Performance Assessment of Solar-Powered Irrigation Project in Nueva Ecija

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Abstract: - Solar energy is one of the most perfect sustainable energy we could have. With its many significant uses such as for industrial, commercial, agriculture and etc., this could be beneficial for everyone in pursuing sustainable economic development. The province of Nueva Ecija has been the largest-producing rice crop in the country for decades naming it the “Rice Granary of the Philippines”. Not only that, but there are also lands that produce high-value crops such as onion, mango, banana, calamansi, garlic, and different types of vegetables. With this agricultural effort done by the province, this would undoubtedly be needing a modern irrigation system. The study investigates and analyzed the performance of the Solar-Powered Irrigation System (SPIS) project in Nueva Ecija by opinion survey method. For the survey, a sample size of 30 is taken through a stratified random sampling method from the province that would compose of technical persons from the National Irrigation Authority (NIA), farmers, and households. The analysis has been done with percentages, averages, weighted scores, and ranking methods.

Key Words — ***Solar-Powered Irrigation System, Photovoltaic Generation, Centrifugal Motor Pump.***

I. Introduction

Agriculture is the single largest employer in the world, sustaining the livelihoods of 40 percent of the world’s population, many of whom continue to live in poverty (United Nations, 2015). Irrigation is among the measures that can improve yields, reduce vulnerability to changing rainfall patterns and enable multiple cropping practices (FAO, 2011).

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The National Irrigation Authority (NIA) has introduced a modern irrigation system called the “Solar-Powered Irrigation System (SPIS)” in Nueva Ecija. This project of NIA will help alleviate the lives of more than 14,000 farmers by reducing the use of diesel-fuel water pumps. When the Russia-Ukraine war erupted, millions of Filipinos are complaining about the price hike of gasoline and diesel, most of this are farmers from different parts of the country. It is in the best interest of the farmers that this project should be initiated.

As investment costs for solar powered irrigation systems (SPIS) are coming down and subsidy schemes for SPIS are being rolled out, solar technologies are becoming a viable option for both large and small-scale farmers. SPIS provide reliable and affordable energy, potentially reducing energy costs for irrigation. In rural areas where diesel fuel is expensive or where reliable access to the electricity grid is lacking, they can provide a relatively flexible and climate-friendly alternative energy source. SPIS can be used in large-scale irrigation systems as well as for decentralized, small-scale irrigation. (FAO, 2018).

In a statement of NIA Administrator, Ricardo R. Visaya, he reiterated that they are committed to its mandate of providing efficient, reliable, and sustainable irrigation service to Filipino farmers while making a strategic contribution to the development of the country's agricultural sector. Indeed, nueva ecijano farmers are benefitting on the said project.

II. Literature Review

2.1 Foreign Studies

According to the article "Solar-powered irrigation: A solution to water management in agriculture?" by Stéphanie Roblin (2016). In many rural areas, especially in developing and emerging countries, the access to the electricity grid is not always guaranteed. In this case, farmers cannot rely on the traditional irrigation system. Thus, using an independent and alternative energy system can be a solution for the farmer to secure a safe power source and for the public grid to avoid saturation. Diesel pumps are slightly more efficient than AC powered pumps as they allow greater flexibility. However, one of the main constraints is that this system relies on the fuel availability, added to a greater impact on the environment. Diesel-driven pumps are cheaper than solar-powered pumps but the operating costs are quite high and depend heavily on the diesel price. In solar-powered systems, it works the other way round, that is, although this system is relatively expensive, the source of energy is free, therefore, after the amortization period, there are no longer operating costs (only the maintenance costs must be considered). Therefore, solar pumps turn out to be a viable long-term investment.

According to Tambe, R.K. & Parashar, A.K. (2017). Solar power is not only an answer to today's energy crisis but also an environmentally friendly form of energy. Photovoltaic generation is an efficient approach for using the solar energy. Solar panels (an array of photovoltaic cells) are nowadays extensively used for running street lights, for powering water heaters and to meet domestic loads. The cost of solar panels has been constantly decreasing which encourage sits usage in various sectors. One of the applications of this technology is used in irrigation systems for farming. Solar powered irrigation system can be a suitable alternative for farmers in the present state of energy crisis in India. This a green way for energy production which provides free energy once an initial investment is made.

In the current state, PV systems are far more viable in comparison to solar thermal systems especially as small-scale farming solutions in the technological sense. Assisted further by the drop of cost of solar cells, seamless integration with available technology, reduction in price of Lithium-Ion batteries and rapid commercialization of the technology. In this section, a summary of the advantages and disadvantages of the systems are presented in the context of small-scale irrigation in the remote and rural areas of Sub-Saharan African region. (Mohammed Wazed, S. et.al, 2018)

Schnetzer J. & Pluschke L., (2017) on their study "SPIS have some direct potential to reduce greenhouse gas (GHG) emissions in irrigated agriculture by replacing fossil fuels for power generation with a renewable energy source, i.e. solar energy. The operation of the water pump in SPIS is free of GHG emissions. Most GHG emissions in SPIS are related to the production and disposal of the PV panels. Life cycle assessments (LCA), taking into account these emissions in a cradle-to-grave approach, indicate a potential reduction in GHG emissions per unit of energy used for water pumping (CO2-eq/kWh) of 95 to 97 percent as compared to pumps operated with grid electricity (global average energy mix) and 97 to 98 percent as compared to diesel-pumps (GIZ 2016). However, while these improvements are significant, the comparatively small energy demand of irrigation equipment would require very large numbers of SPIS to, for instance, replace a single 100 MW coal-fired power plant. More significant GHG emission avoidance may be achieved indirectly however through the modernization of irrigation facilitated through SPIS: reduced pollution, more targeted fertilizer use, more precise irrigation, more benign water extraction."

2.2 Local Studies

Based on the Philippine Agricultural and Biosystems Engineering Journal (2020), "The performance of the SPIS depends on the output of the PV array, efficiency of the controller, height of the pump set from the source to the delivery outlet (Total Head), size of the inlet and outlet pipes, number of pipe bends, water quality, and efficiency of the pump set. The performance of the system is also highly affected by the available solar irradiance. The performance of the SPIS can improve even under overcast conditions by increasing the design capacity of the PV array."

In an online article by the Philippine News Agency (2020), quoted the statement of DA Bicol Spokesperson, Emily Bordado "The SPIS are indeed the best option in areas where big irrigation systems are not feasible and they can contribute significantly to increase yield of rice and other crops in rainfed and upland areas."

According to the study "Socio-Economic and Environmental Analyses of Solar Irrigation Systems for Sustainable Agricultural Production" by Guno & Agaton (2022). The solar irrigation system has no variable operational costs as it uses no fuel but runs with energy coming from sunlight. Conversely, the fixed maintenance cost accounts for the labor and transportation costs, as well as the replacement costs of a submersible water pump that needs to be replaced in 8 to 15 years, depending on the siltation and quality of the water source. The solar panel needs no maintenance except for the constant cleaning of the panels to ensure maximum capture of sunlight.

According to an online article "Crop yield rises with solar-powered irrigation" by pv-magazine.com (2020). The government of the Philippines has installed solar-powered irrigation systems in the province of Camarines Sur to help rain-dependent farmers become able to plant rice in three cropping seasons. The solar system in Barangay Malawag – the Aguik-ican Malawag Solar-Powered Irrigation System (SPIS) – cost PHP6 million ($118,000) and can pump an average 1,000m3 in 6-8 hours. Powered by 60 solar panels, the irrigation system can discharge 35.42 liters per second, with the supply pipe able to discharge 20.62 liters per second.

III. METHODOLOGY

The methodologies and procedures that will be employed in this study will be described. Specifically, the research design, locale of the study, samples and sampling procedure, respondents of the study, research instrument, data gathering procedure and data analysis techniques. These will include the information on how to determine the responses of the population sample and the procedures on gathering and analyzing the data gained.

3.1 Research Design

The research aims to systematically and precisely describe a population and situation. Descriptive research is an appropriate choice in this study because the research aim is to identify characteristics, frequencies, trends, and categories. Qualitative research emphasizes the dynamic, holistic and individual aspects of the human experience, and attempts to capture those experiences in their entirety, within the context of those experiencing them (Polit & Beck 2004:16; Streubert & Carpenter 1999:15). The researcher chose to follow a qualitative research process to assess the performance of solar-powered irrigation in Nueva Ecija. Through this approach, it is possible for the researcher to deeply engage and interact with farmers through phenomenological interviews, and rich data will be generated based on the experiences of the farmers using the solar-powered irrigation project.

3.2 Locale of the Study

The study will be conducted in Nueva Ecija. The respondents will be interviewed in their houses or any comfortable place that the respondent will choose to. The researchers chose the place of implementation because it will give the researchers the needed information for people with the great knowledge in this field and with the technology that can be adapted. The study will be conducted in the first semester of the academic year 2022-2023.

3.3 Samples and Sampling Procedure

Sampling refers to the process of selecting a portion of the population that conforms to a designated set of specifications to be studied. A sample is a subset of a population selected to participate in the study (Polit & Beck 2004:731; Uys & Basson 1991:87). A purposive sampling method was used, which is most common in phenomenological inquiry.

According to Brink (1996:141), purposive sampling requires selecting participants who are knowledgeable about the issue in question, because of their sheer involvement in and experience of the situation. While Creswell (2003:185) states that purposive sampling refers to selection of sites or participants that will best help the researcher understand the problem and the research question, they must be willing to reflect on and share this knowledge. Farmers in Nueva Ecija were found to be the best source of rich and valuable information regarding their experiences during placement in field settings, as they are experts regarding their own farming practice experiences (Lincoln & Guba 1985:290; Talbot 1995:487-488). The participants were selected based on their particular knowledge of the phenomenon, for the purpose of sharing their knowledge and experiences with the researcher (Streubert & Carpenter 1999:58).

3.4 Respondents of the Study

The study's respondents are residents of the Nueva Ecija. One of the critical processes for the success of this study. Random sampling was used to select all of these participants. This sampling method is used when every member of a population has the potential to become a member of the sample.

Table 1 presents the total population, sample respondents and the percentage of the two groups of respondents.

Table.1. Classification of Respondents

	N	n
Farmers	9	9
Land Owners	21	21
Total	30	30

Table shows the classification of the respondents, as it shown it has 30 respondents, 21 for land owners and 9 for farmers.

3.5 Research Instruments

The research instrument used in data gathering is questionnaire checklist. It is the most appropriate tool in collecting data, all information the researchers want to know are already there and the respondents answered based on the options given.

3.6 Data Gathering Procedure

The researchers sought the assistance of respondents to come up with analysis interpretation and conclusions of the study entitled "Performance Assessment of Solar-Powered Irrigation Project in Nueva Ecija".

The researchers administered questionnaires to the respondents. As a result, it helps in bringing ideas on the subject studied. Also, the researcher employed personal interviews and observation in some instances, such as when certain information seems not accurate.

3.7 Data Analysis Technique

The researchers used the following statistical tools.

3.7.1. Frequency Distribution

It is tabular arrangement of data by classes or categories together with their corresponding class frequencies. Class frequency refers to the number of the observations belonging to a class interval, or the number of the items within the categories a class interval is a grouping or category defined by a lower limit band upper limit (Tan, 2006).

P% = F/N x 1OO

Where:

P= Percentage

F= Frequency of distribution

N= total number of respondents

3.7.2 Weighted mean

There are times when values are given more importance than other. The mean derived in this case is known as the weighted mean.

The formula that used in computing the weighted

WM = WF/N

Where:

WM = weighted mean

(WF) = summation of all weights multiplied by the corresponding frequency

n = total number of frequencies

IV. Results and Discussion

This chapter presents the Presentation of Data, Data Analysis, Interpretation, Discussion of Results, and the Summary of Findings. These are sequentially presented in tabular form following the order of the specific problems they are intended to answer.

4.1. Profile of the Respondents

The study's respondents are residents of Nueva Ecija. One of the critical processes for the success of this study. Random sampling was used to select all of these participants. This sampling method is used when every member of a population has the potential to become a member of the sample. Table 3.1 presents the profile of the residents which are mixed group of farmers and land owners that covers their age and gender.

Table 3.1: Profile of the Respondents; n= 30

Profile		Frequency (F)	Percentage (%)
Gender	Male	26	86.67
	Female	4	13.33
	Total	**30**	**100**
Age	18-30	1	3.33
	31-45	16	53.33
	46-60	11	36.67
	61 - older	2	6.67
	Total	**30**	**100**
Classification	Farmer	9	30
	Land Owner	21	70
	Total	**30**	**100**

Gender: In terms of gender, the number of male respondents is 26 while female respondents tallied a total number of 4. According to the data, men are the most common gender among respondents. The results collected revealed that, male respondents make up 86.67 percent of the sample, while female respondents make up 13.33 percent. This indicates that the majority of the respondents and participants in the research study are male.

Age: In terms of age, the number of respondents from age bracket 31-45 is 16; 46-60 is 11; 61-older is 2; and, 18-30 is 1. According to the data, 31-45 years old are the most common age bracket among respondents. The results collected revealed that, 31-45 respondents make up 53.33 percent of the sample; while 46-60 is 36.67 percent; 61-older is 6.67 percent; and, 18-30 is 3.33 percent respectively.

Classification: In terms of classification, the number of land owner respondents is 21 while farmer respondents tallied a total number of 9. According to the data, land owners are the most common classification among respondents. The results collected revealed that, land owner respondents make up 70 percent of the sample, while female respondents make up 30 percent. This indicates that the majority of the respondents and participants in the research study are land owners.

Table 3.2: Types of Farm; n= 30

Particulars		Frequency (F)	Percentage (%)
Type	Commercial	20	66.67
	Smallholder	5	16.67
	Substinence	5	16.67
	Others	0	0
	Total	**30**	**100**

Assessment: Table 3.2 shows the types of farms owned and managed by the respondents. In terms of farm types, the number of commercial farm type respondents is 20 while both smallholder and substinence farm types respondents tallied a number of 5, respectively. According to the data, commercial farm types are the most common type among respondents. The results collected revealed that, commercial farm respondents make up 66.67 percent of the sample, while both smallholder and substinence farm types respondents make up 16.67 percent. This indicates that the majority of the respondents and participants in the research study are commercial land owners.

Table 3.3: Water Used in the Farm; n= 30

Particulars		Frequency (F)	Percentage (%)
Type of Water	Borehole	19	63.33
	River/ Dam	11	36.67
	Total	**30**	**100**

Assessment: Table 3.3 shows the types of water used in the farm by the respondents. In terms of water types, the number of borehole users from the respondents is 19 while river/ dam water users tallied a number of 11. According to the data, borehole water type users are the most common type among respondents. The results collected revealed that, borehole water type users make up 63.33 percent of the sample, while river/ dam water users respondents make up 36.67 percent. This indicates that the majority of the respondents and participants in the research study are borehole water-type users.

Table 3.4: Solar Power Irrigation System Used in the Farm; n= 30

Particulars		Frequency (F)	Percentage (%)
Type of System	Furrow	18	60
	Sprinkler	11	36.67
	Micro-Sprinkler	1	3.33
	Drip Irrigation	0	0
	Center Pivot	0	0
	Total	**30**	**100**

*Assessment***:** Table 3.4 shows the solar power irrigation system used in the farm by the respondents. In terms of solar power irrigation system types, the number of furrow users from the respondents is 18; sprinkler users are 11; and, micro-sprinkler users are 1. There no existing drip irrigation and center pivot users among the respondents. According to the data, furrow type users are the most common type among respondents. The results collected revealed that, furrow type users make up 60 percent of the sample, while sprinkler users respondents make up 36.67 percent; and micro-sprinklers 3.33 percent. This indicates that the majority of the respondents and participants in the research study are furrow type solar powered irrigation users.

Table 3.5: Solar Panels Used in the Farm; n= 30

Particulars		Frequency (F)	Percentage (%)
Type	Thin Film	17	56.67
	Mono-crystalline	11	36.67
	Poly-crystalline	2	6.67
	Others	0	0
	Total	**30**	**100**

Assessment: Table 3.5 shows the solar panels used in the farm by the respondents. In terms of solar panel types, the number of thin film type respondents is 17; while mono-crystalline is 11; and, poly-crystalline is 2. According to the data, thin film types are the most common type among respondents. The results collected revealed that, thin film type respondents make up

56.67 percent of the sample; while mono-crystalline is 36.67 percent; and, poly-crystalline is 6.67 percent. This indicates that the majority of the respondents and participants in the research study are thin film solar panels users.

Table 3.6: System Battery Existence; n= 30

Particulars		Frequency (F)	Percentage (%)
Existence	With Batteries	17	56.67
	No Batteries	13	43.33
	Total	**30**	**100**

Assessment: Table 3.6 shows the system battery existence used in the farm by the respondents. In terms of batteries, the number of users of batteries from the respondents is 17 while no batteries users tallied a number of 13. According to the data, battery type users are the most common type among respondents. The results collected revealed that, battery type users make up 56.67 percent of the sample, while non-battery users respondents make up 43.33 percent. This indicates that the majority of the respondents and participants in the research study are battery users.

Table 3.7: Type of Pump Used; n= 30

Particulars		Frequency (F)	Percentage (%)
Type of Pump	Submersible multistage centrifugal motor pump set	24	80
	Submersible pump with surface mounted motor	6	20
	Reciprocating positive displacement pump	0	0
	Floating pump set	0	0
	Surface Suction Pump Set	0	0
	Total	**30**	**100**

Assessment: Table 3.7 shows the type of pump used in the farm by the respondents. In terms of pump types, the number of submersible multistage centrifugal motor pump set users from the respondents is 24; and, submersible pump with surface mounted motor users are 6. There no existing reciprocating positive displacement pump, floating pump set, and surface suction pump set users among the respondents. According to the data, submersible multistage centrifugal motor pump set users are the most common type among respondents. The results collected revealed that, submersible multistage centrifugal motor pump set users make up 80 percent of the sample, while submersible multistage centrifugal motor pump set users respondents make up 20 percent. This indicates that the majority of the respondents and participants in the research study are submersible multistage centrifugal motor pump set users.

Table 3.8: Grid Connection Status; n= 30

Particulars		Frequency (F)	Percentage (%)
Is the system connected to the grid?	Yes	25	83.33
	No	5	16.67
	Total	**30**	**100**

Assessment: Table 3.8 shows the grid connection status in the farm by the respondents. In terms of grid connection, the number of users connected to the grid from the respondents is 25, while no connection to the grid tallied a number of 5. According to the data, grid-connected users are the most common type among respondents. The results collected revealed that, grid-connected users make up 83.33 percent of the sample, while non-grid connection users respondents make up 16.67 percent. This indicates that the majority of the respondents and participants in the research study are connected to the grid.

Table 3.9: Water Tank Existence; n= 30

Particulars		Frequency (F)	Percentage (%)
Existence	With Water Tank	16	53.33
	No Water Tank	14	46.67
	Total	**30**	**100**

Assessment: Table 3.9 shows the water tank existence in the farm to store excess water pumped. In terms of water tanks, the number of users with water tanks from the respondents is 16 while no water tank users tallied a number of 14. According to the data, water tank users are the most common type among respondents. The results collected revealed that, water tank users make up 53.33 percent of the sample, while non-water tank users respondents make up 46.67 percent. This indicates that the majority of the respondents and participants in the research study are water tank users.

Table 3.10: System Generator Existence; n= 30

Particulars		Frequency (F)	Percentage (%)
Existence	With Generator	27	90
	No Generator	3	10
	Total	**30**	**100**

Assessment: Table 3.10 shows the system generator existence in the farm to provide backup power. In terms of generators, the number of users with generators from the respondents is 27 while no generator users tallied a number of 3. According to the data, generator users are the most common type among respondents. The results collected revealed that, generator users make up 90 percent of the sample, while non-generator users respondents make up 10 percent. This indicates that the majority of the respondents and participants in the research study are generator users.

Table 3.11: **Power Source Used before Solar Energy; n= 30**

Particulars		Frequency (F)	Percentage (%)
Type	Diesel power	20	66.67
	Grid Electricity	8	26.67
	No power	2	6.67
	Others	0	0
	Total	**30**	**100**

Assessment: Table 3.11 shows the power source used before solar energy in the farm by the respondents. In terms of old power source used, the number of diesel power type respondents is 20; while grid electricity is 8; and, no power is 2. According to the data, diesel power types are the most common type among respondents. The results collected revealed that, diesel power type respondents make up 66.67 percent of the sample; while grid electricity is 26.67 percent; and, no power is 6.67 percent. This indicates that the majority of the respondents and participants in the research study are diesel power users prior solar energy.

Table 3.12: Crops Under Irrigation; n= 30

Particulars		Frequency (F)	Percentage (%)
Type of Crops	Rice	23	76.67
	Vegetables (Root Crops)	6	20
	Fruits	1	3.33
	Total	**30**	**100**

Assessment: Table 3.12 shows the types of crops under irrigation in the farm by the respondents. In terms of crops, the number of rice farmers from the respondents is 23; while vegetables (root crops) farmers tallied a number of 6; and fruit farmers tallied 1. According to the data, rice farmers are the most common type among respondents. The results collected revealed that, rice farmers make up 76.67 percent of the sample; while vegetables (root crops) farmers tallied 20 percent; and fruit farmers tallied 3.33 percent. This indicates that the majority of the respondents and participants in the research study are rice farmers.

Table 3.13: Pressure and Flow Rate Problems Status; n= 30

Particulars		Frequency (F)	Percentage (%)
Do you have pressure and or flow rate problems?	Yes	8	26.67
	No	22	73.33
	Total	**30**	**100**

Assessment: Table 3.13 shows the pressure and flow rate problems status in the farm by the respondents. In terms of pressure and flow rate problems, the number of users with existing problems from the respondents is 8, while no problems encountered tallied a number of 22. According to the data, no pressure and flow rate problems among users are the most common type among respondents. The results collected revealed that, no pressure and flow rate problems among users make up 73.33 percent of the sample, while users with existing problems make up 26.67 percent. This indicates that the majority of the respondents and participants in the research study are not having pressure and flow rate problems as of the moment.

Table 3.14: Year of Solar Power Irrigation Installation; n= 30

Particulars		Frequency (F)	Percentage (%)
Year	1990-1999	0	0
	2000-2006	3	10
	2007-2012	6	20
	2013-2019	16	53.33
	2019-2022	5	16.67
	Total	**30**	**100**

Assessment: Table 3.14 shows the power year of solar power irrigation installation in the farm by the respondents. In terms of year origin, the number of solar power irrigation installed in year 2013-2019 among the respondents is 16; while year 2007-2012 is 6; year 2019-2022 is 5; and, year 2000-2006 is 3. According to the data, the number of solar power irrigation installed in year 2013-2019 are the most common among respondents. The results collected revealed that, solar power irrigation installed in year 2013-2019 make up 53.33 percent of the sample; while year 2007-2012 is 20 percent; year 2019-2022 is 16.67 percent; and, year 2000-2006 is 10 percent. This indicates that the majority of the respondents and participants in the research study started installing their solar power irrigation on the year 2013-2019.

V. Findings, Conclusions and Recommendations

5.1 Findings

Based on the data gathered and analyzed, Men are the most common gender among respondents. The results collected revealed that, male respondents make up 86.67 percent of the sample, while female respondents make up 13.33 percent. This indicates that the majority of the respondents and participants in the research study are male.

31-45 years old are the most common age bracket among respondents. The results collected revealed that, 31-45 respondents make up 53.33 percent of the sample; while 46-60 is 36.67 percent; 61-older is 6.67 percent; and, 18-30 is 3.33 percent respectively.

Land owners are the most common classification among respondents. The results collected revealed that, land owner respondents make up 70 percent of the sample, while female respondents make up 30 percent.

Commercial farm types are the most common type among respondents. The results collected revealed that, commercial farm respondents make up 66.67 percent of the sample, while both smallholder and substinence farm types respondents make up 16.67 percent.

Borehole water type users are the most common type among respondents. The results collected revealed that, borehole water type users make up 63.33 percent of the sample, while river/ dam water users respondents make up 36.67 percent.

Furrow type users are the most common type among respondents. The results collected revealed that, furrow type users make up 60 percent of the sample, while sprinkler users respondents make up 36.67 percent; and micro-sprinklers 3.33 percent.

Thin film types are the most common type among respondents. The results collected revealed that, thin film type respondents make up 56.67 percent of the sample; while mono-crystalline is 36.67 percent; and, poly-crystalline is 6.67 percent.

Battery type users are the most common type among respondents. The results collected revealed that, battery type users make up 56.67 percent of the sample, while non-battery users respondents make up 43.33 percent.

Submersible multistage centrifugal motor pump set users are the most common type among respondents. The results collected revealed that, submersible multistage centrifugal motor pump set users make up 80 percent of the sample, while submersible multistage centrifugal motor pump set users respondents make up 20 percent.

Grid-connected users are the most common type among respondents. The results collected revealed that, grid-connected users make up 83.33 percent of the sample, while non-grid connection users respondents make up 16.67 percent.

Water tank users are the most common type among respondents. The results collected revealed that, water tank users make up 53.33 percent of the sample, while non-water tank users respondents make up 46.67 percent.

Generator users are the most common type among respondents. The results collected revealed that, generator users make up 90 percent of the sample, while non-generator users respondents make up 10 percent.

Diesel power types are the most common type among respondents. The results collected revealed that, diesel power type respondents make up 66.67 percent of the sample; while grid electricity is 26.67 percent; and, no power is 6.67 percent.

Rice farmers are the most common type among respondents. The results collected revealed that, rice farmers make up 76.67 percent of the sample; while vegetables (root crops) farmers tallied 20 percent; and fruit farmers tallied 3.33 percent.

No pressure and flow rate problems among users are the most common type among respondents. The results collected revealed that, no pressure and flow rate problems among users make up 73.33 percent of the sample, while users with existing problems make up 26.67 percent.

The number of solar power irrigation installed in year 2013-2019 are the most common among respondents. The results collected revealed that, solar power irrigation installed in year 2013-2019 make up 53.33 percent of the sample; while year 2007-2012 is 20 percent; year 2019-2022 is 16.67 percent; and, year 2000-2006 is 10 percent.

5.2 Conclusions

Specifically, the researchers formulated the following conclusions:

Individual solar cell devices are often the electrical building blocks of photovoltaic modules, known colloquially as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 volts to 0.6 volts.

Irrigation water is an important production factor in agriculture. Market-oriented agricultural production without irrigation is not possible in many parts of the world. The extent to which farm households depend on irrigation for their production depends on their geographical or rather agro-climatic location, local hydrological and soil conditions, and actual crop water requirements.

The actual cost of operation of pressurized irrigation systems is low due to automation. Micro-irrigation systems in particular can be operated with a minimum of personnel. Sprinkler irrigation systems require a higher degree of labor input due to the need to move the sprinkler units. Surface irrigation methods are labor-intensive due to the manual water management on field level.

Solar power irrigation system provides reliable and affordable energy, potentially reducing energy costs for irrigation. In rural areas where diesel fuel is expensive or where reliable access to the electricity grid is lacking, they can provide a relatively flexible and climate friendly alternative energy source. It can be used in large-scale irrigation systems as well as for decentralized, small-scale irrigation.

5.3 Recommendations

- It is important to note that solar power irrigation system – if not adequately managed and regulated – bear the risk of supporting unsustainable water use. Once the systems are installed, there is no cost per unit of power and thus no financial incentive for farmers to save on fuel or electricity for water pumping. This can lead to wasteful water use, over-abstraction of groundwater, and low field application efficiency.
- In regards with the quick development of solar power irrigation system, there is an opening to not simply introduce a clean, climate-smart and innovative energy technology, but to think strategically about how this technology can be used to encourage more sustainable use of groundwater resources, to create more inclusive finance and management structures and to foster more integrated thinking about solutions around the water-energy-food connection.
- As investment costs for solar powered irrigation systems are coming down and subsidy from government for such endeavor are being rolled out, solar technologies are becoming a viable option for both large and small-scale farmers. It is recommended for the farmers and the government to provide reliable and affordable program for solar power utilization, potentially reducing more energy costs for irrigation.

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