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Solar Energy Farming for Sustainable Agriculture and Rural Development: Myanmar Dry Zone

Khin Thu Thu Thein

Abstract

Adopting climate technologies is essential for lowering greenhouse gas emissions, boosting the competitiveness of important industrial and commercial sectors, and fostering low-carbon and environmentally friendly growth in Myanmar. The 2019 Global LEAP Awards succinctly stated, "Solar water pumps can play a significant role in delivering a sustainable water supply in an increasingly climate-sensitive world, all while reducing or preventing harmful greenhouse gas emissions and enhancing the incomes and resilience of rural households worldwide. This study aims to demonstrate the agricultural viability and economic viability of Myanmar's Dry Zone's solar pumping technology. The marginal profit of switching from diesel to solar has resulted in 100000 MMK per acre over the past 12 months, a 556 ton reduction in CO2 emissions, and 1499708 million in health benefits per acre. Environmental benefit is included in the BC analysis, which has a 12151504 million MMK NPV, 2.31 B/C ratio, and 25%. According to IRR, the solar pump is economically feasible and viable for the agricultural industry. Farmers in Myanmar's dry zone, like those in other parts of the country, deal with volatile crop prices and greater operating expenses. The government of Myanmar must establish stable market prices for crops and demands for farmers. Additionally, promote spending on renewable energy and assistance for Myanmar's dry zone farmers.

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About Author (s)

Khin Thu Thu Thein, Lecturer, Department of Applied Economics, Yangon University of Economics, Myanmar.

1. Introduction

In order to address societal challenges like the effects of climate change, the need to increase clean energy and reduce emissions, as well as the quick population and economic growth that has led to increased demands for food, water, and energy (Chel and Kaushik 2011; Xue 2017), renewable energies (wind, solar, geothermal, biomass, and hydropower) are expected to continue to grow. Due to the competitive benefits of renewables in agriculture and government measures to increase water, energy, or food security, energy and land usage are becoming more integrated (IRENA 2015). Low running or variable costs, modular design, relative dependability or durability, and the avoidance of emissions, pollution, or soil contamination from fossil fuels are all benefits of using solar panels. The 2015 Paris Agreement has pushed the development of renewable energies coupled with the need to decarbonize economies and lower global CO2 emissions.

The relative high initial investment costs, the need for toxic materials and rare minerals for PV panel production, which tend to produce waste that is harmful to the environment, the risk of groundwater over abstraction, which results in the depletion and degradation of groundwater resources, are all disadvantages of solar panels in farming. According to the FAO and GIZ (2015) and the UN (2015), sustainable agriculture is essential to attaining several of the sustainable development objectives, such as eradicating poverty and ensuring the security of food, livelihoods, and ecosystems. Energy technology social sustainability is discussed from a variety of angles in the literature, including social or public acceptance, social equality, and social effect (Assefa & Frostell, 2007; Bassi, 2015; Eva ns et al., 2009). The adoption of new energy technologies into society depends on public or social acceptance, which is influenced by variables including perceived costs, risks, and benefits, trust, and distributive fairness (Huijts, Molin, & Steg, 2012).

1.1 Description of the Study Area

The Dry Zone is a region in the center of Myanmar that is characterized by a shortage of water supplies, a limited vegetation cover, deteriorated soils, and significant erosion brought on by strong winds during the dry season and by irregular rainfall during the monsoon season. The agricultural systems in the Dry Zone are intricate; farmers raise both large and small livestock in addition to paddy and non-rice crops (such as pulses, oilseeds, cotton, tobacco, vegetables, and others). Small household plots are typically the only places where fruit and vegetables are grown, however certain villages do have commercial onion and chili farms. Primary evidence has been gathered from 6 townships in Myanmar's central Dry Zone, including Yamethin, Pyabwe, Thazi, Magway, Wudwin, and Mahaling, which rely on the distribution structure of service providers, to better understand the difficulties and opportunities that small-scale farmers face when using solar irrigation systems. Regions of the sample studies Yamethin and Pyabwe Township is a township in the Mandalay Region of Burma (Myanmar), in the Yamethin District. Yamethin is well-known for its fried tofu, grape orchards, abundant paddy fields, and excellent agricultural production rates. Magway Region is administrative divisions in central Myanmar. Magway Region’s districts are Magwe, Minbu, Thayet, Pakokku and Gangaw, comprising 25 townships and 1,696 ward village tracts. The major crops of Magway being seasum and groundnut. Other crops grown are rice, millet, maize, sunflower, beans and pulses, tobacco, toddy, chili, onions, and potatoes. Meiktila District is a district of the Mandalay Region in central Myanmar. Sesame is a major oilseed crop of Meiktila Township and 31 % of the gross cropped areas are occupied by sesame cultivated areas. The following table shows the number of respondents from each study area of our survey and percentage of installed base statistics.

Table 1: The number of respondents of the study area

	Survey	Installed Base	Major Crop Under Pump
Yametnin	59	50%	Grape ,Coriander plant
Meiktila	10	7%	Mango, Chili , Tomatoes
Mahaling	4	1%	Chili, Onion
Pyabwe	4	3%	Onion, Chili
Thazi	7	8%	Mango, Grape
Wudwin	8	4%	Flower
MinBu	8	9%	Mango
	100	82%	

Sources: Field Survey 2022

The survey took 82% of the total installed base area. The questionnaires led quantitative approach was adopted for objectivity. Generally open questions were used.

a) **The Status Quo Scenario**

The status quo Scenario current is the scenario that farmers in the dry region of Myanmar switched to solar electricity to irrigate their crops in an effort to increase the profitability of their land and enhance the positive externalities of solar pumps. The study region in Myanmar's Dry zone, where solar pumps were employed to increase the coverage of the schemes from 357.1 hectares to 420.3 hectares, demonstrates the transformational impact of these systems. All of the solar farmers used direct pumping over their plants and DC motor pumps with submersible pumps in wells. The status quo Scenario assume that the farmers from Myanmar dry zone adopted solar power for watering their crop in sense that they desire to expand the profit of their land and improve positive externalities of solar pump. The transformation impact of solar pumping system is evident in study area of Myanmar dry zone, where solar pump were used to expand the coverage of the schemes from 357.1 acreage to 420.3 acreage. All of solar farmers used DC motor pump with submersible pumps in a well and direct pumping over their plant. After they installed solar pump irrigation, farmers were able to grow at least three crops annually and rotate crops to grow a variety of nutritious and cash crops, including tomatoes, chilies, grapes, onions, flowers, vegetables, and mangoes, among others. This has given women more employment opportunities. Women's employment options have resulted in increased earnings and more dependable projected cash flows, ensuring that they can now make decisions independently and take care of their families' needs for food, education, and medical attention. In the case of the status quo, all respondents in the Myanmar Dry Zone indicated that they were completely satisfied with their usage of solar pumps for farming.

b) Behavioral change scenario

The 20–35% efficiency of diesel pumps for irrigation in Myanmar (Henderson 2019). According to our survey, the average cost of diesel at the pump is $240, plus an additional $300 on average every year (due to a sharp increase in fuel prices that will more than double in 2019 owing to lockdowns caused by the coronavirus). After only two to three years, farmers usually replace the fuel pump. Additionally, the diesel pumps need frequent maintenance (such as oil, filter, coolant, and refueling replacements), which causes crop failure during the idle period. Some farmers used a shared system to rent the diesel pump during the dry season. Grapes, onions, coriander plants, onions, chili plants, vegetables, and flowers are some of the major crops grown near diesel pumps. Due to increased fuel costs that could affect their ability to profit from their land, the majority of farmers wish to switch from diesel to solar pumps in their farming operations. However, they are hesitant to embrace solar pumps because they lack the necessary funds (high installing costs), lack expert knowledge regarding solar pumps, and are wary of embracing new technologies. They anticipated receiving financial assistance from government initiatives, long-term credit, or loans, which are frequently required to get through the initial capital cost barrier connected to solar irrigation systems.

2. Literature Review

A decoupling of the growth of pumping land areas from the use of fossil fuels is possible with solar-based pumping systems, which may be scaled to satisfy a variety of energy demands while enhancing livelihoods. This section examines the major socioeconomic and environmental benefits of solar-powered irrigation systems, building on case studies from various projects. Before people are ready to invest in the technology, there needs to be a better understanding of renewable energy. Before people are ready to invest in the technology, there needs to be a better understanding of renewable energy. Technological innovation has been seen as a crucial element in business and economics (Jain, 2018). Verbruggen (2010) provides a detailed analysis of the economic, technological, socioeconomic, physical, and market potentials of renewable energy. A new market could lead to the production of more jobs for the economy, as well as fewer market failures, different lifestyles, new technologies, and a more environmentally friendly environment for future generations. The first study on WTP for adopting renewable energy in Myanmar was carried out by Numata et al. in 2021. In this study, electricity generation by biomass, small hydropower, and solar photovoltaic plants was examined. The results revealed lower WTP for biomass and small hydropower electricity generation (USD 1.13 and USD 1.17, respectively) and higher WTP for solar power (USD 1.92) with 10% share in the energy mix.

The economic viability and feasibility of deploying PV solar energy in the State of Kuwait were investigated by Ramadhan & Naseeb (2011). The true economic cost of LCOE of a PV system will decrease dramatically, per their cost-benefit analysis, once the value of energy resources saved from producing conventional power and the cost of reducing CO_2 emissions are taken into consideration. In a drip irrigation system with micro tubes, Alves et al. (2014) compared the water pumping expenses of an electric motor supplied by solar energy and a diesel motor. They discovered that the solar-powered lift system for pumping water had a higher initial investment cost but a lower overall cost. When compared to a lift powered by diesel, the solar-powered lift is more financially feasible. The analysis of the expenses of water pumping systems was based mostly on the pumping cost. According to Hossain et al. (2015), solar pumps for sustainable irrigation in Bangladesh are feasible. They claimed that after five years, the solar pump's life cycle cost was less than the cost of a pump powered by a diesel engine. Solar pumps were found to have greater benefit-cost ratios, net present values, and internal rates of return than diesel-powered pumps. A solar irrigation pump is an environmentally benign irrigation device compared to a diesel engine-powered irrigation pump that releases carbon dioxide and pollutes the environment. By utilizing straightforward random sample procedures, Singh et al. (2017) investigated the usage of solar energy in agriculture for increasing farmers' income in north-western Rajasthan. 124 sample farmers provided the main data, which were gathered. Their research indicates that solar tube wells offer farmers significant financial and water-saving advantages, and that solar tube well investment at the current rate of subsidy has been shown to be feasible. An overview of the agricultural situation, the conventional pumping method, and the potential for solar pumping in Bangladesh are presented by Islam et al. (2018). They came to the conclusion that because most farmers in Bangladesh are impoverished and the country lacks adequate energy, solar irrigation could be beneficial to both individual farmers and Bangladesh's overall crop production. For Jordan's vulnerable water basins, Lahham & Al-Saidi (2019) investigated solar energy farming as a development innovation. This article analyzes a project from the Azraq Basin in Jordan and gives comparative examples from other countries, especially India. From the water-energy-food nexus perspective, it evaluates solar energy farming as an innovation incorporated into the design of sustainable agricultural and food-related industrial systems.

A standalone solar water pumping system for rural areas in Myanmar's dry region was investigated by Cho et al. (2019). The main objectives are the computed costs of the more economically advantageous solar pumping system designs and the potential for optical concentration to lower the cost of solar water pumping systems, both of which have been mentioned on several occasions. This study found that PV power pump systems provide simplicity, dependability, and low maintenance for a variety of applications, ranging from small hand pumps to substantial generator-driven irrigation pumps. In rural areas of the Sagaing region, Khin et al. (2019) investigated the cost of solar pumping and the development of solar pumping technology. They applied a method of cost estimation. They discovered that solar water pumping systems are extremely advantageous since, once the system is installed, the energy is almost free.

3. Methodology

CBA may be carried out at many stages of a project's or policy's life cycle. CBA compares a proposed project or projects with a project that wouldn't be pursued (or displaced) if the project(s) under consideration were to move forward. We need a mechanism to combine the advantages and expenses that come over time for a project whose effects span years. In a CBA, present values (PV) of future benefits and costs are calculated by discounting them in relation to current benefits and costs. The net present value (NPV) equals the present value of benefits (PV (B)) minus the present value of costs (PV(C)).

$$NPV=PV(B)-PV(C) \quad (1)$$

If the proposed project's NPV = PV (B) PV (C) > 0—that is, if its (incremental) benefits outweigh its (incremental) costs—the analyst should advise moving forward with it: The study's 10-year solar panel lifespan is used to determine the net present value of two projects. Sensitivity analyses are therefore a crucial CBA step for figuring out how sensitive the NPV is to changes in important factors. To independently undertake the analysis of the Project's resistance to changes in each variable.

$$SI = \frac{dNPV/_{NPV}}{dv/_{V}} = \frac{(NPV_b - NPV_s)/_{NPV_b}}{(V_b - V_s)/_{V_b}} \quad (2)$$

Where SI = Sensitivity indicator

dV = Net change in a key variable

$NPVb$ = Value of NPV in the base case

$NPVs$ = Value of NPV in the sensitivity test

Vb = Value of a key variable in the base case

Vs = Value of a key variable in the sensitivity test

$$SV = (1/\ ) \times 100 \quad (3)$$

The project is 'sensitive' to the variable if the SI value is greater than 1. When the SI value is less than 1, however, it is 'insensitive' to the variable. The project is 'neutral' to the variable if the SI is equal to 1. In other words, a larger SI value indicates that the project's risk depends more on the variable than it does on the NPV. An indicator of the SI, or the percentage change in a variable required for the NPV to be zero, is referred to as a switching value (SV). The project is vulnerable to the variable if the value of SV is less than 100%. The project is insensitive to the variable if it is more than 100%. According to the CBA's findings, the option with the biggest net benefit is the best one for the research; however the sensitivity analysis reveals that the option with the highest NPV isn't always the best one. Using the CBA results as a foundation, propose suitable policies for the relevant study.

Data Collection

According to the number of installed pumps in each township, 100 farmers from Yamethin, Pyabwe, Meiktila, Thazi, Wudwin, and Mahlaing townships in the Mandalay region and 100 farmers from Minbu in the Magway region were chosen to study the cost and benefit factors of the farmers. Due to the region's dispersed spatial distribution, 90% of survey participants were surveyed using questionnaires on their farms, and the other 10% were contacted by phone. These 200 sample farms served as the major source of information for the 2020–2021 study. Interviews were conducted with 59 respondents in the Yamethin Township (7 villages), 10 respondents in the Meiktila Township (5 villages), 4 respondents in the Pyabwe Township (1 village), 8 respondents in the Wudwin Township (3 villages), and 8 respondents in the Minbu Township (3 villages), respectively.

Group 1: These 200 sample farms served as the major source of information for the 2020–2021 study. Interviews were conducted with 59 respondents in the Yamethin Township (7 villages), 10 respondents in the Meiktila Township (5 villages), 4 respondents in the Pyabwe Township (1 village), 8 respondents in the Wudwin Township (3 villages), and 8 respondents in the Minbu Township (3 villages), respectively. These farmers used the Agro Solar method to irrigate their agricultural area. Submersible centrifugal solar pumps are offered by the solar pump design so that farmers can save time and energy. The majority of farmers made upfront purchases. Studies have shown that replacing diesel water pumps with low-cost solar pumps can save smallholder farmers up to half (Chandel et al. 2015) to one-fourth of the cost over a 20-year lifespan.

Group 2: The second group included the diesel used farmers from the same location. The interview focuses on the outweigh cost over benefit from diesel pump; verify the determinants influence on the diesel used farmers change from traditional practices to modern practices. The major plants with diesel covered fruit trees and vegetables under 266 acres. The initial investment of diesel pumps cheaper than the solar pump. But they incurred maintenance cost and fuel cost over to run the pump. Currently the majority of respondent's desire to change solar pump due to slightly higher in fuel cost. The higher initial investment is the main barriers. The farmer afraid to get require service professionals and installation service which is rarely in rural areas. They believe that if a solar system is not installed or constructed properly, they will lose money and return to utilizing the comfortable and well-known diesel pumps.

Table: 1 - Land use Pattern of Myanmar Dry Zone under Pump Unit (million MMK)

No	Crop Type	Total Acreage	Total Revenue (MMK)	Average Revenue (MMK)	Total Cost (MMK)	Average Cost (MMK)
1	Grape	313	754,760,000	2,411,373	270,505,000	864,233
2	Onion	60.5	108,955,000	1,800,909	201,194,000	3,325,520
3	Mango	62	39,800,000	641,935	67,854,000	1,094,419
4	Chili	55	79,322,000	1,442,218	33,768,600	613,974
5	Paddy	40	25,330,000	633,250	12,992,100	324,802
6	Coriander Plant	77.8	259,892,500	3,340,520.	136,769,400	1,757,961
7	Tomatoes	14.5	38,690,000	2,668,275	7,811,500	538,724
8	Papaya	11	5,160,000	469,090	300,000	27,272
9	Tragacanth Gum Herb	7	10,000,000	1,428,571	500,000	71,428
10	Maize	13	3,380,000	260,000	4,055,000	311,923
11	Flower	20.3	35,990,000	1,772,906	20,808,000	1,025,024
12	Sunflower	9	21,750,000	2,416,666	881,000	97,888
13	Green germ	6	2,600,000	433,333	485,400	80,900

Source: Survey Data 2022

Note: 1USD= 2120 MMK

According to the survey study, grapes are grown on 23% of the parcels with solar pumps and 18% with diesel pumps. The coriander plant, which accounts for roughly 9% of solar pump parcels and 16% of diesel pump parcels, is the next significant revenue crop of two pumps.The other significant crop, such as chilli, paddy, and onion, accounts for 7%, 5%, and 4% of the solar pump, respectively. Paddy is a subsistence crop for both communities, and all farmers who were surveyed said that fruit and vegetable growing are now their main sources of income. The majority of the two communities' land use patterns are do The above table displays the net revenue per acre for each crop, which is calculated by subtracting the total revenue from the total operation costs but including capital costs.

Using this method, the previous year's tomatoes had the highest net profit per acre, followed by coriander plants and grapes. Although their productivity remained unaffected, the price of onions was extremely low, and as a result, farmers suffered losses. 95 percent of the households in the sample that owned or operated agricultural property produced one or more of the 13 crops that are primarily grown in the Dry Zone. There were typically 3 crops planted each household, with an annual crop count ranging from 1 to 8. Sesame, paddy, peanuts, pigeon pea, chickpea, green gram, sorghum, as well as tree fruit and vegetable, flower, and long-term crop under pump, are the most extensively planted crops. 21% of the parcels are cultivated for this cash crop by grapes.

4. Result and Discussion

4.1 Abatement of carbon emissions

When compared to electric or diesel pumps, both of which are very carbon intensive, the usage of solar pumps might dramatically reduce greenhouse gas emissions as well as other pollutants (Vasilis M. Fthenakis, Kim, & Alsema, 2008; Gopal, Mohanraj, Chandramohan, & Chandrasekar, 2013). In the case of a PV station, there are three to six panels, each rated at 375W. Approximately (8–10–15 lb) less CO2 will be released into the atmosphere each day. When operated for 8 hours per day and priced at $34.99/ton, reducing CO2 emissions costs between $47 and $94 annually (or roughly 5.20 kwh/year). This number accounts for the health benefit per kilowatt-hour from CO2 emission reduction. Each solar panel is thought to provide an annual health benefit of $85 (Table - 2).

Table -2: Reduction in CO2 emissions by the PV system

Station Types	No of Panels	Output per panels(w)	Output per day(kwh)	CO2 emission per day(factor=0.846lb)	Value of CO2 emission per year ($34.99/ton)
PV	3	375	9	7.61	47.42
	4	375	12	10.15	63.23
	6	375	18	15.22	93.65

4.2 The Economic Costs and Benefits in the converting Diesel pump to Solar pump

The profit that can be made from switching from a diesel pump to a solar pump is the revenue generated by the solar pump. The financial report for solar and diesel pumps for agricultural revealed the categories of the following direct costs and benefits: 1) Installation cost, 2) Maintenance cost, 3) Operation cost, and 4) Crop sales revenue. According to the table below, the total project costs for the solar pump are anticipated to be 5062 million MMK, compared to 330 million MMK for the diesel pump.

Maintenance expenses, operating expenses, crop sales revenue, and so forth. According to the table below, the total project costs for the solar pump are anticipated to be 5062 million MMK, compared to 330 million MMK for the diesel pump. Both types of pumps benefited from the sales revenue from crop sales in the interim. The solar pump's revenue was 887 million MMK more than the diesel pump's 524 million MMK.For the case study, 12964 gallons of gasoline are required annually for irrigation at a cost of 5064 MMK per gallon in 2021, which equals 65659100 MMK in fuel expenses alone (excluding transportation costs). The projected annual maintenance cost is 9594100MMK. A 13 kW diesel pump has a capital cost of 50782000 MMK, but its lifespan is just 2 years, as opposed to the solar pump's lifespan of 5–10 years, which can water 266 acres of vegetables.

Table 3 - Summary of Cost and Benefit Estimated for Solar Pump and Diesel Pump

Unit (million MMK)

		Solar Pump (MMK)	Diesel Pump (MMK)
Benefit	Revenue	887	524
Cost	Installation cost	149	
	Maintenance cost	0	9
	Operation cost	356	206
	Fuel Cost	0	65
	Total operation cost	506	330

Source: Field Survey 2022
Note: All figures rounded to the nearest million. 1 USD = 2120 MMK

Although the initial cost of a solar pumping system was found to be three times greater than that of a diesel pump, once the pump was installed, fuel and maintenance costs were reduced. Then the farmers expanded the crop cycles and the farmed land, which led to an increase in their income. Solar is expected to generate a profit per acre of 1300000 MMK as opposed to diesel's predicted profit of 1200000 MMK. Solar energy was 0.58 times less expensive to operate than a diesel pump. Due to the service provider's provision of a 2-year pump warranty, the maintenance cost for solar panels is listed as nothing. Assume that for the entire impacted region (13440063 acres), the installation cost per acre of 354761.9048 MMK will remain constant. According to numerous real-world case studies, smallholder farmers increased their profits by switching from diesel to solar irrigation by doing so because doing so reduced labor costs for operating the pump, fuel costs, maintenance, increased yield of at least 50% up to 300% (Kirby 2020) by being able to afford to irrigate their crops fully (as most can only afford to do so), eliminated evapotranspiration losses, along with reduced loss of downtime when the diesel pump was necessary. Farmers that switched to solar irrigation also gained additional time and resources to maybe launch another enterprise. "Using tiny canoes to transport a lot of gasoline and repair parts for the pumps has significantly simplified our lives thanks to solar energy. We now simply visit to observe how much the plants have grown; otherwise, we truly have nothing to worry about (Seal, 2020).

The energy consumed in power plants to create electricity makes up a significant portion of the pollution cycle. The cost associated with the environmental effects of conventional fuels is very significant and may be of a similar order of magnitude in operation cost estimates. The CO_2 saved emissions of the planned SPIS were estimated in this study to be 556 lbs per acres for the previous year. A reduction in CO_2 of 3740427 tons would result from replacing the solar pump on the entire 13440063 acres of the Myanmar Dry Zone. The amount of CO_2 emissions that were prevented in the preceding years was 277460 million MMK.

Table 4 - Value of CO2 Avoided Emission

Diesel Fuel per acres (liter)	219
kwh per acre (l liter generate 3 kwh)	657
CO2 (lbs) per acre (co factor =0.846/kwh)	556
Total CO2 from total affected area (Tons) (CO2 reduction) / years	3740427
Value in dollars 34.99 per tons	130877561
Value in million MMK ($1= 2120 MMK)	277460

In case of health benefit per kilowatt hours, the switching of solar pump was generating 1499708 MMK for the whole Myanmar Dry Zone (13440063 acres) valuing with EPA's benefit per kwh values.

Table 5 - Value Health Benefit Estimation of Solar Pump

kwh per acre from Fuel (liter)	657
total kwh per year of affected area	8842618445
Health Value in million dollar $0.08/kwh	707.41
Health Value in million MMK ($1= 2120 MMK)	1.5

Source: Author Calculation

The overall project cost in this scenario would be identical to the CBA results with no external impact. In our CBA study, we also considered indirect benefits from reducing CO2 emissions and health benefits.

4.3 **Economic Analysis**

From the net balance of the costs and benefits, the NPV is 12151504.06 million MMK which is considered to be economically viable because the NPV is above zero. With the NPV calculation, results of the CBA of the project is summarized (Table 6). The B/C Ratio is calculated at 2.31, which is greater than 1and it analyzed as having economic feasibility. Meanwhile, the EIRR is analyzed as 25% which is larger than the discount rate, 6%. Therefore, it would be concluded to approve the suitable case.

Table 6 - The Summary of CBA Results for the Solar Pump with environmental impact

NPVat the discount rate 6%	12151504.06 million MMK
IRR	25%
B/C Ratio	2.31

Source : Author Calculation

The consulting program assumed that the project cost might increase by 20% (2) the project marginal benefit might decrease by 20% or (3) the project cost might increase by 20 % and the project benefit might decrease by 20%.

Table 7 - Sensitivity Analysis for the Solar Pump with environmental impact

Variations of Factors	NPV (million MMK)	EIRR (%)	B/C Ratio	SI	SV (%)
Base Case	12151504.06	25	2.31	-	-
20% Decrease in Marginal Profit (Case 1)	11743077.47	24	2.27	*3.74*	*27*
20% Increase in Cost (Case 2)	10298272.73	18	1.93	-0.76	-131
Case 1 + Case 2	9889846.145	18	1.89	*0.26*	384

Source: Author Calculation

The results indicate that the projects are sensitive to change in the marginal benefit because the SI values is more than 1 and the SV values are less than 100% (See Italic value in the Table 7). The variations do not, however, affect the projection choice because the EIRRs remain above the discount rate, indicating economic viability. Because the sign of the net benefits remained unchanged, the outcome of the sensitivity analysis demonstrated that the cost-benefit analysis was reliable. The efficiency switching diesel to solar pump was seen in the CBA show that the solar pump project an unfeasible investment when excluded the environmental benefit. Environment benefits have a positive NPV 10619359 million MMK using 6% discount rate which is economically feasible added environment impact. B/C ratios 2.5 more than 1 stated that environment increase the net benefit of solar pump. EIRR 22% which is favorable considering the higher the rate of return, the more potential of profitability the investment has. The payback is then the number of years for the sum of NPV to break-even with the initial investment and is found to be 4.5 years. Another study found SPIS for medium-sized systems have paybacks of about 2-3 years with small systems in as little as 18 months.

Conclusion and Policy Implications

The results of our analysis point out that the farmers from Myanmar Dry Zone overcome the pressure of water deficiency with the help of solar pumping system with no operation cost.A financial analysis of the solar irrigation system's 10 year liferesulted in a NPV of 12151504 million MMK with a 6 % discount rate, IRR of 25% with the impact of enviornmental impact.The total benefit of 37 million tonnes of CO2 avoided over its 10 year life or 15% of Myanmar's total emissions reductions 244.52 million t CO2e uncinditionally (Myanmar National Determined Contribution,2021), if all diesel irrigation pumps (total 13440063 acres) in Myanmar Dry Zone were replaced with solar pump. The marginal benefit of converting diesle pump to solar pump was 100000 million per acres.After using the solar pump system, the cropping changes include starting cash crop such as fruit tree, flowers, vegetables and coriander plant, all of which can make profit in short term and changes in land use, to grow cash crops that require steady control over water. An increase in crop cycles, up to 2 to 10 cycles per year, has also been observed. As a result social benefit from land by using solar energy in farming have positive impact.

Farmers in the Myanmar Dry Zone have previously experienced uneven and harmful water distribution, which has made the region's dry conditions even worse. Rain-fed agriculture is an unreliable growth strategy because of the limited and irregular precipitation, but the Dry Zone's great majority of farmed area currently relies on it. Additionally, it is predicted that climate change would lengthen the dry season and increase the water-related pressures that are already endangering livelihoods. Additionally, it is predicted that climate change would lengthen the dry season and increase the water-related pressures that are already endangering livelihoods. From 8 AM to 5 PM, the solar pump system may pump water for cultivation, meeting the plant's water needs.

The drawback of using a solar pump for farming is that it is more physically demanding than using a diesel pump because farmers are working within in the sun. Nevertheless, as a result of the increased crop acres and crop cycles, women from the Myanmar Dry Zone have more employment opportunities compared to before.

According to CBA results with external consequences, the Myanmar government must encourage all diesel farmers in the Myanmar Dry Zone to switch over to solar-powered pumps. One of the government of Myanmar's many long-term plans and objectives is the improvement of renewable energy in rural areas. The high initial cost and skepticism regarding the effectiveness of solar pumps are the main barriers to their implementation.
Small farmers are collaborating daily with Agrosolar's growing local team of sales representatives, technicians, and support staff to help them overcome the challenges of farming. Agrosolar Myanmar helps 30 farmers from the Meiktila area by providing these potential clients with a $ 250 donor subsidy. The overall cost of the system will be reduced by 1/3 as a result. The subsidy will replace the down payment for these 30 customers, allowing them to stop paying for diesel fuel and reinvest their savings in their business. With these money, the farmers would be able to pay back their debts in 4 instead of 8 months (Agrosolar).

In order to provide economic opportunities, government policies must direct the private sector, such as Agrosolar and INGO, which can assist in the development of farmer groups that enhance their access to essential services. To achieve these goals, the Myanmar government must place a higher priority on agricultural spending when allocating public funds, and local government agencies must have the necessary resources and authorization to respond to farmer-identified trials by providing allowance services and financing. Then, promote more public and private investment in the agricultural sector, on which the bulk of the population depends.

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