrigation offers long-term economic benefits, such as energy savings and greater agricultural output. These benefits could boost farmers' incomes, food security, and the environment.

Section III, the ways to make solar power irrigation socioeconomically acceptable. To satisfy the section,

- Considering social and cultural aspects that may impact solar-powered irrigation system adoption. By understanding the socio-cultural background, the findings help engage communities and overcome adoption challenges.
- Farmers' perspectives, attitudes, and knowledge about solar-powered irrigation systems were examined. Analysis showed variances in these characteristics, underlining the necessity for tailored educational programs and awareness efforts to ensure accurate information and farmer trust.
- The Research aimed to increase knowledge and acceptance of solar-powered irrigation in certain communities. Find effective tactics like knowledge-sharing platforms and relationships with local stakeholders to create complete implementation plans.

By addressing these three major points, this research provides a comprehensive analysis of the factors influencing the economic viability and socio-economic acceptability of solar-powered irrigation systems in Bangladesh. The findings aim to inform policymakers, researchers, and stakeholders to develop evidence-based strategies that promote the widespread adoption of solar-powered irrigation systems, leading to sustainable agricultural practices and improved livelihoods for farmers.

Section I: Familiarity with the Solar Powered Irrigation System

4.1 Familiarity with the Solar Powered Irrigation System

Individual respondents' familiarity with data can help them understand solar-powered irrigation systems better. Data analysis reveals reoccurring issues, system efficiency, user

happiness, and policy insights. A thorough understanding of the technology promotes advancement and refinements that will enable the widespread use of solar-powered irrigation systems, leading to a sustainable agriculture future.

Table 4.1: Respondents' Familiarity

Name	Designation	Type of Respondents	Familiarity
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	There is a high demand and popularity of solar-powered irrigation systems in Bangladesh. Farmers, particularly those involved in vegetable production and flower gardens, are familiar with and interested in utilizing solar-powered irrigation for crops like summertime tomatoes and hybrid vegetables.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	Solar energy for irrigation is highly appreciated globally, including in Bangladesh. The use of solar energy in agriculture has been implemented through large government-funded projects, focusing on both horizontal and vertical farming. Solar panels are utilized to support irrigation work and reduce reliance on diesel, thereby decreasing the pressure on fossil fuels.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	Solar-powered irrigation systems are in high demand in Bangladesh, particularly for vegetable production and flower gardens. Farmers are familiar with and interested in utilizing solar-powered irrigation for crops like tomatoes and hybrid vegetables. Farmers are familiar with solar irrigation systems and find them useful for crops that require irrigation during the summer, like tomatoes.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	Eng Arif has been working in the field of solar-powered irrigation systems for approximately 5 years and has a good understanding of the technology and its implementation.
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	There are various solar irrigation projects in the area, including programs for solar irrigation, home systems, and sea slides, which are monitored
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	The adoption of solar-powered irrigation systems in Bangladesh has reduced dependence on the grid for irrigation tasks. Solar systems ranging from three kilowatts to fifteen kilowatts are commonly used for irrigation in Bangladesh. Designing efficient solar systems and addressing energy wastage are key concerns for researchers and implementers.

Salek Rahman	CEO, Salek Solar Power	Solar System Equipments Business	Solar-powered irrigation systems are becoming more popular as farmers realize their advantages over fuel-powered pumps. These technologies guarantee crop watering without electricity or gasoline. Demonstrations and farmer experiences help farmers comprehend and use the technology.
Sujaul Islam		Farmer	Solar-powered irrigation systems are becoming increasingly common as farmers recognize the advantages they provide over traditional fuel-powered pumps. These systems ensure a reliable water supply for crops independently of electricity or fuel supplies. Exposure to demonstrations and learning from other farmers' experiences helps increase understanding and adoption of the technology.
MD Atikur Rahman Selim		Farmer	Solar-powered irrigation is advantageous as it allows farmers to access water for their land at any time, without being dependent on the availability of electricity. This ensures timely irrigation, which is crucial for crop growth and prevents damage to crops due to water shortages.
MD Abul Kalam Azad		Farmer	Solar-powered irrigation is seen as beneficial for the country, as it can fulfill the electricity demand and is cost-effective for farmers.

Source: Field Survey.

Bangladesh's agriculture sector is adopting solar-powered irrigation systems. These systems are popular for vegetable and flower bed maintenance. Renewable energy from solar panels powers irrigation and reduces diesel use. Bangladeshi farmers know and like solar-powered tomato and vegetable irrigation systems. Solar-powered irrigation systems provide crops with water regardless of electricity or fuel availability. Farmers can learn and apply technology via demonstrations. Farmers may acquire water without electricity with solar-powered irrigation. This technology can meet power needs and be profitable for farms, benefiting the nation.

4.2 Disadvantage of Irrigation Through Solar Pump

By examining the individual viewpoints on the disadvantages of solar-powered irrigation systems, a diverse range of challenges and limitations can be uncovered. This collection of insights offers a nuanced understanding of the real-world experiences and concerns faced by users. From small-scale farmers to agricultural experts, the disadvantages section presents an array of valuable data that can shape future research and improvements.

Table 4.2: Response on the disadvantage of irrigation through solar pump

Name	Designation	Type of respondents	Disadvantage of irrigation through solar pump
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	One of the challenges mentioned was that solar-powered irrigation systems cannot be implemented on large areas of land at once. Instead, the land needs to be divided into smaller plots ranging from 20-50 satak. Additionally, solar irrigation systems face limitations during nighttime operation and can be more challenging to use during rainy seasons.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	One of the challenges faced in the adoption of solar-powered irrigation systems is the high initial investment. While large-scale farmers can benefit from these systems, marginal farmers may find it difficult to afford the upfront costs. Cooperative efforts between large-scale and marginal farmers are necessary for successful implementation.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	Solar irrigation systems face limitations as they cannot be implemented across large land areas at once due to technical constraints. The land needs to be divided into smaller plots for solar irrigation. They also have limitations during nighttime when there is no sunlight, and during rainy seasons when sunlight may be reduced.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	The main disadvantage of solar-powered irrigation systems is the financial cost. The initial setup cost, including the space required for solar panels and control rooms, can be expensive. Additionally, the respondent mentions the need for tanks and the potential for theft of solar panels, which requires additional security measures
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	No specific disadvantages of solar-powered irrigation were mentioned. It is considered a positive industry with minimal challenges, except for the one-time capital needed for installation.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	Solar-powered irrigation systems in Bangladesh have caused certain issues, particularly with the use of professional and inexperienced workers. Some people that put profit above quality may provide low-quality solar panels or make design

			flaws, causing system inefficiencies and farmer losses.
Salek Rahman	CEO, Salek Solar Power	Solar business	The main challenge cited is the high initial capital costs required for installation, which remains prohibitive for some small-scale farmers despite subsidies. Solar energy generation may also be insufficient during periods of low sunlight.
Sujaul Islam		Farmer	The main challenge cited is the high initial capital costs required for installation, which remains prohibitive for some small-scale farmers despite subsidies. Solar energy generation may also be insufficient during periods of low sunlight.
MD Atikur Rahman Selim		Farmer	It may not have significant drawbacks based on their personal experience.
MD Abul Kalam Azad		Farmer	There is need for extra electricity during the winter when the sun's heat is low, which increases the cost and hassle slightly.

Source: Field Survey.

Respondents highlighted solar pump irrigation's disadvantages. Challenges include the inability to implement solar-powered irrigation systems on vast land areas at once, the necessity to divide the land into smaller plots, nighttime and rainy season constraints, and the high initial expenditure. Technical issues including poor solar energy output under low sunshine and solar panel theft were also raised. Working with competent and unskilled people was another challenge. These findings help researchers understand and overcome solar-powered irrigation system constraints.

4.3 Advantage of Irrigation Through Solar Pump

In order to develop a comprehensive understanding of the advantages of solar-powered irrigation systems, this section focuses on extracting specific aspects from the responses of individual respondents. By analyzing these extracted parts, valuable insights can be gained, allowing for a holistic perspective on the benefits offered by solar-powered irrigation systems.

Table 4.3: Response on Advantage of Irrigation Through Solar Pump

Name	Designation	Type of respondents	Advantage of irrigation through solar pump
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	The advantage of solar-powered irrigation systems is that they are cost-effective compared to traditional diesel-powered machines. Solar energy is seen as a cheaper alternative, reducing reliance on expensive diesel and minimizing the overall hassle of using traditional machines. The availability of solar energy, especially for high-value crops, has led to a preference for solar irrigation systems.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	Solar-powered irrigation systems offer the advantage of reducing the cost of diesel for irrigation. By utilizing renewable energy, such as solar power, farmers can decrease their dependence on fossil fuels and contribute to sustainable practices. These systems are particularly beneficial in areas prone to temporary droughts, such as char areas.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	Solar irrigation systems are seen as advantageous compared to traditional diesel-powered machines due to their lower operating costs. Solar energy provides a cheaper alternative for irrigation while reducing reliance on expensive diesel fuel and the problems associated with transporting and using diesel. This makes solar irrigation more cost-effective over time.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	The advantages of solar-powered irrigation include cost minimization benefits in the long run due to reduced electricity bills, as well as the eco-friendly nature of solar energy. Solar-powered systems also offer a potential solution to the increasing cost of electricity in the agricultural sector.
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	Solar-powered irrigation is economically viable, as the investment in solar panels can be recovered within 6-7 years of its 20-year lifetime. It provides clean and cost-free energy during its lifespan.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	In locations without grid electricity, solar-powered irrigation devices ensure groundwater-based irrigation runs continuously. Farmers can execute irrigation activities whenever needed with solar-powered irrigation systems, eliminating grid dependence. Solar pumps can last 25 years, but diesel pumps may fail after 5-7 years.

Salek Rahman	CEO, Salek Solar Power	Solar business	Solar pumps allow independent irrigation without reliance on external fuel or electricity sources that are subject to disruptions. As a renewable energy technology with no direct fuel costs, solar pumping significantly reduces long-term operating expenses. Adequate water access optimizes crop growth and productivity.
Sujaul Islam	Farmer	Farmer	Solar pumps enable independent irrigation without fuel or electricity interruptions. Solar pumping saves long-term operational costs because it uses no fuel. Crop yield is maximized by water availability.
MD Atikur Rahman Selim	Farmer	Farmer	Solar-powered irrigation provides several benefits, including the ability to ensure timely water supply to the land, which is essential for optimal crop growth. Unlike traditional methods that rely on electricity, solar energy is readily available, enabling farmers to access water whenever needed
MD Abul Kalam Azad	Farmer	Farmer	Solar-powered irrigation is advantageous due to its low cost compared to diesel-powered options and its ability to provide clean and cost-effective energy.

Source: Field Survey.

Solar-powered irrigation systems offer numerous advantages over diesel-powered ones. They are cost-effective, sustainable, and provide uninterrupted energy for groundwater-based irrigation. Solar energy eliminates the need for fuel purchases and transportation, reducing long-term running costs. Solar irrigation systems are an attractive solution to rising electricity costs and improve crop yields. Farmers shared their projects of Solar Powered Irrigation Pump through pictures with us. Some of the pictures are added to the Annexure.

Section II: To Find Options to Make Solar Power Irrigation Economically Viable in Bangladesh

4.4 The Cost-effectiveness

To gain a comprehensive understanding of the cost-effectiveness of solar-powered irrigation systems, this section focuses on extracting the perspectives of individual respondents. By analyzing their viewpoints, this collection of insights provides valuable information that aids in developing an overall insight into the financial aspects of implementing and operating solar-powered irrigation systems.

Table 4.4: Response on the cost-effectiveness

Name	Designation	Type of respondents	The cost-effectiveness
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	Solar-powered irrigation systems are considered economically reasonable, particularly for root-level farmers who prioritize cost-efficiency. The project coordinators have successfully communicated the cost-effectiveness of these systems to farmers, leading to widespread acceptance and adoption.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	Although the initial investment for solar panels is high, the long-term benefits outweigh the costs. By reducing expenses on diesel and decreasing reliance on fossil fuels, solar-powered irrigation systems can be cost-effective for farmers in the long run.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	Solar irrigation systems are considered economically viable for small farmers prioritizing costs, as the initial setup costs can be recovered over time through lower operating expenses compared to diesel. Communicating the cost savings has led to increased adoption among farmers.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	A solar-powered irrigation system requires space for solar panels and control rooms, which can be costly. Solar-powered devices have lower operational and maintenance costs than regular pumps, the reply says. Solar panel washing every 15 days is the main maintenance. A night guard is also needed to avoid panel theft, according to the reply.
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	The total cost of installing a solar-powered plant for farmers depends on the project size. For a 1 horsepower pump, including panels and other components, the cost ranges from 2.5 to 3 lac taka. Solar-based irrigation is considered highly cost-effective compared to diesel-based systems.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	Solar pumps may cost more than diesel pumps initially, but a long-term cost-benefit analysis reveals they are cheaper. Solar pumps offer lower operational expenses than diesel pumps since grid electricity is much cheaper. Diesel pumps cost more when fuel costs rise, but solar pumps are more steady and cost-effective.
Salek Rahman	CEO, Salek Solar Power	Solar business	While upfront investment is high, solar pumping provides irrigation without fuel expenses over its lifespan of 20-25 years. It becomes increasingly cost-effective compared to diesel pumps requiring regular fuel over the

			long run. Subsidies enhance affordability and payback period.
Sujaul Islam	Farmer	Farmer	While upfront investment is high, solar pumping provides irrigation without fuel expenses over its lifespan of 20-25 years. It becomes increasingly cost-effective compared to diesel pumps requiring regular fuel over the long run. Subsidies enhance affordability and payback period.
MD Atikur Rahman Selim	Farmer	Farmer	Solar-powered irrigation appears to be cost-effective compared to diesel-powered pumps. The high cost of diesel and associated service charges make diesel-powered pumps less feasible for meeting irrigation demands. In contrast, solar energy is generated naturally and does not require purchasing, making it a more economical option
MD Abul Kalam Azad	Farmer	Farmer	Solar-powered irrigation is considered cost-effective compared to diesel-powered pumps, as it requires significantly less investment.

Source: Field survey.

Summarized, solar-powered irrigation systems are cost-effective for cost-conscious farmers. Solar panels are expensive, but they pay off in the long run. Small farmers can afford solar-powered irrigation systems because they save money on diesel fuel and fossil fuels. Compared to regular pumps, solar-powered systems are cheaper to operate and maintain. Solar pumps are cheaper to operate than diesel pumps, making them a long-term solution. In general, solar-powered irrigation is cheaper and more ecological than diesel pumps.

4.5 Potential Financial Incentives or Support Mechanisms for Farmers

This section gathers respondents' opinions to understand the financial incentives and support mechanisms accessible to farmers who use solar-powered irrigation systems. This compilation of observations provides valuable data on farmers' financial help for solar-powered irrigation systems by examining numerous perspectives.

Table 4.5: Response on Potential Financial Incentives or Support Mechanisms for Farmers

Name	**Designation**	**Type of respondents**	**Potential financial incentives or support mechanisms for farmers**
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	The Bangladeshi government is pursuing solar technology initiatives. We're trying to lower the cost of key devices and make electricity more accessible. These programs may offer farmers financial incentives and support to use solar-powered irrigation systems.

Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	To encourage the adoption of solar-powered irrigation systems among sharecroppers and marginal farmers, providing low-cost systems and financial support, such as subsidies or loans, can be beneficial. Collaboration between the government and development organizations can help make the technology more accessible and financially viable for farmers.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	The Bangladesh government supports projects to expand access to solar technologies through measures like subsidizing equipment costs and improving electricity infrastructure in rural areas. This aims to incentivize more farmers to adopt solar irrigation.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	Government funding and subsidies are available for solar-powered irrigation projects. Many projects are funded by the government, including those carried out by Energy One Bangladesh Ltd.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	Cooperative or agricultural loan arrangements and irrigation projects help Bangladeshi farmers finance solar panels. Farmers benefit from government projects that are paid for over time. Financial incentives, subsidies, loans, and awards can help farmers adopt solar irrigation systems.
Salek Rahman	CEO, Salek Solar Power	Solar business	Governments provide subsidies covering 30-50% of installation costs to promote adoption. Subsidized loans and financing schemes help farmers invest in solar pumping. Additional incentives could make the technology more accessible.
Sujaul Islam	Farmer	Farmer	Some governments provide subsidies covering 30-50% of installation costs to promote adoption. Subsidized loans and financing schemes help farmers invest in solar pumping. Additional incentives could make the technology more accessible.
MD Atikur Rahman Selim	Farmer	Farmer	
MD Abul Kalam Azad	Farmer	Farmer	Government funding and subsidies are available for solar-powered irrigation projects, and training on animal and fisheries plants is provided.

Source: Field survey.

The Bangladeshi government is developing solar technology to lower electricity prices. These programs encourage farmers to employ solar-powered irrigation systems with financial incentives. Subsidies and loans can help sharecroppers and marginal farmers adopt. Technology can be more affordable and profitable with government-development organization collaboration. Government and cooperative subsidies promote solar-powered irrigation projects. With farmers, the government runs long-term installment initiatives. Installation subsidies of 30-50% stimulate adoption, and more incentives could make technology more accessible.

4.6 The Long-term Economic Benefits

To gain a comprehensive understanding of the long-term economic advantages of solar-powered irrigation systems, this section centers on extracting the viewpoints of individual respondents. Through analyzing their perspectives, this compilation of insights offers valuable information that contributes to an overall understanding of the financial benefits linked to the extended utilization of solar-powered irrigation systems.

Table 4.6: Response on the Long-term Economic Benefits

Name	Designation	Type of respondents	The long-term economic benefits
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	While large-scale implementation of solar-powered irrigation may have limitations, it has shown economic success for high-value crops. The yield is sufficient to justify the cost, and with proper maintenance, these systems can provide long-term economic benefits to farmers.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	Solar-powered irrigation systems have the potential to bring long-term economic benefits to farmers. By reducing costs and increasing productivity, farmers can improve their financial stability while contributing to climate conservation efforts.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	Solar irrigation can provide long-term savings for farmers growing high-value crops, as the energy from the sun is free, and solar systems have low maintenance needs if properly installed initially. This makes solar irrigation economically sustainable for farmers over the long run.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	Solar-powered irrigation systems have the potential for long-term economic benefits. By reducing electricity bills and offering cost-minimization benefits, these systems can contribute to the economic sustainability of farmers and the agricultural sector.

Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	Solar-powered irrigation has long-term economic benefits, such as reducing fuel and equipment import costs. It positively impacts the environment and benefits users directly.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	Solar-powered irrigation systems offer long-term economic benefits due to their longevity and lower operational costs compared to diesel pumps. Solar pumps can work reliably for up to 25 years, while diesel pumps may require frequent repairs or replacements, resulting in higher maintenance costs. The lower operational costs of solar pumps, including reduced fuel expenses, contribute to the long-term economic viability of solar-powered irrigation systems.
Salek Rahman	CEO, Salek Solar Power	Solar business	Widespread use of solar pumping boosts agricultural productivity and rural incomes by ensuring reliable irrigation. This contributes to overall socioeconomic development through agricultural growth and diversified livelihoods.
Sujaul Islam	Farmer	Farmer	Widespread use of solar pumping boosts agricultural productivity and rural incomes by ensuring reliable irrigation. This contributes to overall socioeconomic development through agricultural growth and diversified livelihoods.
MD Atikur Rahman Selim	Farmer	Farmer	There is optimism about the potential benefits of widespread adoption of solar-powered irrigation for Bangladesh's economy. While acknowledging that every technology has its pros and cons, they believed that solar energy could contribute positively to the country's overall economic growth.
MD Abul Kalam Azad		Farmer	Solar-powered irrigation has long-term economic benefits, including increased crop yield, lower electricity costs, and the ability to supply water to previously inaccessible areas.

Source: Field survey.

So, analyzing the above part, to make solar power irrigation economically viable in Bangladesh, the most possible options are:

1) **Focus on high-value crops**: Highlight the economic viability of solar power irrigation systems for high-value crops like summertime tomatoes and hybrid

vegetables. Showcase the higher profitability and yield of these crops when using solar-powered irrigation systems.

2) **Cost reduction**: Explore solar irrigation system cost reductions. This could involve collaborating with the government to lower instrument prices and increase accessibility. To save import costs, make delicate machine parts locally.
3) **Reducing the cost of solar panels**: Innovation and local manufacturing should be researched to lower solar panel prices. Farmers, especially marginal farmers who cannot afford expensive solar panels, may find solar panels more affordable and accessible.
4) **Cooperative approach**: Coordinate marginal and large-scale farmers to install solar irrigation systems. Marginal farmers can benefit from economies of scale and cost-sharing by working together, making the investment cheaper.
5) **Government support**: Government and development organizations can help make solar irrigation profitable. They can assist marginal farmers install solar panels cheaply with subsidies, loans, or labor. This help can make solar irrigation more affordable for farmers and increase its use.
6) **Research and development**: Research and development can lower solar panel prices, enhance local maintenance, and boost storage technology. Increasing solar power irrigation system efficiency and price can make them more profitable for farmers.
7) **Training and follow-up**: Provide sufficient training to farmers to ensure they understand the benefits of solar power irrigation and are equipped with the necessary skills to operate and maintain the systems effectively. Continuous training and follow-up support should be provided to address any challenges or issues that may arise.
8) **Promotion of subsidies**: Provide subsidies to farmers to offset the initially high installation costs of solar-powered irrigation systems. Increased subsidies can further improve viability.
9) **Improve awareness programs**: Enhance awareness programs about the long-term benefits and cost-effectiveness of solar power irrigation systems. Educate farmers about the return on investment and the potential for increased productivity.
10) **Government co-investment**: Encourage government co-investment with private companies to spread solar irrigation systems faster and on a larger scale. This can help lower costs through economies of scale.
11) **Address challenges from government institutions**: Increase regulations, transparency, and service speed to handle government issues. Simplify loan and bureaucracy processes to help farmers finance solar power irrigation systems.

Section III: To Find the Way to Make Solar Power Irrigation Socially Acceptable

4.7 The Social and Cultural Factors Influencing the Acceptance

This section focuses on extracting the perspectives of individual respondents on the social and cultural factors that influence the acceptance of solar-powered irrigation systems. By

analyzing their viewpoints, this collection of insights provides valuable information that aids in developing an overall insight into the societal and cultural aspects that shape the adoption of these systems.

Table 4.7: Response to the Social and Cultural Factors Influencing the Acceptance

Name	**Designation**	**Type of respondents**	**The social and cultural factors influencing the acceptance**
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	The acceptance of solar-powered irrigation systems is influenced by social and cultural factors. The preference for solar energy over traditional diesel-powered machines is driven by the supply-demand mismatch in electricity and the overall cost reductions and convenience associated with solar energy. Solar panels are being installed in many buildings, further indicating social acceptance.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	Acceptance of solar-powered irrigation systems among farmers can be influenced by social and cultural factors. Assurances of long-term benefits and observing the positive impact on neighboring farmers can motivate others to adopt the technology.
Md. Rashedul Alam	Assistant Director (Solar), SREDA	Energy Sector	Solar energy is gaining wider acceptance in Bangladeshi society as more people install solar panels on homes and businesses due to the benefits of reliability and reduced energy costs compared to grid electricity. This social trend indicates growing openness to solar technologies.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	Positive results and benefits experienced by farmers who have adopted solar-powered irrigation systems are influencing other farmers to accept and adopt this new technology. The social influence of successful implementation and cost-saving benefits plays a significant role in the acceptance of solar-powered systems.
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	The main challenge in widespread adoption of solar-powered irrigation is the lack of awareness among farmers. People have limited knowledge about the feasibility and return on investment of this technology.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	Farmers primarily consider costs when deciding between solar and conventional irrigation systems. Other stakeholders,

			such as government, local government, and suppliers, consider factors such as electricity supply and cost-effectiveness when making decisions. Trust and confidence in solar systems have been affected by the behavior of implementers and the quality of products in the past.
Salek Rahman	CEO, Salek Solar Power	Solar business	Lack of awareness about technical and economic benefits of solar pumping can negatively impact farmer perceptions. Training programs aim to build understanding while demonstrations highlight applications in real-life settings to farmers.
Sujaul Islam	Farmer	Farmer	Lack of awareness about technical and economic benefits of solar pumping can negatively impact farmer perceptions. Training programs aim to build understanding while demonstrations highlight applications in real-life settings to farmers.
MD Atikur Rahman Selim	Farmer	Farmer	Farmers' interest in solar-powered irrigation depends on its benefits. Farmers must be informed about solar energy's benefits to consider it. Farmers may resist solar-powered irrigation due to ignorance.
MD Abul Kalam Azad	Farmer	Farmer	No specific social or cultural factors influencing acceptance were mentioned.

Source: Field survey.

The acceptance of solar-powered irrigation systems is influenced by social and cultural factors. Farmers' acceptance of this technology can be influenced by observing the positive impact on neighboring farmers and assurances of long-term benefits. Overall, positive results, cost-saving benefits, and social influence play significant roles in the acceptance of solar-powered irrigation systems.

4.8 The Perceptions, Attitudes, and Knowledge of Farmers

The extraction of perspectives from individual respondents plays a crucial role in building an overall insight into the perceptions, attitudes, and knowledge of farmers toward solar-powered irrigation systems.

Table 4.8: Response on the Perceptions, Attitudes, and Knowledge of Farmers

Name	Designation	Type of respondents	The perceptions, attitudes, and knowledge of farmers
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	Farmers' perceptions and attitudes have shifted towards preferring solar irrigation over traditional methods due to factors such as cost-efficiency and reduced hassle. The

			perception of solar-powered irrigation as a viable and beneficial technology has increased among farmers.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	Farmers may have uncertainties about the benefits of solar-powered irrigation systems. Providing training and follow-up support to enhance their knowledge and skills in using the technology effectively is crucial.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	Farmers' attitudes have shifted towards solar irrigation because they recognize the financial benefits relative to diesel in terms of lower fuel and maintenance costs. More farmers see solar irrigation as a practical option.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	Solar irrigation systems were initially unpopular with farmers due to high installation costs. However, farmers have learned to appreciate these methods' long-term benefits and cost savings. This has increased uptake and improved farmers' views of solar-powered systems.
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	Farmers have shown interest in solar-powered irrigation, particularly those who have been exposed to commercial initiatives. However, overall perceptions, attitudes, and knowledge about solar irrigation vary among individuals.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	Farmers in Bangladesh have shown great interest in solar panels, but affordability remains a challenge. Farmers consider the costs of installation, sustainability, and the coverage area of the irrigation pump when deciding between solar and conventional systems.
Salek Rahman	CEO, Salek Solar Power	Solar business	Opportunities to learn from other farmers' experiences directly address any doubts among farmers by demonstrating proven benefits of solar pumping applications. Hands-on learning helps change attitudes by increasing confidence in the technology.
Sujaul Islam	Farmer	Farmer	Opportunities to learn from other farmers' experiences directly address any doubts among farmers by demonstrating proven benefits of solar pumping applications. Hands-on learning helps change attitudes by increasing confidence in the technology.
MD Atikur Rahman Selim	Farmer	Farmer	Farmers are more likely to show interest in solar-powered irrigation if they perceive it to be more beneficial compared to other methods, such as diesel-powered pumps. Increasing farmers' awareness and knowledge

			about solar energy and its advantages is essential for promoting adoption.
MD Abul Kalam Azad	Farmer	Farmer	Farmers have shown interest in solar-powered irrigation, and more people are expected to adopt the technology as they witness its success. However, the initial setup cost may be a barrier for some farmers.

Source: Field Survey.

Farmers' perceptions and attitudes towards solar-powered irrigation have shifted positively due to factors such as cost-efficiency, reduced hassle, and recognition of financial benefits compared to traditional methods.

4.9 The Strategies to Promote Awareness and Encourage the Adoption in the Local Community

This section focuses on devising strategies to promote awareness and encourage the adoption of solar-powered irrigation systems within the local community.

Table 4.9: Response on strategies to promote awareness and encourage the adoption in the local community

Name	Designation	Type of respondents	Strategies to promote awareness and encourage the adoption in the local community
MD. Humayun Kabir	Joint Director, BADC	Agriculture Sector	BADC has trained and promoted solar-powered irrigation systems for years. Training in areas without infrastructure is limited. BADC is expanding coverage and training to promote solar-powered irrigation systems. A dedicated Agriculture Ministry section could improve solar-powered irrigation projects.
Sheikh Mehedi Mohammad	Director of Farm, Technology, Irrigation and Water Management, RDA	Agriculture Sector	Research to reduce the cost of solar panels, develop local maintenance capabilities, and improve storage technology can help promote adoption. Additionally, providing subsidies, loans, or manpower support through government and NGO initiatives can make the technology more accessible and sustainable for marginal farmers.
Md. Rashedul Alam -	Assistant Director (Solar), SREDA	Energy Sector	Organizations like BADC provide training to raise awareness of solar irrigation among farmers while working to expand the reach of these programs. Establishing a dedicated division could further boost the effectiveness of solar irrigation projects.
Arif Hosen	Engineer, Energy One Bangladesh	Energy Sector	Installation subsidies and tool discounts can make solar-powered irrigation systems more socioeconomically acceptable. Resolving the design and reducing the systems' size can make them more affordable and accessible to rural farmers, enlarging the market. Farmers need

			training and awareness to operate and maintain the systems.
Md. Fazor Ali	Head of Operation, Energy One Bangladesh	Energy sector	Efforts are being made to implement awareness initiatives for solar-powered irrigation. Organizations like IDCOL have taken steps, including providing loans with a downpayment, to encourage adoption of this technology.
Mahbub Suman	Renewable Energy Researcher	Energy sector and Solar Business	Incentives, subsidies, loans, and regulatory simplification can promote solar-powered irrigation systems. 1. Establishing quality standards, reducing design errors, and covering repair costs can develop farmer trust. Secure financing and reliable execution can raise awareness and acceptance of solar-powered irrigation systems.
Salek Rahman	CEO, Salek Solar Power	Solar business	Farmers can receive information from targeted awareness campaigns, community gatherings, and extension programs. Low-cost solar pumping system subsidies encourage adoption. Providing post-installation customer assistance and maintenance boosts technology utilization. Government-private sector co-investment can accelerate solar pumping technologies.
Sujaul Islam	Farmer	Farmer	Targeted awareness campaigns, community meetings, and extension services can effectively disseminate information to farmers. Subsidy programs also incentivize the adoption of solar pumping for irrigation.
MD Atikur Rahman Selim	Farmer	Farmer	Awareness campaigns are needed to promote solar-powered irrigation among the local community. Solar energy education, training, and farmer consultations can raise awareness and implementation of this sustainable irrigation technology.
MD Abul Kalam Azad	Farmer	Farmer	To encourage adoption, easy loan systems and simplified setup processes are suggested. Increasing awareness about the benefits of solar-powered irrigation is also important.

Source: Field survey.

Efforts are being made to promote awareness and encourage the adoption of solar-powered irrigation systems in the local community. In order to foster the adoption of solar-powered irrigation within the local community, it is imperative to implement effective initiatives that raise awareness, enhance accessibility, and disseminate knowledge regarding its benefits.

The comprehension of the aforementioned section provides insights into the strategies for achieving socio-economic acceptability of solar power irrigation.

1) **Social acceptance:** Highlight the increasing social acceptance of solar energy in Bangladesh by emphasizing preference over traditional diesel machines due to

cost savings and convenience. Also showcase solar panel installations in recent buildings as a sign of acceptance.

2) **Knowledge dissemination and awareness:** Continue raising awareness about the benefits of solar power irrigation through training, information campaigns, and sharing success stories and case studies to build trust in the technology.
3) **Community engagement:** Make farmers aware of socioeconomic benefits like reduced fuel costs, electricity for household use, and climate change mitigation. Emphasize long-term returns and low maintenance costs to motivate adoption.
4) **Demonstration projects:** Implement demonstration projects in areas like Bogra to showcase benefits and success stories of solar power irrigation so farmers see peers benefiting from the systems.
5) **Sharecroppers support:** Provide affordable solar-powered irrigation systems for sharecroppers through subsidies or low-cost financing tailored to their needs since they make up a significant portion of farmers in Bangladesh.
6) **Government collaboration:** The Ministry of Agriculture and Ministry of Power should collaborate on a unified approach for implementing and regulating solar power irrigation to ensure a holistic view of impacts on water resources and productivity.
7) **Financial incentives:** Offering incentives like tax breaks or grants can encourage farmer adoption by helping offset initial investment costs and making solar power irrigation more attractive and economically viable.
8) **Long-term planning:** Have a long-term vision and plan for widespread adoption considering the balance between productivity and sustainable groundwater management practices.

5. Recommendations

Based on the findings and analysis, the following recommendations are proposed for the successful implementation and widespread adoption of solar power irrigation systems in Bangladesh:

- Focus on high-value crops and highlight their economic viability with solar power irrigation systems.
- Invest in research and development to improve the efficiency and affordability of solar power irrigation systems.
- Provide comprehensive training and follow-up support to farmers for effective operation and maintenance of solar power irrigation systems.
- Promote subsidies to offset initial installation costs and increase the viability of solar-powered irrigation.
- Foster collaboration between the Ministry of Agriculture and Ministry of Power for a unified approach to implementing and regulating solar power irrigation.
- Develop a long-term vision and plan for widespread adoption while considering productivity and sustainable groundwater management practices.

By implementing these recommendations, solar power irrigation can become a more viable and accepted solution in Bangladesh, leading to increased agricultural productivity, reduced fuel costs, and a more sustainable farming sector.

6. Concluding Remarks

To conclude, the implementation of solar power irrigation systems in Bangladesh holds great potential for enhancing agricultural productivity, reducing fuel costs, and promoting sustainable farming practices. By focusing on high-value crops and showcasing their economic viability when using solar-powered irrigation systems, farmers can be incentivized to adopt this technology. Efforts to reduce the costs associated with solar panels and irrigation systems, such as exploring local manufacturing and collaborating with the government, can further improve affordability. Additionally, a cooperative approach that facilitates collaboration between marginal farmers and large-scale farmers can help share costs and benefits, making solar power irrigation more accessible to small-scale farmers. Government support through subsidies, loans, and manpower is crucial in making solar power irrigation financially feasible for farmers, while research and development investments can drive technological advancements and cost reductions in the long term. Training, continuous support, and effective customer service are also essential for the successful implementation and operation of solar power irrigation systems. By addressing these recommendations, solar power irrigation can become a sustainable and economically viable solution for agricultural development in Bangladesh.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

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Annexure: Pictures of Solar Power Irrigation System