Upscaling Lowland Rice Production to Improve Food Security through Improved Solar Powered Irrigation Practices

AFCIA 2021000017

Enabling Environment Roadmap and Monitoring & Evaluation Framework (Output 6)

Prepared for:

Climate Technology Centre & Network (CTCN), MoA & EPA

May 2024

C21081.LD0162

Upscaling Lowland Rice Production to Improve Food Security through Improved Solar Powered Irrigation Practices

Output 6: Enabling Environment Roadmap and Monitoring & Evaluation Framework

This document has been issued and amended as follows:

Issue	Revision	Date	Description	Prepared by	Checked by	Approved by
1	0.0	29/02/2024	Draft for Comment	OT	AK	OT
2	0.1	13/05/2024	Final	OT	AK	OT

Contents

Tables

Figures

Acronyms and Abbreviations

AfDB	African Development Bank
AIICO	Agriculture Infrastructure Investment Company
AWD	Alternate Wetting and Drying
BMZ	German Federal Ministry for Economic Cooperation and Development
CAC	County Agriculture Coordinator
CAO	County Agriculture Officer
CARI	Central Agricultural Research Institute
CBO	Community-Based Organization
CHAP	Community of Hope Agriculture Project
CTCN	Climate Technology Centre and Network
DAO	District Agriculture Officer
DOA	Department of Agriculture
EIA	Environmental Impact Assessment
EPA	The Environmental Protection Agency of Liberia
FAO	Food and Agriculture Organization of the United Nations
FDMC	Fuamah District Multipurpose Cooperative
FED	Food and Enterprise Development Programme
FFS	Farmer Field Schools
FUN	Farmer Union Network
GAP	Good Agricultural Practices
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoL	Government of Liberia
IPM	Integrated Pest Management
LIGIS	Liberia Institute of Geo-Information Services
LNRDS	Liberia National Rice Development Strategy
M&E	Monitoring and Evaluation
MICAT	Ministry of Information, Cultural Affairs & Tourism
MGD	Ministry of Gender and Development
MoA	Ministry of Agriculture
MoE	Ministry of Education
MoF	Ministry of Finance
MICAT	Ministry of Information, Cultural Affairs & Tourism
MoYS	Ministry of Youth & Sports
NDE	National Designated Entity
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance

OPIC	Overseas Private Investment Corporation
PAEGC	Powering Agriculture: An Energy Grand Challenge for Development
PV	Photovoltaic
RAC	Region Agriculture Coordinator
Sida	Swedish International Development Cooperation Agency
SPIS	Solar Powered Irrigation Systems
SRI	System of Rice Intensification
SWG	Stakeholder Working Group
TA	Technical Assistance
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization (UNIDO)
USAID	United States Agency for International Development
WAAPP	West Africa Agricultural Productivity Program
WARDA	West Africa Rice Development Association
WE4F	Water and Energy for Food
WUA	Water Users Association

1 EXECUTIVE SUMMARY

1.1 Background and Objectives of this Report

The objective of the Technical Assistance (TA) is to introduce SPIS technology and SRI practices by implementing a pilot scheme in one lowland county, with the intention of later upscaling at a national level. This report provides an update on work conducted to provide Outcome 6, covering the design of an M&E Framework (Chapter 3), formulating an enabling environment roadmap to scale up the use of SPIS and SRI (Chapter 4) and the workshops to present these to municipal and national officers and train the rice farmers.

1.2 Monitoring & Evaluation Framework

The M&E Framework has been designed in the format of simple Excel spreadsheets to monitor and report on SPIS and SRI operations, providing the information required to manage and regulate the schemes, reducing the risk of unsustainable water use, ensuring the benefits of reducing dependency on carbon fuels and enhancing access to water and energy.

The M&E Framework consists of four key areas that enable the rice farmer(s) to monitor the implementation of this technology and SRI production:

- Agricultural Production
- Water Management
- Energy Generation
- Maintenance Activities.

1.3 Enabling Environment Roadmap

An enabling environment roadmap has been defined, including recommendations about financing mechanisms and other key aspects, that could support the country in scaling up the use of SPIS and SRI technologies across Liberia. The elements of this enabling environment roadmap are summarised below and discussed further in the report.

1. Policy Development and Advocacy	
Create a supportive legal framework	Develop and implement policies that encourage and support the adoption of Solar Powered Irrigation Systems (SPIS) and Systems of Rice Intensification (SRI).
Incentives for adoption	Provide financial incentives, subsidies, and tax breaks for farmers and businesses adopting SPIS and SRI practices.
Advocacy and awareness campaigns	Conduct awareness programs to educate farmers, local communities, and policymakers about the benefits of SPIS and SRI.
2. Capacity Building	
Training programs	Establish training programs for farmers on the installation, operation, and maintenance of SPIS and the principles of SRI.
Extension services	Strengthen agricultural extension services to provide ongoing support and guidance to farmers adopting these technologies.

Educational initiatives	Integrate information on SPIS and SRI into agricultural curriculum at educational institutions.
3. Infrastructure Development	
Technology dissemination	Establish further demonstration farms and pilot schemes showcasing successful implementation of SPIS and SRI to encourage widespread adoption.
Access to finance	Facilitate access to affordable finance for farmers and businesses to invest in SPIS and SRI practices.
Rural electrification	Invest in rural electrification solar, mini-grid projects to enhance the availability and reliability of electricity for powering irrigation systems.
4. Research and Development	
Local adaptation	Support further research on adapting SPIS technology and SRI principles to local climatic and soil conditions.
Innovation hubs	Establish innovation hubs to foster collaboration between researchers, technology developers, and farmers for continuous improvement and innovation.
Monitoring and evaluation	Implement the monitoring and evaluation framework to assess the impact of SPIS and SRI on agricultural productivity, water use, and income generation.
5. Market Development	
Market incentives	Introduce market incentives for the installation of SPIS and production/sale of rice grown using and SRI practices.
Value chain development	Strengthen agricultural value chains to ensure a smooth transition from production to market for farmers adopting these technologies.
Public-private partnerships	Encourage partnerships between government agencies, private sector entities, and NGOs to facilitate the deployment and maintenance of SPIS schemes.
6. Environmental Sustainability	
Resource management	Promote sustainable water use practices through the implementation of efficient techniques, such as drip irrigation and Alternate Wetting and Drying (AWD).
Climate-resilient practices	Integrate climate-resilient agriculture practices and continuous research within the framework of SRI practices to enhance long-term sustainability.
Environmental impact assessment	Conduct regular assessments to monitor and mitigate any adverse environmental impacts of SPIS and SRI practices.
7. Community Engagement and Social Inclusion	
Community involvement	Involve local communities in decision-making processes, project design and implementation to ensure social acceptance and ownership.

Gender inclusion	Promote gender-inclusive policies and programs to ensure that both male and female farmers benefit equitably from SPIS and SRI initiatives.
Social safety nets	Deploy social safety nets to protect vulnerable individuals and communities from potential negative consequences as a result of SPIS development and new agricultural practices.
8. Regulatory Framework	
Standards and certifications	Develop and enforce standards for the quality and performance of SPIS and SRI practices to ensure reliability and efficiency.
Regulatory compliance	Establish mechanisms to ensure that all actors in the sector comply with relevant regulations and guidelines.

1.4 Workshops and Training

Workshops with municipal and national officers, and the rice farmers at the Bong Mines pilot scheme, were planned to present the M&E framework and enabling environment roadmap, and to reiterate the O&M activities to be carried out. The committee members of the Fuamah District Multipurpose Cooperative (FDMC) were to be trained on the objectives and data collection methods for the M&E framework, but due to the partial theft of the SPIS equipment from the Bong Mines Pilot scheme in March 2024, this event was not realised. The presentation and training materials are presented in the Appendices.

1.5 Conclusions and Recommendations

The M&E Framework proposed in this report aims to collect the data on the SPIS infrastructure and SRI practices to ensure that the system is run and maintained effectively and that rice production is undertaken efficiently. The focus is to ensure that unsustainable water use is avoided and to regularly and systematically report on the following:

- Water
- Energy
- Maintenance and repairs
- Agricultural production
- Other aspects, such as the empowerment of women and youth.

The Enabling Environment Roadmap provides a starting point for a process of policy dialogue, to use the information collected through the M&E Framework and further in-depth studies to prioritise issues and prepare action plans to enable scaling-up of Solar Powered Irrigation Systems (SPIS) and Systems of Rice Intensification (SRI) in Liberia.

2 INTRODUCTION

2.1 Background

Agriculture is a major sector of Liberia employing more than 70% of the population. However, Liberia's agriculture system is predominantly rain-fed, with heavy dependence on consistent rainfall, and climate change is posing serious challenges to all sectors and is threatening the sustainability of agricultural production. This is happening prior to Liberia recovering from 14 years of civil conflict, global recession, Ebola, and now the COVID-19 pandemic.

In response, the adoption of Solar Powered Irrigation Systems (SPIS) and a System of Rice Intensification (SRI) is being investigated to increase rice yields whilst lowering water usage. Potential benefits of adopting this irrigation technology includes guaranteeing yields in an increasingly dry climate, where there is a lack of natural soil moisture, and reducing energy consumption as a climate change mitigation; whilst also reducing water consumption and avoiding the production of CO_2 and pollution from fossil fuel driven pumps.

2.2 Objectives and Scope of this Report

Against this background, the objective of the Technical Assistance (TA) is to introduce SPIS technology and SRI practices to increase rice production in one lowland county in Liberia (Selected as Bong County), with the intention of later upscaling at a national level. To achieve this, the TA is divided into six outcomes, as follows:

Outcome 1: Analyse the current irrigation and rice cultivation practices in one county of Liberia.
Outcome 2: Design appropriate irrigation and solar water pumping technologies for SRI based farming in the selected county.
Outcome 3: Select an appropriate SPIS technology.
Outcome 4: Pilot a small-scale implementation of the solar pumping system in the selected county.
Outcome 5: Elaborate and disseminate training materials and workshops.
Outcome 6: Formulate an enabling environment roadmap and a M&E framework.

This report provides an update on work conducted to provide Outcome 6, covering four activities, as follows:

Activity 6.1: Design a M&E Framework
Activity 6.2: Formulate an enabling environment roadmap to scale up the use of SPIS
Activity 6.3: Organize a workshop with municipal and national officers to present the M&E and enabling environment roadmap
Activity 6.4: Train rice farmers on the M&E framework.

2.3 Introduction to Solar Powered Irrigation Systems (SPIS)

A Solar Powered Irrigation System (SPIS) is like any other irrigation system, except its power source comes from the sun. An SPIS can be divided into three components:

1. **Electrical System**, including:
   - Solar (PV) panels, mounting structures
   - Controller (Usually Maximum Power Point Tracking – MPPT)
   - Pump (DC or AC, variable motor speed and pump volume)
   - Electrical cables
   - Optional extras:
     - Monitoring system (Volume, Timer etc)
     - Alternative energy uses (Rice mill etc)
     - Energy storage (Batteries)
     - Mini-Grids and Hybrid systems
     - Security fencing.
2. **Irrigation System**, including**:**
   - Water storage (Tanks, reservoirs)
   - Distribution network (Pipelines, canals)
   - Application method (Surface, Overhead or Drip)
3. **Agriculture System** including (As described in Section 3.2 Introduction to the System of Rice Intensification):
   - Crop/seed variety
   - Land selection and preparation
   - Methods of cultivation:
     - Planting and transplanting
     - Weed and pest management
     - Application of fertilizers and other chemicals
     - Water / irrigation management
   - Harvesting, processing and marketing.

Water from the source, such as groundwater (e.g. wells or boreholes) or surface water (e.g. pond, lakes, rivers or reservoirs) is pumped through a rising main to the fields. The energy to drive the pump is provided by the solar panels. In some systems water is stored in an elevated tank to enable irrigation at any time of the day, but the simplest systems only operate when the sun is shining. Based on the preferred method of irrigation for the crop to be grown, the water is applied to the fields either by gravity/flood/surface irrigation, overhead/pressurised sprinklers or through low pressure drip lines to all parts of the irrigated area (See Figure 1).

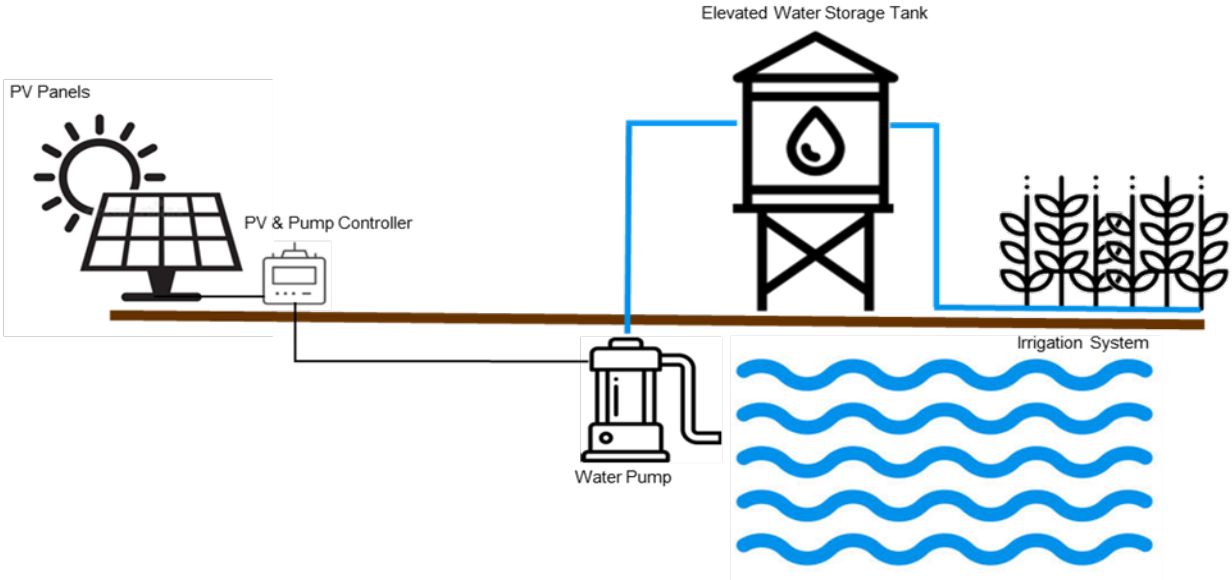


Figure 1: Simple SPIS System

A pilot SPIS has been installed at Bong Mines, Bong County, representing the simplest configuration, without the elevated water storage, but with the capability of using any excess generated power for alternative uses (Rice mill etc). Details can be found in the Bong Mines Pilot Scheme - Operation & Maintenance Manual (Output 5).

2.4 Introduction to System of Rice Intensification (SRI)

A System of Rice Intensification (SRI) was proposed to be used in conjunction with the pilot SPIS, including the choice of seed and a suite of best practices for growing healthy rice and efficient water management. SRI for successful rice production, as a business, encourages farmers to develop a plan for what to plant (i.e. Crop/seed variety), where to plant (i.e. Land selection and preparation), how to cultivate (i.e. Methods of planting and transplanting, weed and pest management, application of fertilizers and other chemicals), water / irrigation management by Alternate Wetting and Drying (AWD), and how best to sell the produce (i.e. Harvesting, processing and marketing), as described in the Bong Mines Pilot Scheme - Operation & Maintenance Manual (Output 5).

Activities	January				February				March				April				May				June	
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2
Land preparation 1	X	X																				
Application of organic manure			X																			
Land preparation 2			X																			
Application of full dose of P			X																			
Levelling				X																		
Nursery preparation				X	X																	
Planting						X	X															
Gap filling								X	X													
Need based N as per LCC											X		X		X							
Application of Potash											X					X						
Mid season drainage											X	X										
Weeding by Cono weeder										X	X	X	X									
Pest and Diseases Management										X			X									
Bird scaring																		X	X	X	X	
Pre harvest operations																			X	X		
Harvest																					X	X

Figure 2: Typical SRI Rice Production Activities

3 MONITORING & EVALUATION FRAMEWORK

Technical information is needed to ensure that new SPIS infrastructures are run and maintained effectively, ensuring that the low energy costs do not lead to wasteful water use, over-abstraction of groundwater and low field application efficiencies. A Monitoring and Evaluation (M&E) framework has been designed (in the format of simple Excel spreadsheets) to monitor and report on SPIS operations, providing the information required to adequately manage and regulate the schemes, thereby reducing the risk of unsustainable water use and ensuring the aims are met of reducing dependency on carbon fuels and enhancing access to water and energy.

The M&E Framework consists of four key areas that enable the rice farmer(s) to monitor the implementation of this technology for SRI production:

- Agricultural Production
- Water Management
- Energy Generation
- Maintenance Activities.

Ideally, the data would be collected at the schemes by the farmers and entered directly into the spreadsheets and uploaded for analysis by the Ministry of Agriculture (MoA), but currently the FDMC do not have such facilities, so the management committee would enter the data onto hard-copy forms to be collected, collated and analysed on a quarterly and annual basis by the MoA.

3.1 Agricultural Production

Table 1 below collects and collates seasonal agricultural data on the farm, cultivation practices and the costs and income from these activities. Recording and quantifying this information will enable the farmers to monitor the performance of the farms on the scheme and evaluate some key parameters, as follows:

- Increase/Decrease in the quantity of rice production (i.e. Total and Rice Yield, kg/ha)
- Improvement/Changes in harvest quality (i.e. 1000 grains weight and Rice price/kg)
- Frequency of rice cultivation (i.e. 2 or 3 times annually) and the diversity of other crops grown, with associated benefits for food security and nutrition
- Participation and empowered of women and youth in scheme activities and decision making
- Other indicators for the benefits to the area of SRI practices and the SPIS technology.

General:						
Pilot area name:				**Address:**		
No. of participating farmers:	Men:			Women:		
	Youth:			Key Contact Person:		
Total area:		acres/hectares		**Rice planted season:**		
Rice variety type:	Short/medium/long duration			**Other crops:**		

Pre-Cultivation details:					
Type of land preparation:	Dry/Wet		**Area of land preparation:**		acres/hectares
Labour/cost required for land preparation:			**Total rice planted area:**		acres/hectares
Levelling field:	Good / Fair / Poor		**Source of seed:**		
Seedling numbers/hill or bunch:			**Rice variety name:**		
Transplanting date:			**Seed rate:**		kg/ha
No.of workers/ha:			**Plant spacing:**		
Labour/cost for transplanting:			**Cost of Seeds:**		

Cultivation details:					
	First weeding date:		**Second weeding date:**		**Subsequent weeding**
No.workers/ha:					
Labour/cost required for weeding:					
Use of Cono weeder:					
Coverage/ha:					
Adoption of new technologies (e.g. usage of young seedling, square planting, LCC and cono weeder etc)					Good/fair/poor
Cost for irrigation:			**Cost of maintenance:**		
Bags of urea applied/ha:			**Other plant protections:**		
Cost of Nutrients:			**Cost of plant protection:**		

Harvesting details:			
Average Tillers (No.of rice plants at PI stage):		**Harvesting date:**	
Average Panicles (No.of plants at harvesting):		**Average grains/panicle (plant):**	
Harvesting labour/cost:		**Harvesting method:**	Reaper/manual
Total Yield (kg):		**Rice price/kg:**	
Rice Yield (kg/ha):	#DIV/0!	**1000 grains weight:**	

Costs vs Benefits:	
Total production cost:	**0**
Total income:	**0**
Net profit:	**0**

Table 1: M&E Agricultural Production

3.2 Water Management

Table 2 below collects and collates seasonal water related data and the irrigation activities undertaken on the scheme. Recording and quantifying this information will enable the farmers to monitor the response of the water source to weather changes and irrigation usage, and evaluate the efficiency of irrigation, as well as other key parameters, as follows:

- Optimising irrigation schedules, through regular and systematic water accounting of the way the rice is irrigated (i.e. frequency, quantity)
- Maximising the use of rainwater and soil moisture, to apply irrigation more precisely where and when it is needed
- Allocating charges to farmers for the water that they actually used
- Other indicators for the benefits to the area of the SPIS technology.

Record the general weather conditions and water level in the pond at the start of the day. For each plot being irrigated, record the area, crop and growth stage, as well as the soil moisture, start time and duration of irrigation, with an assessment of the flow.				**Plot(s) being irrigated:**															
				Plot:				**Plot:**				**Plot:**				**Plot:**			
				Farmer:				**Farmer:**				**Farmer:**				**Farmer:**			
				M/F/Y:				**M/F/Y:**				**M/F/Y:**				**M/F/Y:**			
				Area:			acre/ha	**Area:**			acre/ha	**Area:**			acre/ha	**Area:**			acre/ha
				Crop:				**Crop:**				**Crop:**				**Crop:**			
				Stage:				**Stage:**				**Stage:**				**Stage:**			
Day	**Routine checks**	**Weather Condition**	**Water Source**	**Soil**	**Start time**	**Duration (hrs)**	**Flow**	**Soil**	**Start time**	**Duration**	**Flow**	**Soil**	**Start time**	**Duration**	**Flow**	**Soil**	**Start time**	**Duration**	**Flow**
01-Jan	Debris around the pump inlet	||| Heavy Rain	High	Dry	9am	3	Normal	PWP	12am	2	Strong	Moist (FC)	1pm	1	Normal	Saturated	2pm	0.5	Normal
02-Jan	Leaks from pipelines or valves	¦¦¦ Light Rain	Normal																
03-Jan	Panels dirty or shaded	:::: Humid	Low																
04-Jan	Damaged panels or cables	Cool/Windy																	
05-Jan	Any Other Damage	Hot and Dry																	
06-Jan	Warning lights/alarms																		
07-Jan	Overheating or unusual pump noise																		
08-Jan	Equal distribution of water																		
09-Jan																			
10-Jan																			
11-Jan																			
12-Jan																			
13-Jan																			
14-Jan																			
15-Jan																			
16-Jan																			
17-Jan																			
18-Jan																			
19-Jan																			
20-Jan																			
21-Jan																			
22-Jan																			
23-Jan																			
24-Jan																			
25-Jan																			
26-Jan																			
27-Jan																			
28-Jan																			
29-Jan																			
30-Jan																			
31-Jan																			
Totals						**3.0**				**2.0**				**1.0**				**0.5**	

Table 2: M&E Water Management

Notes for daily records:

1. **Weather conditions**: Heavy Rain, Light Rain, Humid, Cool/Windy, Hot and Dry
2. **Water source**: High, Normal or Low
3. **Plot** being irrigated; the lead **Farmer,** noting their gender and age; the **Area** in acres or hectares; the **Crop** and **Growth stage**, including any preparatory phases (e.g. Puddling, Nursery, Initial, Crop development, Mid-season, Late season)
4. **Soil Moisture:** Assess and record before irrigating, using simple visual assessment methods - By sticking a finger into the soil, noting the colour and feel, and using the farmers' experience to assess whether the soil is Dry, at the Permanent Wilting Point (PWP), Moist or at Field Capacity (FC), Saturated or Flooded.
5. **Start time** and **Duration** of irrigation and an assessment of the **Flow** compared to normal (e.g. Strong, Normal or Weak).

To simplify this exercise, the farmer records the general weather conditions and routine checks at the start of the day and the pond water level compared to its normal level. For each plot being irrigated, the records capture the area, the crop and growth stage, including any preparatory phases, as well as the soil moisture before irrigation, assessed by simple visual assessment methods, and the start time, duration of irrigation and an assessment of the strength of flow.

3.3 Energy Generation

Table 3 below is used to record data for an assessment of the energy generation and usage; it takes some information from the Water Management form, using estimates of the sunshine and pumping hours to determine the potential for energy generation and compare this to the actual usage recorded by the solar equipment, and estimates the cost savings, as compared to alternative grid power, and the reduction in CO_2 compared to an alternative fossil fuel driven pump. This information will enable the farmers to monitor the performance of the PV panels and pump in different weather changes and identify issues, as well as other key parameters, as follows:

- Energy generated/used for irrigation system pumping
- Availability of excess solar generation capacity for other uses
- Seasonal/Annual consumption of energy and estimated CO_2 savings
- Seasonal/Annual cost of energy for the farmer
- Other indicators for the benefits to the area of the SPIS technology.

Energy Generation/Utilisation:													
No. of panels	17		Panel Rating		540	W	Total Generation Capacity			9.2	kW	21.1%	Annual Total
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Inverter/Controller Reading (kWhr):	0												0
Hours Pumping (hrs):	11.5												12
Estimated Pumping Energy (kWhr):	8.9												9
Efficiency Usage:	14%												14%
Potential Energy:													Annual Total
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Sunshine Estimate (hrs):	31.8												31.8
Potential Energy Generated (kWhr):	61.6												62
Excess available energy:	52.7												53
Environmental and Financial Benefits:													Annual Total
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Costs (US$):	2.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.35
Every 1 kWhr of electricity produced by solar represents a cost saving from alternative grid power											0.264	US$/kWhr	
Carbon (CO_2) (kg):	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.6
Every 1 kWhr of electricity produced by solar accounts for 0.846 lbs of carbon from an alternative fossil-fuele driven pump											1.865	kg	

Table 3: M&E Energy Generation

3.4 Maintenance Activities

The final M&E Form (Table 4) records whether routine checks have been undertaken and summarises any activities that were carried out to ensure the system continues to operate correctly. It confirms that these checks have been undertaken and identifies any damage or unusual issues, as well as the actions taken, the labour, materials and spare parts required for corrective actions and the costs incurred so that an annual maintenance costs can be established.

	Routine Checks:									Operations:				Maintenance Activities:			
Month	Pond level	Debris around the pump	Records of pump operations (Hours/Volume)	Signs of leaks from pipelines or valves	Panels dirty	Panels shaded	Damaged panels	Damaged cables	Describe Any Other Damage	Warning lights/alarms	Overheating or unusual pump noise	Normal flows	Equal distribution of water	Describe Actions Taken	Describe Materials & Spares Used	Labour (man-days)	Cost (US$)
January	OK	No	No	No	No	No	No	No		No	No	No	No				
February	Low	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes				
March	High																
April																	
May																	
June																	
July																	
August																	
September																	
October																	
November																	
December																	
Equal distribution of water																**0**	**0**

Table 4: M&E Maintenance

4 ENABLING ENVIRONMENT ROADMAP

4.1 General

Experience shows that multiple rice crops each year and higher yields in lowland swamps are realistic, when appropriate technology is utilised for improved irrigation, water management, farming practices and post-harvest activities. Low-cost, low-maintenance and environmentally sustainable irrigation schemes, combined with appropriate intensification and modernisation of agricultural practices, have considerable potential for smallholder farmers, provided that coordinated policies provide a favourable environment for the necessary changes and infrastructural developments. This enabling environment should also involve improved engagement, communication and knowledge sharing with farming communities, particularly the younger farmers, to support the change process, and organisations and institutions should coordinate and collaborate to regularly exchange information from their projects and programmes, for the benefit of all.

The requirements to enable scaling-up of Solar Powered Irrigation Systems (SPIS) and Systems of Rice Intensification (SRI) in Liberia can be summarised in the Enabling Environment Roadmap below, with the individual elements discussed further in the following sections.

9. Policy Development and Advocacy	
Create a supportive legal framework	Develop and implement policies that encourage and support the adoption of Solar Powered Irrigation Systems (SPIS) and Systems of Rice Intensification (SRI).
Incentives for adoption	Provide financial incentives, subsidies, and tax breaks for farmers and businesses adopting SPIS and SRI practices.
Advocacy and awareness campaigns	Conduct awareness programs to educate farmers, local communities, and policymakers about the benefits of SPIS and SRI.
10. Capacity Building	
Training programs	Establish training programs for farmers on the installation, operation, and maintenance of SPIS and the principles of SRI.
Extension services	Strengthen agricultural extension services to provide ongoing support and guidance to farmers adopting these technologies.
Educational initiatives	Integrate information on SPIS and SRI into agricultural curriculum at educational institutions.
11. Infrastructure Development	
Technology dissemination	Establish further demonstration farms and pilot schemes showcasing successful implementation of SPIS and SRI to encourage widespread adoption.
Access to finance	Facilitate access to affordable finance for farmers and businesses to invest in SPIS and SRI practices.

Rural electrification	Invest in rural electrification solar, mini-grid projects to enhance the availability and reliability of electricity for powering irrigation systems.
12. Research and Development	
Local adaptation	Support further research on adapting SPIS technology and SRI principles to local climatic and soil conditions.
Innovation hubs	Establish innovation hubs to foster collaboration between researchers, technology developers, and farmers for continuous improvement and innovation.
Monitoring and evaluation	Implement the monitoring and evaluation framework to assess the impact of SPIS and SRI on agricultural productivity, water use, and income generation.
13. Market Development	
Market incentives	Introduce market incentives for the installation of SPIS and production/sale of rice grown using and SRI practices.
Value chain development	Strengthen agricultural value chains to ensure a smooth transition from production to market for farmers adopting these technologies.
Public-private partnerships	Encourage partnerships between government agencies, private sector entities, and NGOs to facilitate the deployment and maintenance of SPIS schemes.
14. Environmental Sustainability	
Resource management	Promote sustainable water use practices through the implementation of efficient techniques, such as drip irrigation and Alternate Wetting and Drying (AWD).
Climate-resilient practices	Integrate climate-resilient agriculture practices and continuous research within the framework of SRI practices to enhance long-term sustainability.
Environmental impact assessment	Conduct regular assessments to monitor and mitigate any adverse environmental impacts of SPIS and SRI practices.
15. Community Engagement and Social Inclusion	
Community involvement	Involve local communities in decision-making processes, project design and implementation to ensure social acceptance and ownership.
Gender inclusion	Promote gender-inclusive policies and programs to ensure that both male and female farmers benefit equitably from SPIS and SRI initiatives.
Social safety nets	Deploy social safety nets to protect vulnerable individuals and communities from potential negative consequences as a result of SPIS development and new agricultural practices.
16. Regulatory Framework	
Standards and certifications	Develop and enforce standards for the quality and performance of SPIS and SRI practices to ensure reliability and efficiency.

Regulatory compliance	Establish mechanisms to ensure that all actors in the sector comply with relevant regulations and guidelines.

In 2012, the Government of Liberia (GoL), through the Ministry of Agriculture (MoA), developed the Liberia National Rice Development Strategy (LNRDS), which aimed for self-sufficiency by expanding the land area under lowland rice cultivation and doubling local rice production by 2018. There was no lowland policy or plan to guide this process, but a technical symposium[1] drew on the significant knowledge and experience in lowland farming to identify best practices and guidelines for future rehabilitation and development of lowland rice farming. Some of the planned activities from this symposium are incorporated and extended in this roadmap.

Sustained financial and technical resources will be essential to support the activities identified in this enabling environment roadmap and will be critical to the successful upscaling of further SPIS and SRI interventions. The GoL and key stakeholders, especially development partners, should aim to harmonize and align financial resource utilization from the GoL, multi-lateral and bi-lateral financial institutions, to support the implementation of this roadmap.

By implementing this comprehensive roadmap, Liberia will be able to create a positive enabling environment for the widespread adoption of Solar-Powered Irrigation Systems and Systems of Rice Intensification, fostering sustainable agricultural practices and improving the livelihoods of its farming communities.

4.2 Policy Development and Advocacy

The continued increase in imported rice prices continues to fuel food insecurity, poverty and vulnerabilities in Liberia … and increasing production would require significant investments in the rice sector as well as policy actions.[2]

A process of policy dialogue should be initiated at local and national levels, using this Enabling Environment Roadmap as a starting point, together with further in-depth analysis of constraints and insights into policy-related problems, to reflect on and validate the priority issues and to prepare recommendations and action plans. These recommendations and plans will later be developed into realistic, actionable and practical policy messages and briefs.

4.2.1 Supportive legal framework

The Government of Liberia will be the focal point in establishing the enabling environment for SPIS and SRI; this will require political will, coordinating collaborations between and among other actors and resource mobilization (financial and technical). However, key in this process will be leadership in developing the policies and legal framework that encourage and support

[1] Symposium on Integrated Lowland Rice Farming in Liberia, GoL/MoA at CARI/Bong County, January 2014

[2] Liberia Economic Update, “Getting Rice Right for Productivity and Poverty Alleviation”, World Bank, July 2023.

the adoption of SPIS and SRI. Policy areas could be developed or extended from their current forms to include specifics relating to these technologies as a means to improving food security and reducing poverty, such as the following:

- Diversification of farming systems from upland to lowland areas, including the development and/or rehabilitation of lowland water management structures
- Supporting lowland rice production to reduce the reliance on rice importation
- Improving resource efficiencies and reducing wastage in rice production, focussing on modernising infrastructure, for more efficient water management, and value chain developments, through improvements in pre- and post-production practices
- Ensuring effective communication and sharing of information between and among Stakeholders
- Institutional capacity development to coordinate, monitor and evaluate SPIS and SRI lowland development programmes
- Continual development and improvement of strategies, policies and plans.

Some aspects of the above policies are further outlined in the sections below.

4.2.2 Incentives for adoption

Sustained financial and technical support will be required to implement the roadmap and update the plans, but short- and medium-term incentives are also essential and critical to the successful scaling-up of SPIS and SRI. The GoL and key stakeholders, especially development partners, multi-lateral and bi-lateral institutions and the private sector, are all expected to play a role in providing the financial incentives, subsidies and tax breaks for smallholder farmers to adopt these technologies.

In particular, the GoL will need to consider the following to incentivise farmers to invest in SPIS technologies and transition to SRI agricultural practices:

- Providing subsidies and loans for SPIS equipment and SRI inputs
- Introducing compensation schemes that mitigate the farming risks related to lowland development
- Rewarding the positive impacts of SPIS and SRI on the environment, particularly soil conservation and water resource management
- Improving the value chain and marketing of lowland rice production
- Ensuring land security for farms and enabling co-operative ownership.

4.2.3 Advocacy and awareness campaigns

The GoL and development partners will need to conduct awareness programs to educate farmers, local communities and policymakers about the benefits of SPIS and SRI. These activities should make use of the pilot system at Bong Mines as a demonstration scheme and align with ongoing programmes to introduce, promote and support the cultivation of improved rice varieties and crop diversification.

To avoid raising expectations, it will be important for the GoL to clearly define their role and that of the public sector in lowland SPIS development and SRI, including any boundaries or constraints to activities.

4.3 Capacity Building

It will be crucial to provide training to guarantee that smallholder farmers embrace modern farming methods and to enhance market access and post-harvest management[2].

4.3.1 Training programs

The GoL, it's development partners and all stakeholders involved in the rice sector need to develop their existing training programmes for farmers to incorporate new modules on the installation, Operation and Maintenance (O&M) of SPIS and the principles of SRI. There should be a focus on providing specific training opportunities and entrepreneurship for young farmers with an interest in irrigated lowland farming, as well as related skills, such as Integrated Pest Management (IPM).

All relevant stakeholders, with particular reference to the key ministries[3], should consider including in their plans the necessary financing, technical expertise and material resources to implement a comprehensive capacity building programme targeting all levels, from Government institutions, Community-Based Organizations (CBOs), Non-Governmental Organisations (NGOs), farmers, marketing and Water Users Associations (WUAs), etc and working in collaboration with the private sector suppliers and installation contractors. This programme should aim to promote modern and efficient SPIS and SRI, developing specific knowledge and skills in the following areas:

- Understanding the components of SPIS and SRI, the pros and cons, and the configurations most appropriate for smallholder, lowland rice production
- Defining the objectives and engaging with the target groups/communities
- Sustainable water management, the risks of excessive water extraction and the management measures required for planning and operation
- Detailed site assessment and feasibility analysis of technologies and practices, including land tenure/user rights, solar energy potential, availability of water resources, soils, topography, crop and livestock choices, community awareness and capacity for SPIS and SRI technologies, potential environmental impacts etc
- Detailed market assessments, identifying the market and business environment, including costs, financing and the potential socio-economic contribution, and considering Government and NGO interventions, alternative power sources, crop production inputs and yield benefits, marketing, processing, transport and communication infrastructure
- Planning for project initiation and identifying sources of investment, including assessment of the different financial services available for smallholder farmers (Providers' credit policies and loan procedures and conditions - Loan volume and potential profitability; Borrowers' credit risks and sources of collateral; Cash-flow and repayment schedule)

[3] Ministry of Agriculture (MoA), Ministry of Education (MoE), Ministry of Information, Cultural Affairs & Tourism (MICAT), Ministry of Gender and Development (MGD) and Ministry of Youth & Sports (MoYS)

- Design of SPIS, including data collection, farm sizing, configuration options, intake structures, conveyance, distribution and field irrigation methods, equipment components and material choices etc
- Construction planning, Procurement and contracting a supplier/installer
- Installation of SPIS (Planning and site preparation, Installation, Testing and acceptance, O&M documentation, Hand-over and Training)
- Irrigation operations, including calculating water requirements, setting and adjusting the irrigation schedule, operation of pumps, storage and distribution infrastructure, and measures to improve irrigation efficiency
- Maintenance planning (Scheduled) and routine maintenance activities, see O&M Manual
- Monitoring and Evaluation, see earlier chapter for the M&E framework.

4.3.2 Extension services

The above training in SPIS and SRI techniques would need to be supported by strengthened agricultural extension services, to provide ongoing guidance to those farmers adopting these new technologies. The MoA, CARI and farmers' associations, together with development partners and NGOs, would take the lead in increasing the knowledge and uptake of best practices through extension services, Farmer Field Schools (FFS) and technology transfer between counties, across commodities other than rice and through farmer-to-farmer exchanges. To improve the quality of extension services, these must be planned by competent public agencies, with qualified and experienced staff allocated in strategic and appropriate locations and roles, and with a workforce that is adequately trained and incentivised. To improve the efficiency of delivery of services, tools developed under other programmes and in other countries should be utilised wherever applicable, with training provided to users enabling the tools to be adapted to the Liberian context[4].

4.3.3 Educational initiatives

The Ministry of Education (MoE), supported by MoA and others (MICAT, MGD and MoYS, development partners and NGOs) should aim to raise the profile of SPIS and SRI, and eradicating any negative perceptions associated with lowland farming, by running educational campaigns targeting farming communities, women's groups and young people. These might include community radios, drama clubs, extension programs, etc., but could extend into agricultural curriculum at educational institutions. In conjunction, GoL should invest in improving agriculture education facilities and demonstration pilot schemes, like Bong Mines, in other counties.

[4] Toolbox on Solar Powered Irrigation Systems, 2012, Published by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the Food and Agriculture Organization of the United Nations (FAO), on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) as a founding partner of the global initiative Powering Agriculture: An Energy Grand Challenge for Development (PAEGC) and Water and Energy for Food (WE4F), also including the United States Agency for International Development (USAID), the Swedish International Development Cooperation Agency (Sida), Duke Energy, and the Overseas Private Investment Corporation (OPIC).

4.4 Infrastructure Development

4.4.1 Technology dissemination

The upscaling of SPIS and SRI should be driven by the socio-economic and environmental benefits, and through adoption by individuals and groups of smallholders as commercial investments. The GoL, development partners, NGOs and farmer associations should introduce, promote and support SPIS and SRI in lowland farming areas by disseminating the technologies and demonstrating these benefits. Encouraging more widespread adoption could be achieved by utilising the Bong Mines scheme for farmer-farmer visits and establishing further demonstration farms and pilot schemes, to showcase the successful implementation of SPIS and SRI. The MoA should identify suitable existing and potential new lowland irrigation schemes in the other counties for rehabilitation and conversion to SPIS and establishment of SRI-based production.

Smaller SPIS schemes have the potential advantage of being portable and consideration should be given to establishing community-based farm machinery banks, from where farmers can rent SPIS equipment and purchase packages of the agricultural inputs and tools required for SRI. As a pre-requisite of taking possession of the equipment, the farmers would be trained to ensure that proper Operation and Maintenance (O&M) of the equipment is carried out and the terms of the hire would be detailed in a formal agreement.

4.4.2 Access to finance

The GoL should support the activities recommended in this roadmap to produce, among other things, a conducive policy framework for SPIS technology regulation and tailored training on SRI practices, but farmers and businesses will also need help to access affordable finance to invest in SPIS and SRI. The GoL may not be in a position to mobilise significant financial incentives, subsidies and tax breaks to encourage smallholder farmers to adopt these technologies, so the Ministry of Finance (MoF) and MoA should work together to develop innovative financing mechanisms, based on sustainable business model(s) and appropriate financing structures to extend credit to low-income smallholders, many of whom are unbanked.

Development of these business model(s) and financing structures should involve the financial institutions, including micro-finance institutions, rural banks and non-bank entities, and consider appropriate risk mitigation instruments, including insurances and guarantee structures aimed at crowding in private sector investments. Implicit to the success of these financing structures will be collaboration with the private sector equipment and input suppliers, and aggregation of smallholder farmers to increase the scale of the opportunity.

4.4.3 Rural electrification

The GoL can further encourage the acceptance of solar power, to develop the markets and technical capabilities in related technologies, by investing in rural electrification projects (e.g.

solar mini-grids) to enhance the availability and reliability of electricity in remote areas, which may then be utilised for powering irrigation systems and other agricultural processes.

4.5 Research and Development

4.5.1 Local adaptation

The MoA and other stakeholders should support further research on adapting SPIS and SRI principles to local climatic and soil conditions in other counties. Based on the better understanding of the suitability of the technologies in different situations, studies should be undertaken to assess and map the lowland soils, water resources and land tenure across the Country to determine the potential areas for development, disaggregated at the level of counties and districts. Following on from the Symposium on Integrated Lowland Rice Farming in Liberia (2014), this exercise should include an inventory of lowland farming and identify any related environmental and health-related problems, to assist in developing mitigation measures, including protective equipment most suited to SPIS and SRI.

4.5.2 Innovation hubs

To foster collaboration between researchers, technology developers and farmers for the continued improvement and innovation of SPIS and SRI, the GoL should consider the establishment of innovation hubs; resource centres in key production areas that provide information and train farmers on SPIS technologies and SRI practices. These hubs may be connected directly to pilot schemes, such as Bong Mines, or operate within one of the agricultural research institutions (e.g. CARI). The hubs should promote and encourage county and regional field days, for farmer-to-farmer information and technology sharing, discussion and cataloguing of successes and limiting factors.

Whilst the focus should always be to optimise collaboration and ministries, universities, multi-lateral and bi-lateral partners may have different interests and roles in these hubs, on the basis of their mandates and capacities, the GoL could use the opportunity to maximise innovation by establishing competitive performance standards that remunerate and reward in line with service delivery and/or the merits of any new practices developed (e.g. Annual agricultural innovation competition).

4.5.3 Monitoring and evaluation

The Monitoring and Evaluation (M&E) Framework outlined earlier in this report should be implemented to consistently collect and report data, and assess the impact of SPIS and SRI on agricultural productivity, water use and income generation. Data collection will be the responsibility of the farmers, initially at the Bong Mines pilot scheme, but later to include other demonstration farms and schemes as they adopt SPIS and SRI. The MoA should also co-opt rice farmers from non-SPIS farms where SRI techniques are not being utilised to collect baseline information, as a “without project” comparison.

As more SPIS schemes are developed and farmers adopt SRI techniques, the MoA can collect and collate the data to establish an inventory of SPIS and SRI; the operational coverage

across the country, the system configuration, make and model of equipment used and nature of SRI interventions. The inventory and the M&E Framework should be updated, as required, to to respond to changing realities in the sector.

4.6 Market Development

4.6.1 Market incentives

The GoL should consider introducing further market incentives for the sale and installation of SPIS equipment and production of home-grown rice, using SRI practices. In 2022, an Executive Order No.107 suspended tariffs on off-grid solar renewable energy products, making SPIS equipment cheaper to purchase. The same initiatives could be considered for irrigation equipment, certified rice seed and other agricultural inputs related to SRI, as well as mechanical tools that improve labour efficiency (e.g. Cono Weeder) and post-harvest processing equipment (e.g. rice threshers and mills), which may also be powered using the solar power generated from the scheme.

4.6.2 Value chain development

The GoL, its development partners, NGOs and farmer associations are already implementing a number of programmes that strengthen agricultural value chains across Liberia and these interventions could be further tailored to improve stages in the processes of production and marketing of rice grown using SPIS and SRI technologies. In particular, the following areas are identified:

- Promote small-scale mechanization through introduction of labor-saving equipment; specifically strengthening the capabilities of local artisans to fabricate the tools and implements that are utilised in SRI techniques.
- Continue with construction and/or rehabilitation of feeder roads to improve the access between farms and markets.
- Construction and/or rehabilitation of rural and community markets.
- Introduce, promote and support the utilization of efficient post-harvest technologies and facilities for storage, processing and packaging.

4.6.3 Public-private partnerships

The GoL should encourage local private entrepreneurs to invest in SPIS development, including associated livestock and fish production, rice processing and other aspects of the value chain. The policy environment should be developed to encourage partnerships between government agencies, private sector entities and NGOs to facilitate the deployment and maintenance of SPIS schemes.

4.7 Environmental Sustainability

4.7.1 Resource management

In 2007, a National Integrated Water Resources Management Policy was developed by the Ministry of Lands, Mines and Energy, in collaboration with others, which set out some objectives, priority actions and strategies to promote sustainable water use for agriculture.

The GoL should establish a similar National Integrated Lowland Management Strategy to further protect both land and water resources in the lowlands, ensuring that the quality and quantities of soils and water are maintained and their allocation is done effectively, equitably and transparently, taking consideration of the economic, social and environmental value of the water as well as other demands from other sectors. SPIS and SRI will form an integral part of this strategy, promoting sustainable water use practices through the implementation of efficient water management techniques, such as drip irrigation and Alternate Wetting and Drying (AWD).

4.7.2 Climate-resilient practices

There are many other climate-resilient agriculture practices that could be integrated into the proposed framework of SRI techniques to enhance the long-term sustainability of lowland rice production and the GoL, development partners and NGOs should ensure continuous research and development is carried out to introduce and promote agronomic practices that minimise risks and maximize crop productivity, such as crop rotation, inter-cropping, mixed-cropping, Integrated Pest Management (IPM), etc.

4.7.3 Environmental impact assessment

The proposed M&E Framework will provide data for monitoring the impacts on water resources and provide insights into soil fertility trends. However, regular assessments should be conducted to monitor and mitigate any adverse environmental and social impacts of SPIS and SRI practices. The Environmental Protection Agency (EPA) of Liberia should provide assistance to formulate the scope and methodologies for such monitoring.

4.8 Community Engagement and Social Inclusion

4.8.1 Community involvement

Involving the local communities in decision-making processes, project design and implementation will ensure social acceptance and ownership, which will enhance the level of understanding and capacity for effective O&M and efficient management, and improve the sustainability of implemented schemes. The implementing partners should ensure that baseline studies with potential beneficiary communities should be conducted to determine the level of acceptability of any proposed SPIS and SRI interventions and their socio-economic and environmental impacts. The M&E Framework will also include the farming communities in the monitoring and evaluation of interventions, avoiding past mistakes, ensuring continuous improved performance for future programmes and greater participation of stakeholders.

4.8.2 Gender inclusion

Similarly, the promotion of gender-inclusive policies and programmes will help to ensure that both male and female farmers benefit equitably from SPIS and SRI initiatives. Mainstreaming gender in project and programme design and implementation is the responsibility of all stakeholders and will ensure equitable distribution and utilization of the opportunities

afforded by these technologies and minimize marginalization. Specific policies include ensuring the ability of women to inherit and own land, enabling young farmers and the un-banked to access credits or loans, and ensuring all groups have equal access to extension services, etc.

4.8.3 Social safety nets

In addition to the policies outlined for gender inclusion above, the GoL should ensure that suitable social safety nets are deployed to protect vulnerable individuals and communities from any potential negative consequences as a result of SPIS development and new agricultural practices.

4.9 Regulatory Framework

4.9.1 Standards and certifications

Well written standards on the quality and performance of SPIS and SRI practices have an important role to play in supporting communication and understanding, trade and commerce, legislation and regulation, environmental protection, enhanced resource efficiency and confidence in the products and services available to farmers. Standards can also help avoid bias towards a particular set of stakeholders' requirements and enhance the ability to innovate new technologies and services.

The GoL and development partners should aim to develop and enforce an ambitious but realistic set of compliance standards and certification systems for SPIS and SRI technologies to ensure reliability and efficiency, including the following regulations and guidelines:

- Technology requirements (i.e. Specifications and conformity assessment requirements)
- Measurement standards
- Accreditation and certification systems
- Testing procedures (conformity assessment)
- Research and development areas.

The standards and certification systems should be based on international and regional standards, since harmonization is better for trade, as well as maximising synergies and complementarities with existing national standards to avoid discrepancies and duplications.

4.9.2 Regulatory compliance

The GoL will also need to establish the mechanisms to ensure that all actors in the sector comply with the standards developed. This will include:

- Regulatory compliance requirements (i.e. Laws, Regulations, Legislation)
- Institutional and organisational structures required
- Verification and auditing system
- Appropriate reporting template for data collection, reporting and dissemination.

5 WORKSHOPS AND TRAINING

5.1 Workshop with Municipal and National Officers

A workshop with municipal and national officers to present the M&E and enabling environment roadmap was planned at the Bong Mines pilot scheme in the presence of the relevant national and municipal officers from the Ministry of Agriculture, Ministry of Environment and other relevant stakeholders. During this workshop the Monitoring and Evaluation (M&E) framework and “enabling environment roadmap” was to be presented and discussed (See the Appendix for the full presentation slides). However, due to the partial theft of the SPIS equipment from the Bong Mines Pilot scheme in March 2024, this event was not realised.

5.2 Training the Rice Farmers

A training session for rice farmers at the Bong Mines pilot scheme on the M&E framework and reiterating the O&M activities was planned. The committee members of the Fuamah District Multipurpose Cooperative (FDMC) were to be trained on the objectives and data collection methods for the M&E framework, as well as the overall goal of such reporting and how this will help them improve the use and sustainability of the their system. However, due to the partial theft of the SPIS equipment from the Bong Mines Pilot scheme in March 2024, this event was not realised. The presentation and training materials are presented in the Appendix.

6 CONCLUSIONS AND RECOMMENDATIONS

The Monitoring and Evaluation (M&E) Framework proposed in this report aims to collect the data on the SPIS infrastructure and SRI practices to ensure that the system is run and maintained effectively and that rice production is undertaken efficiently. The key focus of the information collected through the M&E forms is used to ensure that unsustainable water use or wastage of energy is avoided, monitoring and controlling the abstractions of water to match the available resources and minimising the irrigation applications to the fields through careful water management. The M&E framework is based in excel to regularly and systematically collect and report on the following aspects:

- Water accounting:
  - Estimation of available water resources and water used
  - Optimisation by Alternate Wetting and Drying (AWD) techniques; maximising the use of rainwater and soil moisture to only apply irrigation where and when it is required
- Energy accounting:
  - Solar energy generated and its uses for irrigation or other activities
  - Cost of energy for the farmer
  - Estimation of environmental and financial benefits.
- Maintenance and repairs, as defined in the O&M Manual:
  - Cleaning of the solar panels and other regular maintenance
  - Servicing of the pumps and other planned maintenance
  - Use and costs of spare parts.
- Agricultural production:
  - Number of harvests, crop yields and improvements in quality/sales
  - Crop diversity and benefits to soils and nutrition.
- Other:
  - Empowerment of women and youth in rice cultivation.

The Enabling Environment Roadmap provides a starting point for a process of further policy dialogue that should be initiated by the Government of Liberia at local and national levels. Together with the information collected through the M&E Framework and further in-depth studies of the financial constraints and other policy-related issues, such as capacity building, they will be in a position to prioritise issues and prepare recommendations and action plans that form the basis for realistic, actionable and practical policy messages and briefs. Implementation of these policies will enable scaling-up of Solar Powered Irrigation Systems (SPIS) and Systems of Rice Intensification (SRI) in Liberia.

APPENDICES

Appendix A: Workshop Presentation with Municipal and National Officers and Rice Farmers

Technical Assistance for Upscaling Lowland Rice Production to Improve Food Security through Improved Solar Powered Irrigation Practices in Liberia

Bong Mines Pilot SPIS: Learn-by-doing/On-site Workshop

Enabling Environment Roadmap

Operations & Maintenance and System of Rice Intensification Practices

Monitoring & Evaluation Framework

?? 2024

Agenda

- Welcome
- Purpose of the Project
- Pilot Scheme Selection
- SPIS Components, Design & Implementation
- Enabling Environment Roadmap
- **Site Visit** : Learning-by-doing
- Operation & Maintenance Activities:
  - System of Rice Intensification Practices
  - Safety for Operators
  - Regular/Routine Maintenance Activities
- Monitoring & Evaluation Framework
- Questions and Answers/ Next Steps/ AOB

CARES

INTEGRATION
environment & energy

Purpose of the Project

The aims of this project are to introduce Solar Powered Irrigation Systems (SPIS) and practices to intensify rice cultivation and production in one lowland county in Liberia, with the intention of upscaling the technology as an adaptation measure to climate change at a national level.

The expected impacts are to increase the resilience of the county to provide food security, whilst also increasing the access to renewable energy and reducing the reliance on carbon based fuels.

CARES

INTEGRATION
environment & energy

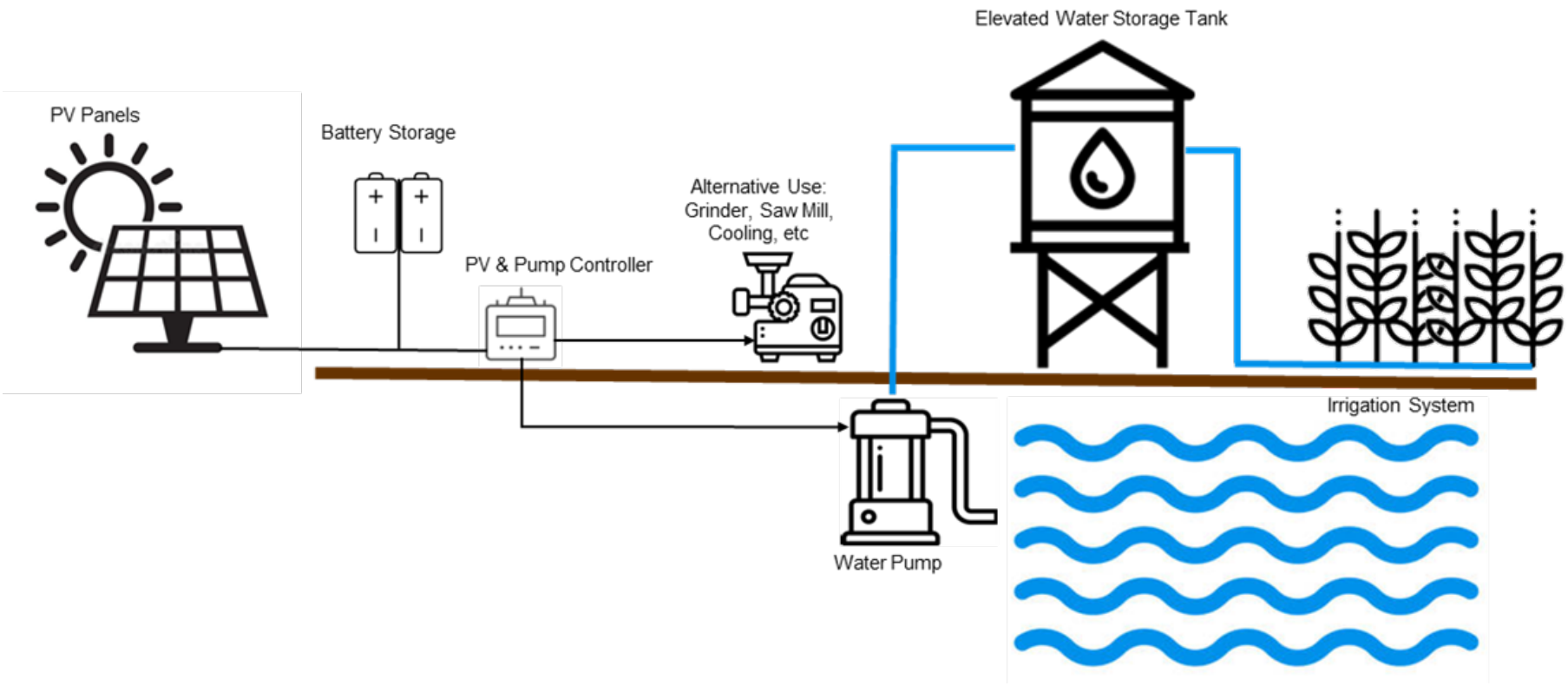
Pilot Scheme Selection

- Stakeholder Working Group (SWG) established to make decisions on the design of the SPIS and ensure these align with Liberian strategic priorities
- Joint site visits with Ministry of Agriculture (MoA) to sites across Bong and Lofa counties
- Assessment based on agreed multiple selection criteria
- Positive reasons for selecting Bong Mines:
  - Availability of stored surface water
  - Existing rainfed rice growing area
  - Motivated farmers co-operative with access to land
  - Ease of access to Monrovia and other counties.
- Limiting factors:
  - Sandy/Silty soils and water, with high iron content, and remote location.

CARES

INTEGRATION environment & energy

SPIS Components & Design



CARES

INTEGRATION
environment & energy

SPIS Components & Design

Electrical Component


The Solar Panel


The Controller


The Solar Pump

Irrigation Component


Storage


Distribution


Application

Agriculture Component


Crop/Variety


Inputs usage


SRI methods

Design depend on multiple factors, including:

- Available water resources
- Soils, crop/variety choice and agricultural production processes
- Climate (sunshine, rainfall, temperature & wind)
- Other potential energy uses
- Farmer's skills and available budget.

CARES

INTEGRATION
environment & energy

Electrical Component

Equipment:

- Photo-voltaic (PV) panels - Generates electrical power
- Mounting structure - Supports panels and provides security
- Controller - Controls and monitors the power to the pump
- Pump - Delivers water from the pond into the irrigation system.

Recommended for Bong Mines Pilot:

- Basic standalone system to start, with option for alternative energy uses (Rice mill etc) in the future
- Security shelter and fencing.

CARES

INTEGRATION environment & energy

Irrigation Component

Storage

Distribution

Application

Equipment:

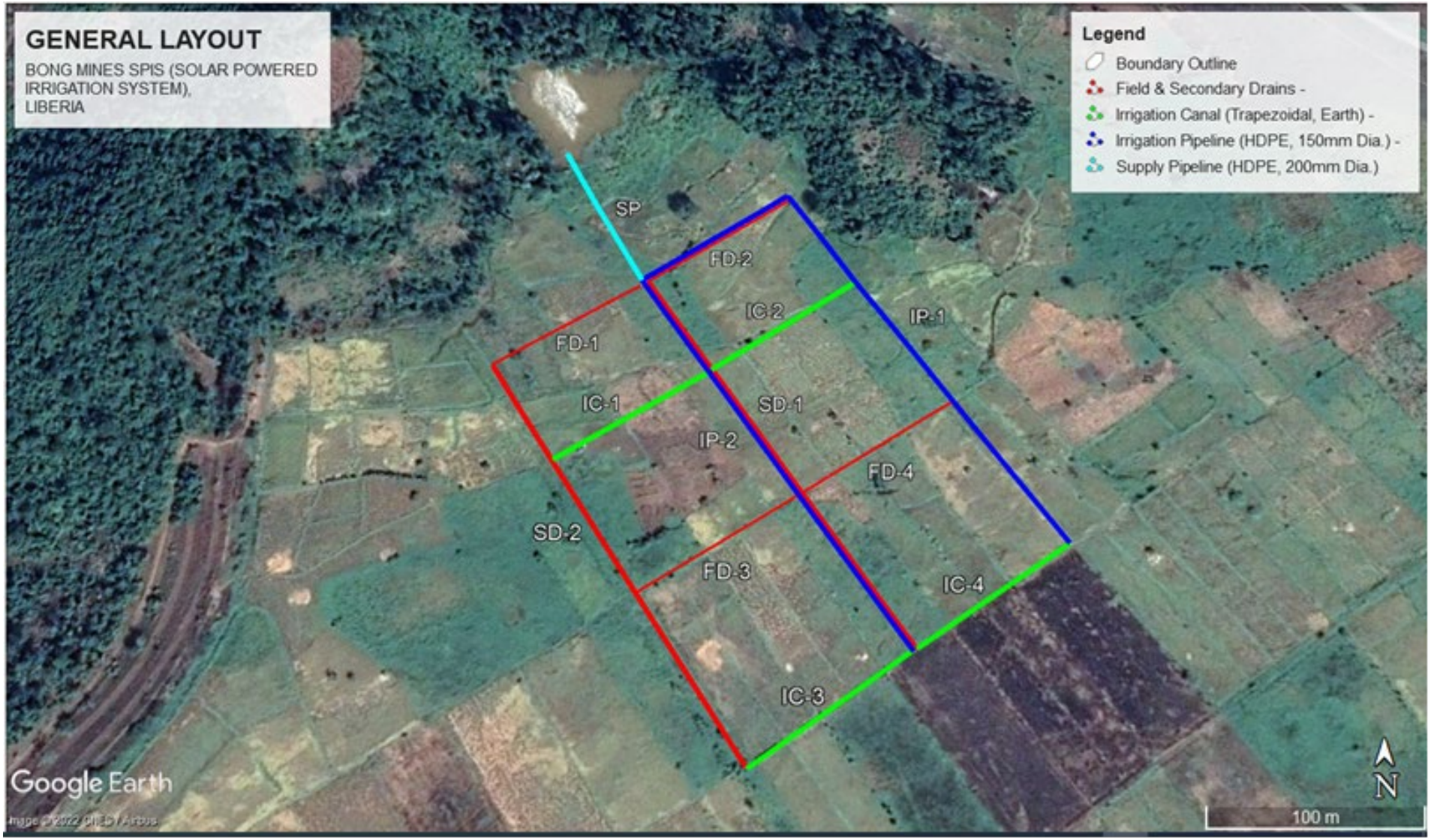
- Natural pond - Existing water storage
- Supply pipeline - Short distance, low head
- Lateral pipelines - Distributes water to all parts of the scheme
- Risers & Valves - Delivers water where and when needed
- Drainage - Removes excess water.

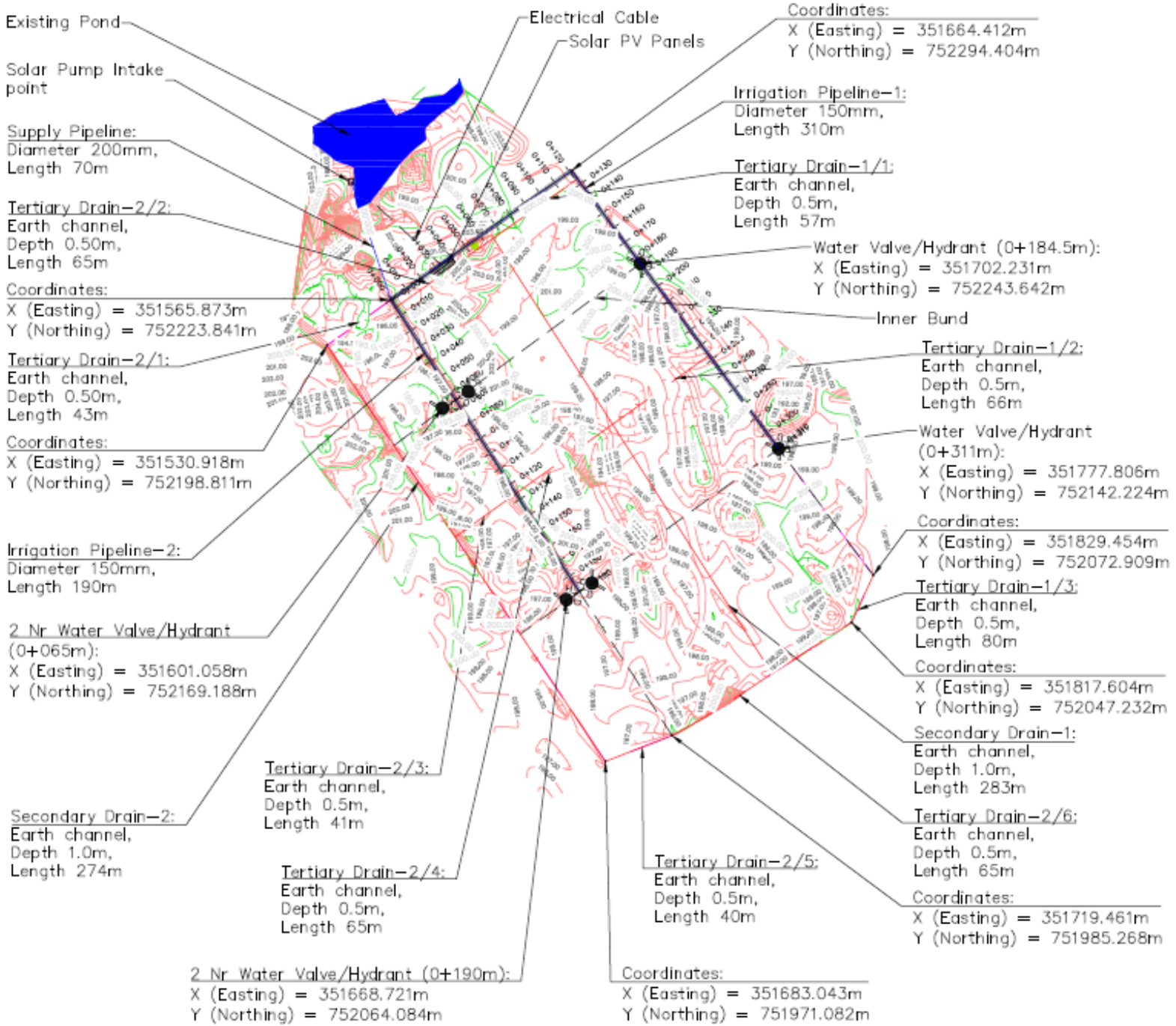
Recommended for Bong Mines Pilot:

- Insufficient budget for elevated storage
- Short distance from water source to field
- Surface/Flood application for rice in flat areas (furrows for vegetables elsewhere)
- Utilise existing drainage.

CARES

INTEGRATION environment & energy


GENERAL LAYOUT
BONG MINES SPIS (SOLAR POWERED IRRIGATION SYSTEM), LIBERIA
Legend
Boundary Outline
Field & Secondary Drains -
Irrigation Canal (Trapezoidal, Earth) -
Irrigation Pipeline (HDPE, 150mm Dia.) -
Supply Pipeline (HDPE, 200mm Dia.)
SP
FD-2
IC-2
IP-1
FD-1
IC-1
SD-1
IP-2
FD-4
SD-2
FD-3
IC-4
IC-3
N
100 m
Google Earth


Existing Pond
Solar Pump Intake point
Supply Pipeline:
Diameter 200mm,
Length 70m
Tertiary Drain–2/2:
Earth channel,
Depth 0.50m,
Length 65m
Coordinates:
X (Easting) = 351565.873m
Y (Northing) = 752223.841m
Tertiary Drain–2/1:
Earth channel,
Depth 0.50m,
Length 43m
Coordinates:
X (Easting) = 351530.918m
Y (Northing) = 752198.811m
Irrigation Pipeline–2:
Diameter 150mm,
Length 190m
2 Nr Water Valve/Hydrant (0+065m):
X (Easting) = 351601.058m
Y (Northing) = 752169.188m
Secondary Drain–2:
Earth channel,
Depth 1.0m,
Length 274m
Tertiary Drain–2/3:
Earth channel,
Depth 0.5m,
Length 41m
Tertiary Drain–2/4:
Earth channel,
Depth 0.5m,
Length 65m
2 Nr Water Valve/Hydrant (0+190m):
X (Easting) = 351668.721m
Y (Northing) = 752064.084m
Electrical Cable
Solar PV Panels
Coordinates:
X (Easting) = 351664.412m
Y (Northing) = 752294.404m
Irrigation Pipeline–1:
Diameter 150mm,
Length 310m
Tertiary Drain–1/1:
Earth channel,
Depth 0.5m,
Length 57m
Water Valve/Hydrant (0+184.5m):
X (Easting) = 351702.231m
Y (Northing) = 752243.642m
Inner Bund
Tertiary Drain–1/2:
Earth channel,
Depth 0.5m,
Length 66m
Water Valve/Hydrant (0+311m):
X (Easting) = 351777.806m
Y (Northing) = 752142.224m
Coordinates:
X (Easting) = 351829.454m
Y (Northing) = 752072.909m
Tertiary Drain–1/3:
Earth channel,
Depth 0.5m,
Length 80m
Coordinates:
X (Easting) = 351817.604m
Y (Northing) = 752047.232m
Secondary Drain–1:
Earth channel,
Depth 1.0m,
Length 283m
Tertiary Drain–2/6:
Earth channel,
Depth 0.5m,
Length 65m
Coordinates:
X (Easting) = 351719.461m
Y (Northing) = 751985.268m
Tertiary Drain–2/5:
Earth channel,
Depth 0.5m,
Length 40m
Coordinates:
X (Easting) = 351683.043m
Y (Northing) = 751971.082m

Agriculture Component

Crop/Variety

Inputs usage

SRI methods

Systems of Rice Intensification:

- Crop/seed variety
- Land selection and preparation
- Methods of cultivation:
  - Planting and transplanting
  - Weed and pest management
  - Use of fertilizers and other chemicals
  - Water / irrigation management.
- Harvesting, processing and marketing.

Recommendations for Bong Mines Pilot:

- Upto 3 seasons: Rice – Rice – Vegetables
- Nurseries and transplanting of rice
- Mechanised weed control
- Leaf Colour Charts
- Alternate Wetting & Drying.

CARES

INTEGRATION environment & energy

SPIS Implementation

Procurement by comparison of selected suppliers' tenders:

- One company or consortium to supply and install entire system
- Procurement notice: Scope of work, specifications, timeframe and instructions
- Evaluation of qualifications, experience and financial offer
- Negotiation and clarifications, leading to a contract award with….

Nation' Innovation System
Mount Barclay, Johnsonville, Montserrado, Liberia

Farmer/Community Activities:

- Memorandum of Understanding with farmers to agree activities
- Site clearance, pipeline trench excavation and backfilling
- Seasonal activities: Land preparation, maintenance and security.

CARES

INTEGRATION environment & energy

Supplier/Contractor Activities

- Supply and transportation of solar equipment and materials to site:

- Laying and jointing of pipelines:

- Panel frame support foundations and steelwork:

CARES

INTEGRATION environment & energy

Supplier/Contractor Activities

- Pump support concrete works:

- Installation of SPIS pump, controller and cabling:

- Commissioning and testing.

CARES

INTEGRATION
environment & energy

Enabling Environment Roadmap

- General
- Diversification and Transitioning of Farming Systems
- Policies
- Lowland and Water Management Structures
- Reduction of Loss and Waste
- Information and Communication
- Institutional Capacity Development
- Coordination, Monitoring and Evaluation
- Strategy Revisions
- Role of the Government and Key Stakeholders

CARES

INTEGRATION
environment & energy

Enabling Environment Roadmap

1. Policy Development and Advocacy	
Create a supportive legal framework	Develop and implement policies that encourage and support the adoption of Solar Powered Irrigation Systems (SPIS) and Systems of Rice Intensification (SRI).
Incentives for adoption	Provide financial incentives, subsidies, and tax breaks for farmers and businesses adopting SPIS and SRI practices.
Advocacy and awareness campaigns	Conduct awareness programs to educate farmers, local communities, and policymakers about the benefits of SPIS and SRI.
2. Capacity Building	
Training programs	Establish training programs for farmers on the installation, operation, and maintenance of SPIS and the principles of SRI.
Extension services	Strengthen agricultural extension services to provide ongoing support and guidance to farmers adopting these technologies.
Educational initiatives	Integrate information on SPIS and SRI into agricultural curriculum at educational institutions.
3. Infrastructure Development	
Technology dissemination	Establish further demonstration farms and pilot schemes showcasing successful implementation of SPIS and SRI to encourage widespread adoption.
Access to finance	Facilitate access to affordable finance for farmers and businesses to invest in SPIS and SRI practices.
Rural electrification	Invest in rural electrification solar, mini-grid projects to enhance the availability and reliability of electricity for powering irrigation systems.

CARES

INTEGRATION environment & energy

Enabling Environment Roadmap

4. Research and Development	
Local adaptation	Support further research on adapting SPIS technology and SRI principles to local climatic and soil conditions.
Innovation hubs	Establish innovation hubs to foster collaboration between researchers, technology developers, and farmers for continuous improvement and innovation.
Monitoring and evaluation	Implement the monitoring and evaluation framework to assess the impact of SPIS and SRI on agricultural productivity, water use, and income generation.
5. Market Development	
Market incentives	Introduce market incentives for the installation of SPIS and production/sale of rice grown using and SRI practices.
Value chain development	Strengthen agricultural value chains to ensure a smooth transition from production to market for farmers adopting these technologies.
Public-private partnerships	Encourage partnerships between government agencies, private sector entities, and NGOs to facilitate the deployment and maintenance of SPIS schemes.
6. Environmental Sustainability	
Resource management	Promote sustainable water use practices through the implementation of efficient techniques, such as drip irrigation and Alternate Wetting and Drying (AWD).
Climate-resilient practices	Integrate climate-resilient agriculture practices and continuous research within the framework of SRI practices to enhance long-term sustainability.
Environmental impact assessment	Conduct regular assessments to monitor and mitigate any adverse environmental impacts of SPIS and SRI practices.

CARES

INTEGRATION environment & energy

Enabling Environment Roadmap

7. Community Engagement and Social Inclusion	
Community involvement	Involve local communities in decision-making processes, project design and implementation to ensure social acceptance and ownership.
Gender inclusion	Promote gender-inclusive policies and programs to ensure that both male and female farmers benefit equitably from SPIS and SRI initiatives.
Social safety nets	Deploy social safety nets to protect vulnerable individuals and communities from potential negative consequences as a result of SPIS development and new agricultural practices.
8. Regulatory Framework	
Standards and certifications	Develop and enforce standards for the quality and performance of SPIS and SRI practices to ensure reliability and efficiency.
Regulatory compliance	Establish mechanisms to ensure that all actors in the sector comply with relevant regulations and guidelines.

CARES

INTEGRATION environment & energy

Site Visit

Learning-by-Doing

Play Video - SPIS Components

CARES

INTEGRATION
environment & energy

Operation & Maintenance Activities

O&M for SPIS includes care and preventative maintenance of the electrical systems and irrigation network, and repairs, as needed.

- **Operations** - Daily tasks to run the scheme to be of value to the farmers. Operations activities include:
- **Preventive Maintenance/Servicing** - Routine, recurring activities required to keep equipment in good working order.
- **Diagnostics and Testing** - Procedures used to understand a failure.
- **Corrective Maintenance/Repair** - Works necessary to re-establish functioning after a problem or failure.
- **Overhaul** - Restoration of equipment at the end of its service-life.

Good O&M avoids the need or minimizes the costs of expensive repairs.

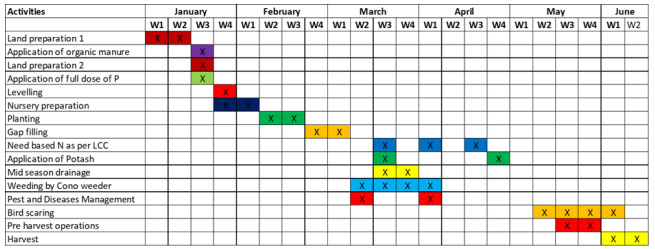
CARES

INTEGRATION environment & energy

System of Rice Intensification Practices

The following will all help maximise production and profits:

- Planning for Production - Crop calendar



Activities	January				February				March				April				May				June	
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2
Land preparation 1	X	X																				
Application of organic manure			X																			
Land preparation 2			X																			
Application of full dose of P			X																			
Levelling				X																		
Nursery preparation				X	X																	
Planting					X	X																
Gap filling							X	X														
Need based N as per LCC									X		X		X		X							
Application of Potash									X							X						
Mid season drainage									X	X												
Weeding by Cono weeder									X	X	X	X										
Pest and Diseases Management									X			X										
Bird scaring																	X	X	X	X		
Pre harvest operations																		X	X			
Harvest																					X	X

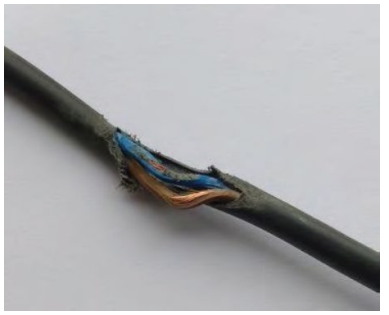
- Selection of Seeds - Buy from trusted/certified dealers
- Land Preparation - Clearing, tilling or ploughing, and levelling
- Planting and Transplanting - Spacing of 30cm × 30cm
- Weed and Pest Management - ConoWeeder in both directions
- Fertilizer Use - Optimise usage with Leaf Colour Chart
- Water Management - Alternate Wetting and Drying (1-10 days)
- Harvesting - When grains are hard and turning yellow/brown
- Post-Harvest Management - Threshing, winnowing, drying etc
- Record Keeping - Monitor and evaluate (Next Section)

CARES

INTEGRATION environment & energy

Safety for SPIS Operations

- Personal safety of farmers and operators is paramount, even above the safety of the system.
- Evaluate the risks before proceeding with any work on the system.
- Ensure that appropriate PPE is available for farmers and operatives at all times.
- **Electrical Hazards**:
  - PVs operate at high voltage - Electrocution risk
  - Damaged or bare wires - Report, Don't Touch
  - Never remove any electrical equipment covers
  - Never work on the SPIS during a lightning storm.



- **Chemical Hazards** - Follow the manufacturers'/ suppliers' recommendations for fertilizers and pesticides.

CARES

INTEGRATION environment & energy

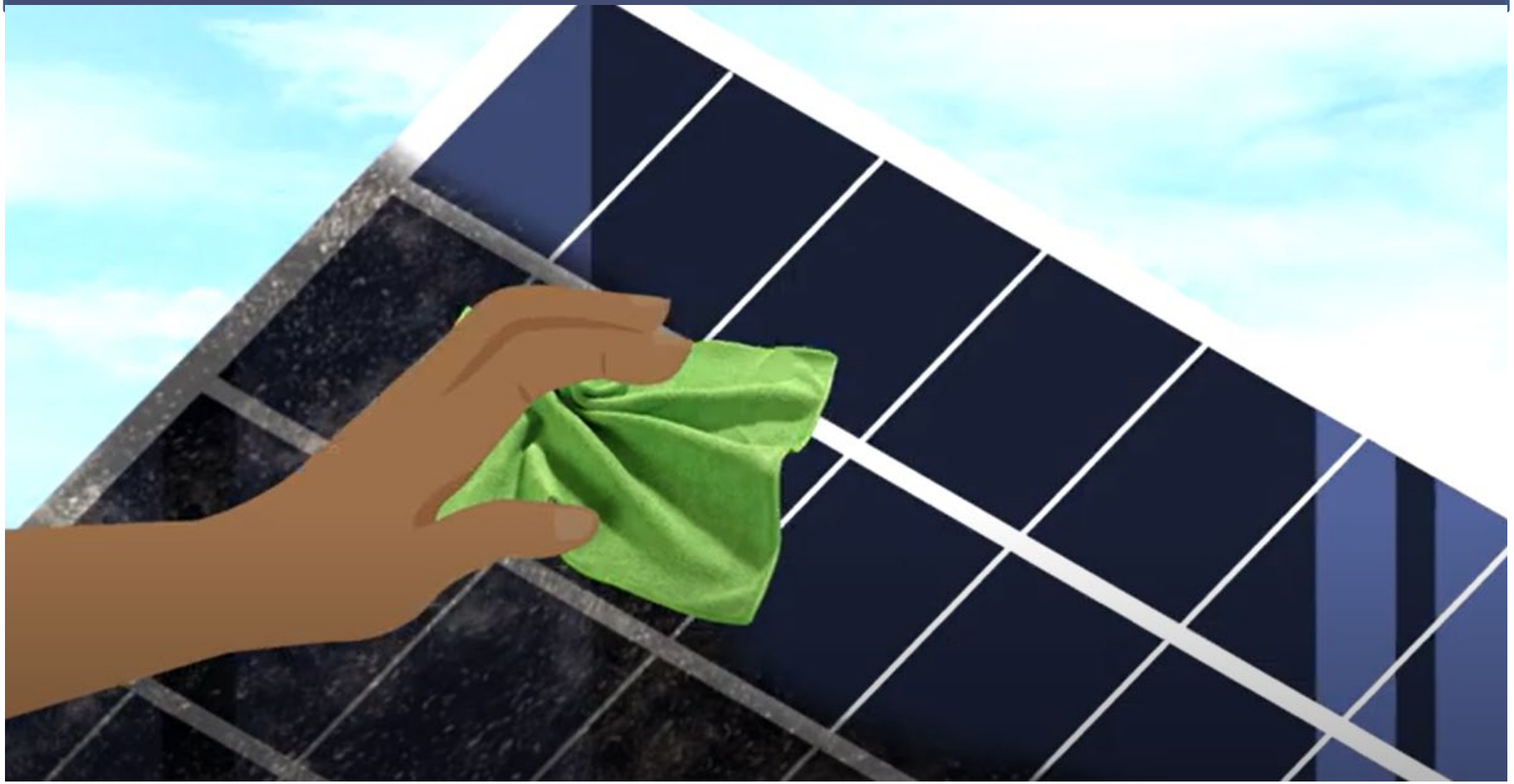
Routine/Regular Maintenance

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
General	Routinely check the proper operation of the system from the pump to the end use through the outlet valves. Continuously check the irrigation pipelines for any leaks.	Follow the agreed pumping schedule for the scheme. Note: Normal operation will not require intervention of the technician, but failure of any cut-off switch or fail-safe may require the farmer to follow manual schedules determined for each site or contact the technician.
Pond/Water source	Record water level before starting pumping in the morning and at the end of irrigating for the day.	If water levels have dropped below minimum operating levels then do not operate the system until they have recovered.
Solar Array	Check if solar panels need to be washed. Check for shade on the panels such as vegetation or structures.	Clean of any dirt/debris on panel surface and note any resulting damage. Any cracks in the panels should be reported to the technician for support. Cut down/trim any form vegetation that may be shading the panels. Always maintain a clean facility.

CARES

INTEGRATION environment & energy

Routine/Regular Maintenance



CARES

INTEGRATION
environment & energy

Routine/Regular Maintenance

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
Controllers / Inverters, etc.	Clean protective box. Check for any warning lights or alarms. Monitor the controller temperature. Record electrical device LED status, input and output voltage, current and power if available on controller and/or inverter. Check for any damage from rodents or animals.	In case of any loose or broken wires, contact the technician. In case of any alarms, switch off system and contact technician for support. Any sign of overheating, stop operations and contact the technician immediately. Report any damages to the technician for support.
Pump	Check for any debris around the pump. Record pumping times and pressures (if meters available).	Clean the pump intake and keep it free of debris. Any unusual pump noise, stop operations and contact the technician immediately.
Water meter (if available)	Record water meter reading at the beginning and end of each pumping cycle.	Records to be used for maintenance cycles and charging for water to farmers.

CARES

INTEGRATION environment & energy

Routine/Regular Maintenance

CARES

INTEGRATION
environment & energy

Routine/Regular Maintenance

SYSTEM COMPONENT	INSPECTION DETAIL	ACTION/RESPONSE
Pipelines	Are any pipes exposed? Are any valves leaking? Are any pipes leaking? (i.e Wet ground along pipeline routes) Are any connections leaking?	Based on the kind of pump use, in case of submersible pumps that are not movable, bury the pipes, in case of surface pumps or pumps that shall be moved, ensure when pumping that it is aligned well. Tighten the valves with a thread tape and report to the technician. Tighten the pipe section leaking with a thread tape then report to the technician. For major connection leakages, close the system and contact the technician immediately.
Distribution System (Irrigation layout)	Walk through the system to check equal and fair distribution of water up to the last outlet in the system.	Flush the system lines to ensure no clogging, or debris along the distribution laterals.

CARES

INTEGRATION
environment & energy

Do’s & Don’ts

What can you do yourself?

- Clean the panels when dirty or dusty
- Cut away any plants blocking the sun from the panels
- Check cleanliness of water coming out of the tank visually and clean or replace the filter if necessary
- **Monthly:** Clean or flush the tank to ensure water is clean
- **Weekly:** Check the system for leaks, corrosion, damages, dust or insects

When to call in a technician

- Leaks in the pipes or the tank
- Open wires in the system
- The pump runs dry
- The pump has strange noises and vibrations
- Water is not released evenly across the field
- Controller shows flashing diodes indicating an error

CARES

INTEGRATION
environment & energy

Questions and Answers

Play Video - Care & Maintenance

?

CARES

INTEGRATION
environment & energy

Monitoring & Evaluation Framework

Data Collection Forms:

- Agricultural Production

General:					
Pilot area name:			**Address:**		
No. of participating farmers:	Men:		Women:		
	Youth:		Key Contact Person:		
Total area:		acres/hectares	**Rice planted season:**		
Rice variety type:	Short/medium/long duration		**Other crops:**		
Pre-Cultivation details:					
Type of land preparation:	Dry/Wet		**Area of land preparation:**		acres/hectares
Labour/cost required for land preparation:			**Total rice planted area:**		acres/hectares
Levelling field:	Good / Fair / Poor		**Source of seed:**		
Seedling numbers/hill or bunch:			**Rice variety name:**		
Transplanting date:			**Seed rate:**		kg/ha
No.of workers/ha:			**Plant spacing:**		
Labour/cost for transplanting:			**Cost of Seeds:**		
Cultivation details:					
	First weeding date:		**Second weeding date:**		**Subsequent weeding**
No.workers/ha:					
Labour/cost required for weeding:					
Use of Cono weeder:					
Coverage/ha:					
Adoption of new technologies (e.g. usage of young seedling, square planting, LCC and cono weeder etc)					Good/fair/poor
Cost for irrigation:			**Cost of maintenance:**		
Bags of urea applied/ha:			**Other plant protections:**		
Cost of Nutrients:			**Cost of plant protection:**		
Harvesting details:					
Average Tillers (No.of rice plants at PI stage):			**Harvesting date:**		
Average Panicles (No.of plants at harvesting):			**Average grains/panicle (plant):**		
Harvesting labour/cost:			**Harvesting method:**	Reaper/manual	
Total Yield (kg):			**Rice price/kg:**		
Rice Yield (kg/ha):	#DIV/0!		**1000 grains weight:**		
Costs vs Benefits:					
Total production cost:	0				
Total income:	0				
Net profit:	0				

CARES

INTEGRATION environment & energy

Monitoring & Evaluation Framework

Data Collection Forms:

- Water Management

Record the general weather conditions and water level in the pond at the start of the day. For each plot being irrigated, record the area, crop and growth stage, as well as the soil moisture, start time and duration of irrigation, with an assessment of the flow.

Plot(s) being irrigated:

				Plot:				**Plot:**				**Plot:**				**Plot:**			
				Farmer:				**Farmer:**				**Farmer:**				**Farmer:**			
				M/F/Y:				**M/F/Y:**				**M/F/Y:**				**M/F/Y:**			
				Area:			acre/ha	**Area:**			acre/ha	**Area:**			acre/ha	**Area:**			acre/ha
				Crop:				**Crop:**				**Crop:**				**Crop:**			
				Stage:				**Stage:**				**Stage:**				**Stage:**			
Day	**Routine checks**	**Weather Condition**	**Water Source**	**Soil**	**Start time**	**Duration (hrs)**	**Flow**	**Soil**	**Start time**	**Duration**	**Flow**	**Soil**	**Start time**	**Duration**	**Flow**	**Soil**	**Start time**	**Duration**	**Flow**
01-Jan	Debris around the pump inlet	||| Heavy Rain	High	Dry	9am	3	Normal	PWP	12am	2	Strong	Moist (FC)	1pm	1	Normal	Saturated	2pm	0.5	Normal
02-Jan	Leaks from pipelines or valves	¦¦¦ Light Rain	Normal																
03-Jan	Panels dirty or shaded	:::: Humid	Low																
04-Jan	Damaged panels or cables	Cool/Windy																	
05-Jan	Any Other Damage	Hot and Dry																	
06-Jan	Warning lights/alarms																		
07-Jan	Overheating or unusual pump noise																		
08-Jan	Equal distribution of water																		
09-Jan																			
10-Jan																			
11-Jan																			
12-Jan																			
13-Jan																			
14-Jan																			
15-Jan																			
16-Jan																			
17-Jan																			
18-Jan																			
19-Jan																			
20-Jan																			
21-Jan																			
22-Jan																			
23-Jan																			
24-Jan																			
25-Jan																			
26-Jan																			
27-Jan																			
28-Jan																			
29-Jan																			
30-Jan																			
31-Jan																			
Totals						**3.0**				**2.0**				**1.0**				**0.5**	

CARES

INTEGRATION environment & energy

Monitoring & Evaluation Framework

Data Collection Forms:

- Energy Generation

Energy Generation/Utilisation:													
No. of panels	**17**		**Panel Rating**		**540**	**W**	**Total Generation Capacity**			**9.2**	**kW**	21.1%	**Annual**
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Inverter/Controller Reading (kWhr):	0												**0**
Hours Pumping (hrs):	11.5												**12**
Estimated Pumping Energy (kWhr):	8.9												**9**
Efficiency Usage:	14%												**14%**
Potential Energy:													**Annual**
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Sunshine Estimate (hrs):	31.8												**31.8**
Potential Energy Generated (kWhr):	61.6												**62**
Excess available energy:	52.7												**53**
Environmental and Financial Benefits:													**Annual**
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Total**
Costs (US$):	2.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.35
Every 1 kWhr of electricity produced by solar represents a cost saving from alternative grid power											0.264	US$/kWhr	
Carbon (CO_2) (kg):	16.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**16.6**
Every 1 kWhr of electricity produced by solar accounts for 0.846 lbs of carbon from an alternative fossil-fuele driven pump											1.865	kg	

CARES

INTEGRATION environment & energy

Monitoring & Evaluation Framework

Data Collection Forms:

- Maintenance Activities

	Routine Checks:									Operations:				Maintenance Activities:			
Month	Pond level	Debris around the pump	Records of pump operations (Hours/Volume)	Signs of leaks from pipelines or valves	Panels dirty	Panels shaded	Damaged panels	Damaged cables	Describe Any Other Damage	Warning lights/alarms	Overheating or unusual pump noise	Normal flows	Equal distribution of water	Describe Actions Taken	Describe Materials & Spares Used	Labour (man-days)	Cost (US$)
January	OK	No	No	No	No	No	No	No		No	No	No	No				
February	Low	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes				
March	High																
April																	
May																	
June																	
July																	
August																	
September																	
October																	
November																	
December																	
Equal distribution of water																0	0

CARES

INTEGRATION environment & energy

Questions and Answers/ Next Steps/ AOB

CARES

INTEGRATION
environment & energy

CARES

INTEGRATION
environment & energy