german cooperation
DEUTSCHE ZUSAMMENARBEIT

For

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Prepared by:

intellecap AAVISHKAAR GROUP

TRI TRANSFORM RURAL INDIA

BISA Borlaug Institute for South Asia

Capacity Development of Agricultural Extension Workers on Solar Powered Irrigation Systems (SPIS)

Capacity Development Program Guide

Contents

List of tables

List of figures

List of Images

Introduction to the Capacity Development Program Guide

About the Guide

Climate change and over-extraction of water resources has resulted in an acute groundwater crisis across India. The per capita availability of water has declined by 70% since 1950. Nearly, 90% of the annual consumption of groundwater goes to the agriculture sector.[1] Majority of the farmers use diesel or electric water pumps to extract water for irrigation. These systems use a high cost and polluting source of fuel which negatively impacts the environment and adds to the economic burden faced by the farmers. Solar powered irrigation systems (SPISs) provide a financially and environmentally sustainable alternative to the traditional pumping systems. The Government of India is promoting these SPISs by provision of subsidies at the national/sub-national level. However, there hasn't been significant uptake of SPIS due to limited awareness among the agricultural extension (agri-extension) workers and farmers on the technical, operational and economical aspects of the technology. By 2020, only 256,156 SPISs were deployed in the country (compared to ~21 million diesel and ~8.8 million electric pumps).[2] Hence, to support the government in scaling up of SPISs, GIZ plans to conduct a three-day capacity building program with agri-extension workers..

This guide provides the outline for the capacity building program, content for the classroom sessions, methodology/process for implementation of the sessions and description of the adult-learning tools and interactive exercises. This guide would be used to facilitate the capacity building program on SPIS for agri-extension workers. It is expected that this guide will be further used by agri-extension workers to generate awareness about SPIS among farmers. It can also be used as a resource book for local government agencies, financial service providers, policy influencers, researchers, NGOs/CSOs and community organisations to understand the technology and process of scaling SPIS.

Audience

This guide can be helpful for agri-extension workers and local government agencies whose role is to design and implement SPIS promotion programs and generate awareness among farmers on efficient water management practices as mandated by the policies at the national/sub-national level. Through this guide they can build an understanding about the different types of SPIS

1 Groundwater Loss in India Threatens Millions of Farmers' Ability to Grow Food, Global Citizen, Feb 2021
2 Energy Statistics of India, MOSPI, 2021

technology and its application, deployment approaches, policies/schemes for promoting SPIS, selection and installation of SPIS and efficient and sustainable use of SPIS, among other key aspects. These agri-extension workers can use this as a resource book to deliver training to farmers on the relevance of SPIS and also support implementation of the systems. The NGOs/CSOs and community organisations can use this guide to design and implement development programs on efficient water management practices focused on implementation and scale up of SPIS. This guide can enable financial service providers to offer customized financial solutions for financing SPIS. Furthermore, this guide can also be used as a knowledge product by researchers to gather information on technology, economics, and operations of SPIS.

Purpose of the Guide

The key purpose of this guide is to provide the content and delivery mechanism for capacity building of agricultural extension workers on solar powered irrigation systems (SPIS). The overall guiding principles of the capacity building program are:

- Impart knowledge about SPIS to agri-extension workers including contextual understanding regarding market, policy and financial ecosystem
- Provide practical demonstrations on usage, installation and maintenance of SPIS
- Enable agri-extension workers to effectively deliver content on SPIS to farmers through adult-learning tools/methods

This guide offers agri-extension workers in selected states the necessary knowledge on technical, economic, and operational mechanisms of SPIS to support scaling of SPIS among farmers.

CAPACITY DEVELOPMENT PROGRAM PLAN AND MODULES

Table 1: Outline of the Capacity Development Program

Outline of the Capacity Development Program		
Day 1	Day 2	Day 3
Session 1.1: Registration, training overview, and learning goals and Introduction to solar technology	Session 2.1: Schemes and Programs for acquiring SPIS	Session 3.1: Efficient use of SPIS and Scaling/Promotion of Solar Irrigation Systems
Session 1.2: Solar irrigation technologies and application	Session 2.2: Selection and Installation of SPIS	Session 3.2: Interactive Session with Experts
Session 1.3: Different models of solar powered irrigation systems	Session 2.3: Visit to farmers' field, group discussion with farmers	Session 3.3: Open Discussion, Training Feedback, Closing

Session Plan

for Day 1 of the Program

Table 2: **Outline of Day 1 of the Capacity Development Program**

Outline of Day 1 of the Capacity Development Program		
Duration	**Sessions**	**Outcome**
95 minutes	Session 1.1: Registration, training overview, and learning goals and Introduction to solar technology	• Introduce the purpose of the capacity building program • Understand best practices regarding SPIS
120 minutes	Session 1.2: Solar irrigation technologies and application	• Enable identification of different types of SPIS technology • Create awareness on benefits of SPIS especially cost-effectiveness
	Lunch Break	
165 Minutes	Session 1.3: Different models of solar powered irrigation systems	• Comprehend the different deployment models for SPIS
	End of Day 1	

1.1 Registration, training overview, and learning goals and introduction to solar technology

The two-fold objective of this session is to (i) introduce the capacity building program agenda and gather insights from the trainees on their expectations from the program; and (ii) examine the existing level of knowledge/experience of the trainees on irrigation technologies and water management practices.

1.1.1 Session outline and delivery process/methodology

Table 3: **Day 1 Session 1.1 Outline and Delivery Process/Method**

Session Outline				
Duration	**Process**	**Learning Method**	**Outcome**	**Material**
		Component: Registration		
15 minutes	• Fill the form with details on name, age, gender, occupation, location, etc. • Give name tags to each trainee for easy identification			• Registration sheet • Name tags
		Component: Welcome and Introduction to the Capacity Building Programme		

Session Outline				
Duration	Process	Learning Method	Outcome	Material
5 minutes	Define the overall objective of the program and explain daily session plan and agenda	Classroom Training	Describe the overall capacity program, define its purpose and understand expectations of the trainees	• Folders with session plan and stationary
10 minutes	Create 3-4 learning groups with equal number of trainees for participative learning, conduct an ice-breaking session and ask trainees to write 2-3 bullet points on their expectations from the capacity building program on coloured cards	Group Exercise 1		• Coloured cards
15 minutes	Ask trainees to fill a pre-training questionnaire to understand existing knowledge	Questionnaire		• Pre-training questionnaire
Component: Challenges in Agriculture and Irrigation Faced by Farmers				
20 minutes	Conduct discussions on key challenges related to irrigation and agricultural practices with the learning groups, and understand the solutions deployed by them	Group Exercise 2	Gather trainees' perspective on key challenges and probable solutions	• Board/Chart paper
10 minutes	Collate these challenges on a board and explain how SPIS could be a viable solution			
Component: Overview of SPIS in Agriculture				
15 minutes	Deliver a short PPT to define the core terminology used for solar applications and explain the concept of SPIS	Classroom Training	Develop an overall understanding on best practices regarding SPIS	• PPT
5 minutes	Show 1-2 videos of farmers experience with SPIS (Link 1; Link 2)	Audio Visual Learning		• Video
10 minutes	Conduct a quiz with multiple-choice questions and also an open discussion/Q&A session			• Quiz sheet
Group Photo and Tea/Coffee Break				

1.1.2 Content for classroom training sessions

Welcome and Introduction to Training Programme

Background:

Climate change has a two-fold impact on agriculture as a result of increased frequency of droughts and rising variability in rainfall. Increased frequency of droughts has induced a groundwater crisis due to over-extraction of water resources, mainly for irrigation purposes. In recent years, with change in rainfall patterns the farmers have also faced challenges related to crop spoilage and decrease in yield/outputs. There are around 30 million irrigation pumps in the country of which 70% are grid-connected electric pumps (~21 million), 29% are diesel pumps (~8.8 million), and less than 1% are solar powered irrigation systems (SPIS) (~200,000). These diesel and electric pump systems use a high cost and polluting source of fuel on a continuous basis which negatively impacts the environment and adds to the economic burden faced by the farmers. The annual fossil fuel usage is estimated as 85 million tonnes of coal for generating electricity and four billion litres of diesel.[3] Further, the existing pumping capacity is not sufficient to meet the irrigation requirements of the farmers. More than 51% of the net sown area is still dependent on rainfall for irrigation purposes.[4] There is a need to promote and scale-up SPIS in the country as they provide a financially and environmentally sustainable alternative to the traditional pumping systems. The government is providing subsidies to the farmers through various national/state level schemes to adopt SPIS. However, there hasn't been significant uptake of SPIS due to limited information on the technology, its benefits, operational mechanism, and deployment approaches among farmers and agri-extension workers.

Objective of the program:

The objective of this three-day capacity building program with the agri-extension workers is to:

- Inform or create awareness about the SPIS technology and its critical features
- Communicate benefits of the SPIS technology vis-à-vis alternate technologies
- Assist farmers to understand the process of acquiring SPISs
- Enable farmers to effectively use the technology post purchase of SPIS

Tools/Methods:

The capacity building program is designed as a participatory learning exercise (including group discussions, games, simulations, field demonstrations and interaction experts) with few classroom training sessions on core thematic areas as defined in the agenda of the program.

Training pre-requisites:

The trainees are not expected to have any prior knowledge of SPIS though they should be aware about the agricultural practices in their area. The trainees will be divided into 3-4 learning groups based on their experience to facilitate collaborative learning during the entire duration of the program. The trainees are expected to abide by a few simple rules:

- Arrange themselves in their respective learning groups at the start of every day
- Ensure timely arrival for all sessions and attend full sessions to get a training certificate at the end of the program
- Actively participate in all the participatory learning exercise and discussions, and respect the viewpoint of different participants
- Support evaluation of the program by undertaking active part in assessments (quizzes, others) and providing feedback on the training pedagogy/mechanism
- Follow all Covid-19 protocols relayed by the facilitator at all times during the sessions, breaks and group activities

3 Solar for Irrigation- A Comparative Assessment of Deployment Strategies, CEEW, Jan 2018
4 Adoption of Methods of Irrigation, PIB, July 2016

Group Exercise 1: Experience mapping of trainees through an ice-breaking session and discussion on expectations from the capacity building program:

The ice-breaking session will help the trainees familiarise themselves and understand each other's background and experience.

The facilitators can ask each trainee to introduce herself/himself by asking them to share their name, place of residence (area, locality), organisation or core experience in the agricultural/livelihoods sector, and some interesting fact about themselves or their work. This sharing of experiences can facilitate the process of cross-learning.

Based on this experience mapping, the facilitator can create 3-4 learning groups (LGs) with 10-12 trainees each. The facilitator should ensure that the learning groups consist of a diverse range of trainees based on key attributes such as gender, age, location, and work experience. After this, the facilitator should conduct a short group exercise with the trainees to gather their expectations from the capacity building program. This exercise would include the following steps:

1. The facilitator will provide one coloured card to each trainee (as per the learning group such as green for LG 1, blue for LG 2, orange for LG 3 and yellow for LG 4).

2. The trainees will be asked to write 3-4 bullet points on their expectation from the capacity building program based on the agenda explained by the facilitator in the introduction.

3. The facilitator will assess the expectations and write down the common interest areas across each LG on a chart paper. This chart paper will be used as a reference point for the facilitator while delivering the planned sessions. The facilitator can place tick marks across these interest areas once they have been covered under a particular session. This will ensure that the facilitator remains aligned to the needs and expectations of the trainees.

The facilitator should clarify with the trainees the objective of the program in case someone's expectations fall outside the purview of the current capacity building program.

Challenges in Agriculture and Irrigation Faced by Farmers

Group Exercise 2: Discussion on challenges and solutions on agriculture and irrigation practices:

The aim of this group discussion is to gather insights from the trainees on what challenges they would like to solve and what solutions have they deployed to solve these challenges related to irrigation practices. The key process for implementing this discussion is:

1. Ask trainees to have an internal discussion within their LGs on the challenges that they face related to irrigation practices and collate 4-5 most common challenges faced by members of their LG.

2. The facilitator randomly selects one member from each LG to share the collated challenges for its LG and documents the same on a chart paper/board.

3. After documentation of the challenges from each LG, the facilitator collates the distinct challenges mentioned on the same chart paper/board and opens the floor for discussion of solutions for each identified challenge.

4. The facilitator explains how SPIS could be a viable solution to address some of these challenges and reiterates the need for this capacity building program.

Overview of SPIS in Agriculture

CORE TERMINOLOGY USED FOR SOLAR APPLICATIONS[5]

a) Solar energy: Energy from the sun converted into electrical or thermal energy is solar energy/power

b) Photovoltaic (PV): Direct conversion of light/sun rays into electricity using semiconductor materials.

c) Semiconductor: Any material that has limited capacity for conducting an electric current

d) Solar/PV cell: It is a semiconductor element that immediately converts light into electrical energy

e) Solar powered irrigation system (SPIS): A SPIS is an irrigation pump (mostly a centrifugal pump) that is powered by solar energy instead of fossil fuel (e.g., diesel/kerosene) or electricity

f) Solar irrigation: Irrigation that uses the sun's energy to power a pump that supplies water to grow and nurture agricultural and horticultural crops is called solar irrigation

g) Alternating current (AC): A type of electrical current of which the direction is reversed at regular intervals or cycles

h) Direct current (DC): A type of electricity transmission and distribution by which electricity flows in one direction through the conductor, usually relatively low voltage and high current.

i) Irradiance: The direct and reflected solar radiation that strikes a surface

j) Kilowatt (kW): A standard unit of electrical power equal to 1,000 watts or to energy consumption at a rate of 1,000 joules per second

k) Kilowatt hour (kWh): It is a unit of energy measured as 1,000 watts consumed over a period of 1 hour

l) Peak watt (Wp): A unit of power used to rate the performance of solar cells or arrays

m) Peak sun hours: The number of hours per day when solar irradiance averages 1,000 watt per metre square

n) Pumping head: This is the maximum height (measured in metres) at which the pump can raise water from the discharge outlet

o) Life: The time period (in years) during which a system is capable of operating above a specified performance level

p) Lifetime cost: The estimated cost of owning (i.e. capital cost/expenditure) and operating (i.e. operating cost/expenditure) a solar energy system for the entire period of its useful life

5 Solar Energy Glossary, EERE

q) Levelized cost of energy (LCOE): The cost of a solar energy system that includes the system's installed price, its total lifetime cost, and its lifetime electricity production

r) Grid connected system: A solar PV system wherein the power is generated through the PV array like a centralised power plant and supplied to the grid

s) Tilt angle: The angle at which a PV array is set to face the sun relative to a horizontal position. This angle can be adjusted to maximise solar energy collection

DESCRIPTION OF SOLAR POWERED IRRIGATION SYSTEM (SPIS)[6]

Functioning: In a SPIS, electricity is generated by solar photovoltaic (PV) modules and used to operate pumps for the abstraction, lifting and/or distribution of irrigation water. The sun rays fall on the PV array and produce direct current (DC). The pump is a simple electric irrigation pump connected to a PV array. If the pump requires alternate current (AC) output, an inverter is used for conversion from DC to AC before being distributed to the motor. The motor runs the pump that helps lift water from the water source. The pipe connected to the pump can be used to directly supply water to the agricultural land or store it in a tank/pond/canal. A SPIS can also be installed with micro-irrigation systems such as drip and sprinkler to ensure better water management.

FIGURE 1
SPIS with Direct Pipeline and Sprinkler System for Water Supply

Difference between SPIS and traditional pumping systems: The main difference between SPIS and traditional pumping systems (i.e., diesel or electric pumps) is that it does not require any fuel (diesel, coal, kerosene, etc.) or electricity connection to operate. It can be easily deployed in remote areas with no electricity connection or unreliable electricity supply with long power outages especially during the daytime. A SPIS also allows for variable frequency operation of the pump. An electric or diesel pump is configured to operate at a fixed minimum speed, while an SPIS can start at lower speed and adjust the same depending on the availability of energy from the sun. Therefore, the water flow fluctuates based on the intensity of the sun. SPIS can enable higher water flow/output especially during the peak sun hours from 11am - 4 pm IST in India.

1.2 Solar irrigation technologies and application

The overarching objectives of the session are to describe the different types of SPIS and their usage, explain the components of a typical SPIS, and state the benefits of technology in comparison to the traditional pumping systems.

6 Source for Image 1: Solar Powered Agricultural Tools in India, Ecoideaz

1.2.1 Session outline and delivery process/methodology

Table 4: **Day 1 Session 1.2 Outline and Delivery Process/Method**

Session Outline				
Duration	**Process**	**Learning Method**	**Outcome**	**Material**
	Component: Solar Irrigation Technologies – Types, Components and Application			
15 minutes	Deliver a PPT explaining the different technologies, components and its application/usage based on varied parameters	Classroom Training	• Enhance knowledge on usage of SPIS • Enable identification of different types & components of SPIS	• PPT
15 minutes	Show videos showcasing different types of pumps (stand-alone submersible/surface, portable, and floating etc.) (Surface Pump – Link; Portable SPIS – Link; Multi-Use SPIS – Link; Success story of USPC – Link)	Audio Visual Learning		• Video
20 minutes	Give each learning group a chart with images of different SPIS technologies and components and ask trainees to place a sticker with the name of that respective technology/ component against its respective image	Group Exercise 3		• Chart paper and stickers
10 minutes	Display the charts with the identified technologies/components of each group and hold an open discussion/Q&A session			• Pamphlet
	Refresher Exercise and Distribution of Pamphlets (with images of SPIS technologies and components that can be used by agri-extension workers during their outreach with farmers) Component: Benefits of SPIS – Disaggregated at two levels (i) by type of pump and (ii) by crop and cropping systems			
15 minutes	Deliver a PPT defining the benefits of SPIS from the perspective of farmers (i.e. reliability, convenience, economical, time savings) by type of pumps as well as based on irrigation requirements of varied cropping systems including a short video on comparison of SPIS with diesel pump (Link)	• Classroom Training • Audio Visual Learning	Create awareness on benefits of technology and facilitate easy demonstration on cost-effectiveness of SPIS	• PPT and Video
30 minutes	Conduct a game on economics of SPIS with the learning groups	Game on economics of diesel pumps/SPIS		• Chart paper • Pens • Coloured tokens • Meta – Cards
15 minutes	Ask one member of each learning group (selected randomly) to describe learnings from the game and clarify any questions			• Observation sheet for facilitators
	Time: Lunch Break			

1.2.2 Content for classroom training sessions

Solar Irrigation Technologies - Types, Components and Applications

Components of a SPIS:

A SPIS or solar pump set consists of the following key components:

FIGURE 2
Solar Array

Solar Array: It is a series of solar modules which are connected in series or possibly a string of modules connected in parallel to harness solar energy and operate the pump. This can be on-ground installations or floating solar modules. It can be fixed or equipped with a solar tracking system to maximise the solar energy yield. The PV array capacity could range from 200 Wp – 5,000 Wp. The capacity of the PV array required to power the pump and its arrangement in parallel/series is based on the power capacity and maximum flow rate of the pump. Increasing the number of solar modules as compared to the power requirement for a specific capacity pump does not result in a higher water flow. Adding solar modules may have an impact on the number of hours of operation of the pump or increase water output during cloudy days. The manufacturers/distributors consider these factors while designing a SPIS and provide all technical specifications for the benefit of the farmer.

Module mounting structure: This is the physical structure that holds the solar modules and ensures safety of the system. It is typically made of stainless steel, aluminium or galvanized metal. There are different structural types such as ground mounted, pole mounted, roof mounted and ground screws. The mounting structure is designed based on various considerations like PV array size, topography, soil type, land availability, environmental conditions (e.g., prone to natural disasters, heavy winds, thunderstorms etc.) and security concerns. There are two alternatives to mount solar modules on a structure that include (i) installation with a fixed tilted angle and (ii) installation with an automatic solar tracking system.[7] The fixed installation structure is the most common in the country. The structure is typically aligned south or north to enable efficient distribution of output at different times of the day. Farmers can also install an automatic solar tracking system that consists of gears and motors which automatically aligns the solar module in the direction of maximum solar irradiation. This eliminates the need for manual adjustment of the modules by the farmers and ensures higher power output up to 30%. However, it adds to the upfront capital cost by almost 10% and increases maintenance costs of the SPIS.

FIGURE 3
Controller
(Source- Greenhouse Solar, India Mart)

Controller: It is an electronic device that matches the output from the PV array to the pump and regulates the operation of the pump as per the input energy from the PV array. The controller starts the pump slowly and adjusts the speed based on the availability of solar energy and power load. This allows for variable frequency of SPIS. Typically, the voltage of a controller ranges from 25-720 V.

Pumps: It comprises an electric motor which drives the movement of a pump impeller that moves the water under pressure. The pump can draw water from surface water resources like deep wells, ponds, lakes or groundwater sources. The water drawn can either

7 Toolbox on Solar powered irrigation system (SPIS), GIZ, March 2018

be poured directly into a storage tank or reservoir or connected via pipelines to the irrigation system (such as canals, drip, sprinkler etc.). The size of the pump depends on the flow rate (m3/hour) and head (m). The power capacity of the pump can range from 0.5 HP to 10 HP for both submersible and surface pumps. In India, majority of the farmers use pumps of size 2 HP, 3 HP and 5 HP. Pumps used for solar irrigation can be classified across two main categories that includes (i) type of motor (AC or DC pumps) and (ii) installation set-up (submersible or surface).

Type of motor

- **DC pump** - A DC pump runs on a motor which operates on direct current. The PV array generates DC current that is directly passed on to the DC pump motor through a controller. There is no conversion of current. This is available for both submersible and surface pumps. The design of the pump can be centrifugal or positive displacement. These pumps are most commonly used for applications with power demand up to 4 kWp.
- **AC pump** - The motor operates on alternating current (AC). This requires conversion of the DC current generated by the PV array to AC through an invertor-cum-controller. This is available for both submersible and surface pumps. The design of the pump is commonly centrifugal.

Table 5: Difference between AC and DC Pumps

Motor Type	Merits	Demerits
DC Pump 	• ~10% higher discharge compared to AC pumps. The discharge varies from 14-100 litres of water per Wp of PV array[8] • No/negligible loss of power between generation and consumption, since the current from the PV array is directly used	• Higher upfront cost compared to AC pump due to higher cost of the DC motor • Lack of after-sales service support in remote location
AC Pump 	• Lower capital cost compared to DC pump • Easy installation and readily available maintenance and repair services	• Lower efficiency and water discharge varying from 13-19 litres per Wp of PV • Loss in power between generation and consumption points • Additional cost for replacement of invertor every 6-8 years

INSTALLATION SET-UP

- **Submersible pump** - These pumps are installed completely submerged under water with a water table deeper than 10-15 metres or in a region with a constantly declining groundwater table. The motors of these pumps should never be operated without water as they would burn out due to dry running. These are most commonly installed in bore wells which may require additional capital cost for the farmer. In certain cases, submersible pumps are also installed inside surface water bodies like lakes, canals etc. depending on the depth of the water. They are available with both AC and DC motors.
- **Surface pump** – These pumps are installed in an area close to an existing water source like a pond, open well, or canal. The pump remains out of the water and has an air-cooled motor which requires proper ventilation for efficient functioning. The pump is prone to failure if it's submerged under water. Surface pumps can draw water from depths of 3 to 10 m. They are also available with both AC and DC motors.

8 Frequently Asked Questions (FAQs)- Solar water pumps, India Waterportal, March 2017

Table 6: Difference between Submersible and Surface Pumps

Pump as per installation set-up	Merits	Demerits
Submersible pump 	• No need for priming since the pump is located within water	• Higher capital and installation cost compared to surface pumps • Additional cost incurred for digging a bore well increases the installation and maintenance cost of the SPIS • Limited efficiency at lower water tables due to pump damage/failure by mud or silt which is not visible on the surface
Surface pump 	• Lower capital cost compared to surface pump • Easier installation and maintenance since the pump and motor remains out of the water	• Requires regular priming in case of high difference in pump location and water level. Dry running can damage the pump • Non-functional in locations with depleting water tables

Irrigation System: The water drawn from the solar pumping system can be directly supplied to the field or connected to an irrigation system. The selection of an irrigation system depends on multiple factors such as cropping system, crop water requirements, water availability, energy supply and farmer's financial capacity. The size and cost of the PV array is also determined by the type of irrigation system and its pressure requirements. Farmers can deploy micro-irrigation systems with relatively low water pressure requirements with solar pumping. This would result in water savings and avoid over-extraction of groundwater sources, thereby enabling environment sustainability. The suitability of few irrigation systems with solar pumping are mapped in the given table.[9]

Table 7: Suitability of Irrigation Methods to Solar Pumping

Irrigation Method/System	Water Application Efficiency	Typical Head	Suitability with Solar Pumping
Low pressure drip irrigation 	80%	1-10 m	Highly suitable especially for high-value crop production like fruits and vegetables
Open canals 	50-60%	0.5-1 m	Suitability depends on local conditions
Flood irrigation 	40-50%	0.5 m	Low suitability due to poor cost-efficiency
Sprinkler 	70-80%	10-20 m	Low suitability due to requirement of high-water pressure points
High pressure drip irrigation	85-95%	10-100 m	

9 Toolbox on Solar powered irrigation system (SPIS), GIZ, March 2018

Additionally, the SPIS may include other components and accessories like electrical cables, switches, water meters, switches/fittings, battery and invertor.

Group Exercise 3: Identifying SPIS technologies and components

The overall objective of this group exercise is to help the agri-extension workers in identification of the different types of SPIS and the key components. This exercise would include the following steps:

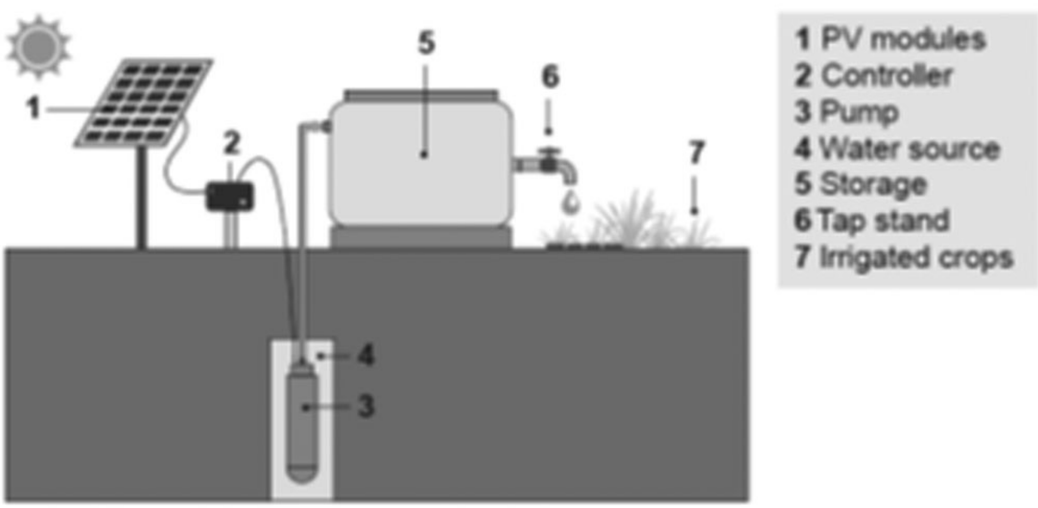
1. The facilitator will provide each LG a chart paper with images of different SPIS technologies and components
2. Each LG will be provided with stickers with names of those respective technologies/components
3. Ask the trainees to discuss within their LGs and place the given stickers against the identified technology/component
4. After identification by the trainees, the facilitator will ask a randomly selected member of the LG to display their chart in the classroom
5. The facilitator will hold an open discussion/Q&A session at the end of the exercise

TYPES AND APPLICATION OF SPIS

There are four common types of SPIS deployed in India mainly differing based on the type of water source, land availability, usage/application, and affordability.

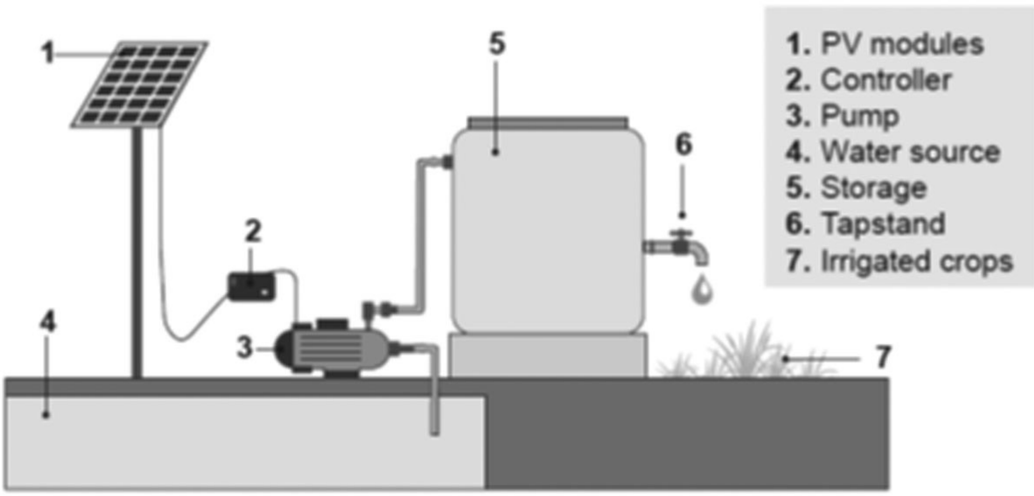
Submersible SPIS: In this system, the solar modules are ground mounted and connected to a submersible pump which is typically installed in a bore well. The power capacity of the SPIS ranges from 0.5 HP to 10 HP. The pump generally requires higher HP due to extraction of water from lower levels and larger solar PV installations.

FIGURE 1
Diagrammatic representation of a Submersible SPIS



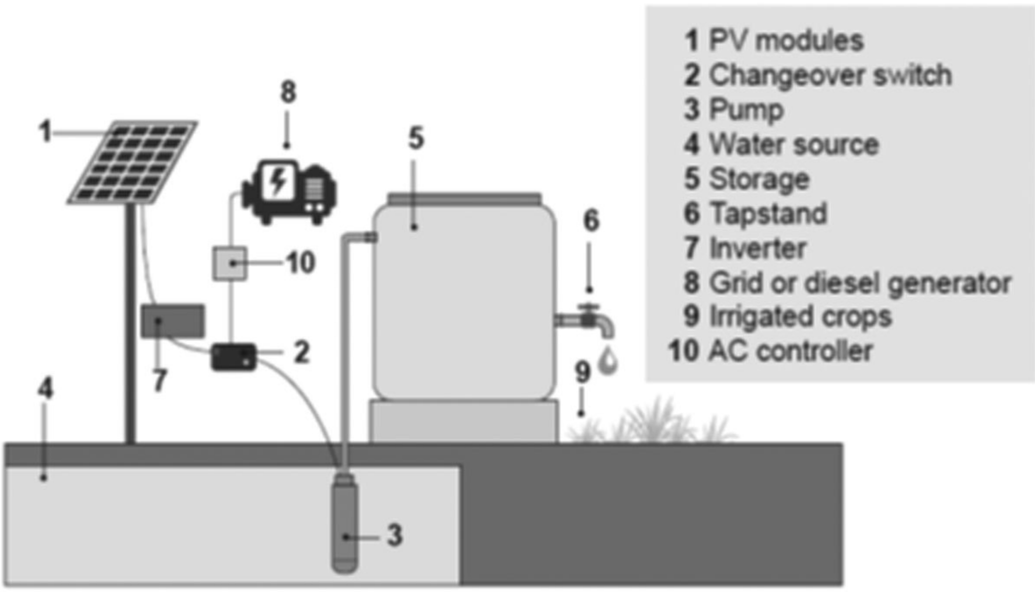
Surface SPIS: The only difference between a submersible and surface SPIS is the type of pump. The solar modules are ground mounted and connected to a surface pump located outside the water. The power capacity ranges from 0.5 HP to 10 HP. Typically, a surface SPIS is cheaper than a submersible SPIS.

FIGURE 2
Diagrammatic representation of a Surface SPIS



Hybrid SPIS: A SPIS that also uses other secondary sources of energy (i.e. electrical or diesel generator) along with solar energy is a hybrid system. A hybrid SPIS is mostly used with existing diesel pumps. This can provide better reliability as the alternative source of energy enables pumping during cloudy days or when pumping via solar is insufficient to meet the irrigation requirements. A hybrid system does not require any battery. In case of integration with the electric grid, a transformer may be required to adjust AC voltage between the grid and inverter. This can be both submersible and surface SPISs.

FIGURE 3
Diagrammatic representation of a Hybrid SPIS



Portable SPIS: These systems consist of solar modules installed over trolleys with small capacity pumps (typically 0.5 HP to 2 HP) resulting in lower water discharge per hour. The portable system tends to be more expensive mainly due to higher maintenance cost of the system, as portability increases wear and tear especially during transportation. A portable SPIS can be deployed as a community-based system, whereby a group of farmers or a local NGO purchases the SPIS, and the farmers pay for irrigation water based on their usage. This significantly reduces the cost for the farmers and improves affordability. Some of the organisations deploying portable SPIS are Claro Energy Private Limited in Bihar, and BAIF Development Research Foundation in Madhya Pradesh.

FIGURE 4
Portable SPIS

Floating SPIS: Floating motor pump sets are placed on top of water bodies such as lakes/canals/ponds or large dams/open wells. This water pump is mounted within a floating device with the pump inlet located in the water source. The pump set is easily portable and there is a negligible chance of the irrigation pump running dry. The PV array is installed on land and water is typically pumped to a storage tank. There is also potential to create a floating platform with solar PV and a pump system. This is especially beneficial in land scarce areas.

FIGURE 5
Floating pump set

Multi-Use SPIS: A type of solar pump (i.e., submersible/surface/hybrid/portable/floating) that is used for multiple uses in addition to pumping water for irrigation is called a multi-use SPIS. On an average irrigation is required for 4-6 hours per day for around 150 days in a year. Any excess solar energy after pumping can be used for other productive uses (such as milling, food processing, grinding etc.) or be supplied to the grid at a pre-determined tariff with the utility. Farmers may need to incur additional cost for installation and maintenance of batteries for operations during non-sunny hours of the day. A multi-use system can improve utilisation of the solar modules and provide alternative sources of income generation for farmers. Furthermore, new technologies like 'Agrivoltaics' can be implemented by farmers. This system uses the space under the PV array for production of high-value crops[10] (like spinach, aloe vera, medicinal plants, grapes etc.) that can be grown in shade.

Benefits of SPIS

SPIS provides significant socio-economic and environmental benefits both at the national and farm level. Some of the overarching benefits of SPIS for farmers are:

10 Agrivoltaics in India, NSEFI, Jan 2021

FIGURE 6
Agrivoltaics System

Reliability: SPIS provides a reliable source of energy for pumping irrigation water in remote areas, especially with no grid connectivity or unreliable energy supply with long power outages. It also helps improve water access as pumped water during the day can be stored in tanks or reservoirs and used for household use after meeting irrigation requirements. This is beneficial in drought prone areas where surface water may need to be collected from long distances for household uses.

Durability: SPIS have a longer lifetime of 25 years compared to 10 years for diesel pumps. The mounting structures are made of galvanized steel or aluminium ensuring structural strength. Manufacturers provide a warranty of 25 years for the solar module and 5 years for the pump and controller.

Cost-effectiveness: SPIS has a higher initial investment though lower operation and maintenance cost makes it more cost-effective than traditional pumping systems. The annualized lifecycle cost of capacity 5 HP is estimated as ~INR 45,000/year compared to ~INR 51,000/year for a 5 HP electric pump and INR 150,000/year for a 5 HP diesel pump. There is 'no energy cost or no fuel cost' which reduces the overall cost of SPIS significantly compared to diesel pumps. Furthermore, there are no additional costs associated with solar pumps such as cost incurred towards transport of fuel from petrol pumps to farms for diesel pumps.

Time-saving: Farmers can potentially save more time by using SPIS as it replaces labour intensive manual irrigation. Also, potential time-saving from traversing long distances to purchase fuel for diesel pumps or collect water for household use. This time can be better utilized for other income generating options such as milling, sawing, cooking etc.

Income enhancement: Farmers can diversify production towards high-value crops (such as fruits and vegetables) with assured supply of energy and water through a SPIS. Energy savings and improved crop yield can increase profitability up to 50% for farmers. Furthermore, there is potential for additional income generation by using excess solar energy for other productive uses (such as milling, food processing, grinding etc.) or supplying to the grid at a pre-determined tariff with the utility.

Sustainability: SPIS is an environment friendly technology as it prevents air pollution and avoids water losses. Replacement of a diesel generator by a typical PV system can potentially save up to 1 kg of carbon dioxide per kWh of output.[11] Moreover, a SPIS helps avoid groundwater and soil contamination due to spillage of fuel on agricultural land.

11 Toolbox on Solar powered irrigation system (SPIS), GIZ, March 2018

Brief note: Game on economics of diesel pumps/SPIS

The facilitators will explain the cost-benefit assessment of diesel pumps vis-à-vis SPIS through a resource economics game. The key steps are:

1. Provide multiple-coloured tokens valued with a specific financial amount (in hundreds, thousands, and lacs) to each learning group
2. Provide multiple cards with the cost of diesel pump and SPIS – capital cost, operating cost, maintenance cost, replacement costs, etc.
3. Create a chart showcasing a lifecycle of 25 years and ask the trainees to put the requisite tokens based on the cards for each type of the pump
4. Pick different scenarios and hold discussions with the learning groups (on aspects such as different size of pumps, location of pumps and to-and-fro cost in fetching diesel, etc.)

This will enable the trainees to visually comprehend the benefit of a SPIS based on cost-economics. This game can be easily replicated by the agri-extension workers with the farmers using easily available material on the field such as pebbles and map it on the ground.

Detailed process and content of the tool is given in Section 4 of the guide.

Note: Comparative economics of electric pumps and SPISs

Electricity tariff is the main cost parameter that determines the cost-effectiveness of SPISs vis-à-vis electric pumps. A higher electricity tariff would increase the operational cost of running an electric pump and make it financially less viable c than a SPIS with 'no/negligible' operational costs (as solar energy is 'free' source of fuel). For instance, the annualized lifecycle cost of 5 HP pump with a tariff of INR 2/kWh is estimated to be ~INR 51,000/year; while for a 5 HP SPIS it is ~INR 45,000/year.[12] Presently, majority of the state governments provide huge subsidies on agricultural electricity (~INR 0.5-2 per kWh) making electric pumps relatively more cost-efficient than SPISs. However, recent trends in policies/regulations show a transition towards reducing the amount of electricity subsidies in the agriculture sector and promoting SPIS through capital subsidies and other benefits. Hence, it is beneficial for farmers to replace their existing electric pumps with SPISs as it would reap higher economic and environmental benefits in the medium to long term.

Few specific advantages of SPIS compared to traditional pumping systems are given in the table.

Table 8: Merits and Demerits of Different Types of Irrigation Pumps

Type of Irrigation Pump	Merits	Demerits
Solar powered irrigation system 	• Reliable and non-polluting energy source especially in weak/off-grid areas • Negligible operational and maintenance cost due to 'free' energy • Longer life expectancy of ~25 years compared to diesel pumps (~10 years) • Higher profitability for farmers up to 50% due to increase in yield and energy savings	• High initial capital cost • Lower efficiency of solar PV system during cloudy and rainy days • Additional investment for establishing a water storage unit for meeting irrigation requirements during night or cloudy/rainy days • Poor after-sales service and repairs require skilled technicians

12 Intellecap Analysis

Type of Irrigation Pump	Merits	Demerits
Diesel pump 	• Low initial capital investment and easy installation • Highly portable system requiring less surface area for installation compared to a SPIS	• High operating costs mainly due to fuel and recurring expenditures such as transport cost for fuel purchase. Diesel irrigation expenditure amounts to ~20% of annual revenue per acre • Shorter life expectancy • Feasible only for shallow depths • Contamination of soil/water due to spillage of diesel
Electric Pump 	• Easy to install and maintain • Grid-connected electricity for agriculture purposes is highly subsidized making it more cost effective than diesel pumps	• Unreliable grid-connected electricity supply with long power cuts and low voltage impacts irrigation potential in weak-grid areas • High cost of maintenance as motors may burn due to power being supplied on the neutral line • Polluting source of energy with additional use of diesel generators

1.3 Different models of solar powered irrigation systems

The key learning outcomes desired from this session are creating a comprehensive understanding of the varied deployment models for solar powered irrigation systems and developing practical skills on usage of different irrigation technologies.

1.3.1 Session outline and delivery process/methodology

Table 9: Session 1.3 Outline and Delivery Process/ Method

Session Outline				
Duration	Process	Learning Method	Outcome	Material
Component: SPIS Deployment Models				
10 minutes	Deliver a PPT with simple flow charts explaining the different deployment models	Classroom Training	• Impart knowledge on different types of implementation models – usage, viability, challenges • Enable visualization of the implementation procedure of few innovative models including key actors and their roles	
30 minutes	Display 3-4 posters with different SPIS deployment models with each learning group and ask them to analyse the poster, discuss as a group and share their learnings on a chart paper	Group Exercise 4		• Posters • Chart papers • Markers/ Pens
5 minutes	Show a video on the cooperative model deployed in Gujarat (Link)	Audio Visual Learning		• Video
Tea/Coffee Break				
Component: Field Visit Day 1 - Demonstration of SPIS at BISA farm				
90 minutes	Demonstrate different types of technologies (including AC/ DC, portable 1 HP pump, drip/ sprinkler irrigation systems, solar components of SPIS) and explain basic installation steps (through a DIY kit) and maintenance techniques	Field Demonstration	Develop practical skills on usage of different irrigation technologies	Source SPIS technology and irrigation technologies (drip/sprinkler)

Session Outline				
Duration	Process	Learning Method	Outcome	Material
30 minutes	Ask each learning group to describe key learnings from the field visit and mention any questions/queries for further clarification on a chart – they can also be asked to come prepare next day after analysing different component during the day	Group Exercise 5		• Charts • Markers/ Pens
End of Day 1				

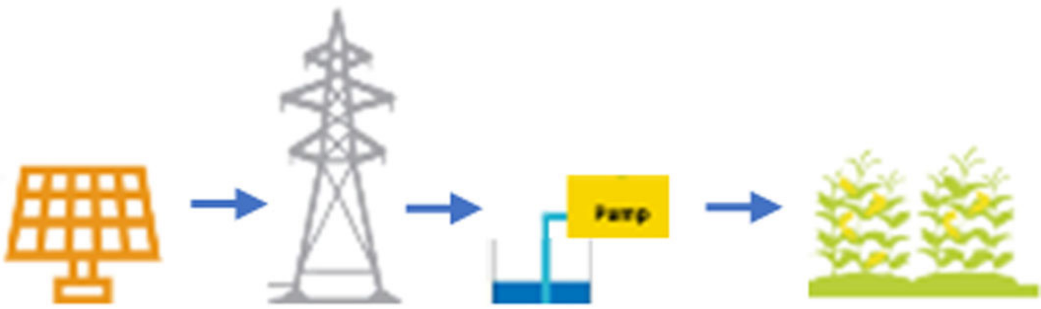
1.3.2 Content for classroom training sessions

SPIS Deployment Models

Classification of SPIS Deployment Approaches

SPIS deployment approaches can be classified across three distinct systems based on the point of deployment of the solar PV system and its primary usage.

FIGURE 7
Representation of a Centralized System



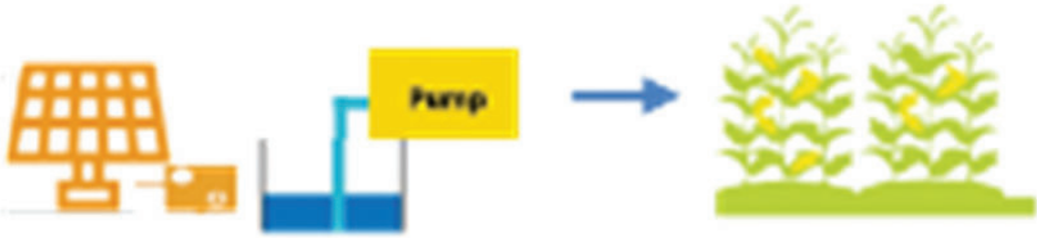
Centralized System: This comprises large solar PV plants (mostly of capacity >1 MW) that are connected to the grid and supply electricity for different loads including agriculture. In this system, solar energy is not being used to directly run the pump. Solar energy is being supplied to the main grid which is connected to the agriculture feeder. The farmers can access solar energy for pumping by connecting their electrical pumps to the agriculture feeder. There is no difference in the functioning of the pump. The energy is purchased at the prescribed agricultural power tariff rate by the state (as low as INR 0.8/kWh). For example, The Maharashtra State Power Generation Corp. Ltd (MPGCCL) is implementing a program to install solar power plants (1-4 MW) directly connected to agriculture feeders, thereby negating the need for transmission.

Distributed System: This entails grid-connected SPIS that supply surplus solar energy to the DISCOM at a pre-decided tariff rate based on the net-metering scheme of the given state. Primarily, the

FIGURE 8
Representation of a Distributed System

energy supplied is utilized for pumping of irrigation water and any excess energy is supplied back to the grid. This provides farmers with additional income from sale of electricity to the DISCOM. For instance, In Gujarat, a cooperative of 6 farmers acquired SPIS with a total solar PV capacity of 56 kWp. The local utility, 'Madhya Gujarat Vij Company Limited' (MGVCL), connected its line to this micro-grid and offered the cooperative a 25 year solar PPA at INR 4.6/kWh. Few states such as Andhra Pradesh, Karnataka and Gujarat have implemented pilot projects to solarise grid connected pumps.[13]

FIGURE 9
Representation of a Decentralized System

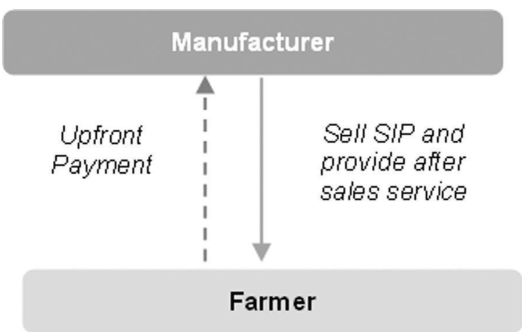


Decentralized System: These are stand-alone solar powered irrigation systems operating in off-grid areas. In this system, the SPIS is only used for pumping of irrigation water, and it is not connected to the grid or any other source of energy. This is the most common system for SPIS deployment across India. The top 4 states with maximum SPISs are Chhattisgarh, Rajasthan, Andhra Pradesh and Uttar Pradesh.

Examples of Approaches for Acquiring of SPIS by Farmers

In India, the two most common approaches of acquiring SPIS are either through government subsidies under the national level PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan) scheme or upfront purchase from the manufacturer/distributor. The description of these approaches is given below:

FIGURE 10
Upfront Purchase Model

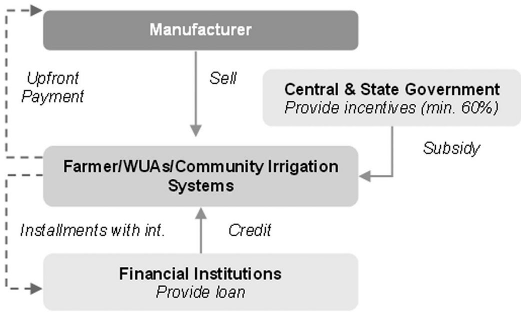


Upfront Purchase: Farmers directly purchase the SPIS from the manufacturer with a warranty of 25 years on the solar module and 5 years on the pump and controller. The manufacturers also provide additional operational facilities such as automatic shut-down, solar tracking systems etc. The system is configured and installed by the manufacturers based on the irrigation requirements of the farmers. In most cases, the manufacturers require the following details from the farmers to identify the appropriate type of SPIS: (i) total daily water requirement, (ii) vertical distance/depth from which water needs to be raised, (iii) total pipeline length from pump discharge to water delivery point and pipe diameter, and (iv) type of irrigation system (drip/sprinkler etc.) and pressure of water required. The manufacturers also provide after-sales service to their customers through their channel partners. This includes regular repair, maintenance and replacement of components. Few key market players are Shakti Pumps, Tata Power Solar, Lubi Solar, Waree, Aquatex Solar Pumps, Falcon Pumps etc.

Government subsidy: The deployment of SPISs is done by state governments as per the state policy guided by the MNRE PM-KUSUM scheme and annual target of SPISs. A 30% subsidy is provided by MNRE under the KUSUM scheme, which is topped by a subsidy amounting to at least 30% by

13 Office Memorandum on Guidelines for implementation of Component-C of PM KUSUM Scheme on Solarization, MNRE, Nov 19

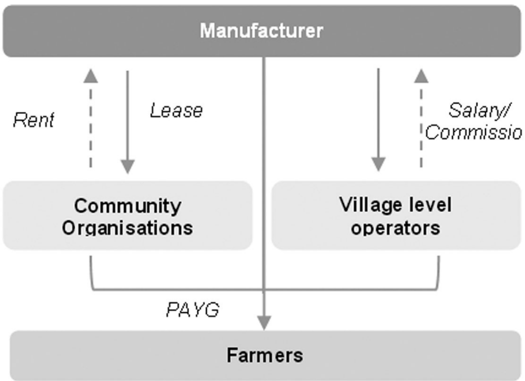
FIGURE 10
Upfront Purchase Model



the state government. In certain cases, beneficiaries can also avail loans from the financial institutions for the remaining 20-30% of the cost. The beneficiary's contribution can range from 5-10% to 40%. The detailed guidelines of the scheme and step-by-step process of implementation is given in Section 2.1 of the guide.

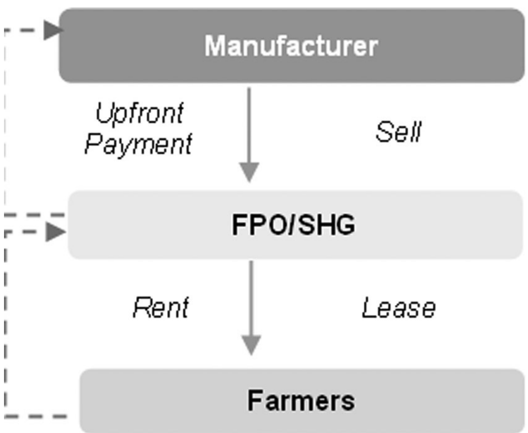
There are various other innovative approaches being piloted by NGOs, solar energy companies and utilities to improve the affordability and accessibility of SPIS especially among small holder farmers. Some of these have been defined below.

FIGURE 11
PAYG Model



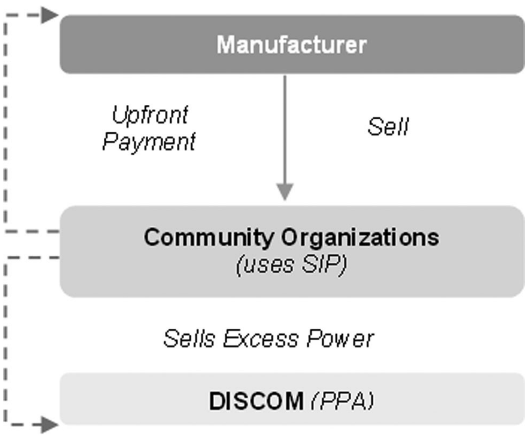
Pay-As-You-Go (PAYG): This approach for acquiring SPIS is mostly used for portable SPIS or community owned and operated SPIS. Herein, the farmer does not own the system and only pays for either the amount of energy supplied (energy-as-as-service) or water consumed (water-as-a-service) for irrigation purposes. This improves the affordability and accessibility of the SPIS for small holder farmers as they do not have to pay the high capital cost of the system and can reap the economic benefits of irrigating their land. This is being piloted by solar energy companies and NGOs. For example, Claro Energy has designed solar movable trolleys (SMTs) with a 2 HP DC surface pump. The farmers use a pre-paid PAYG card (charged by mobile money, cash deposit, or MFIs) to pay for energy-as-a-service for pumping water from their source at a rate of INR 3 per 1,000 litres. It has three business models for promoting PAYG: (i) leasing out SMTs to community organizations at annual rent of INR 45-60,000, (ii) hiring operators at monthly salary of INR 8,000, and (iii) paying commission of INR 0.5/m3 of water sold to an operator.

FIGURE 12
Community Based Rental Model



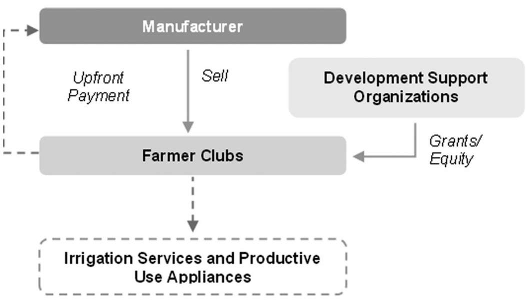
Community based rental model: The ownership and operation of the SPIS lies with a community organisation (like women self-help group, farmer producer organisation etc.). The community organisation leases out the SPIS for a specified time-period and charges each farmer for usage of the SPIS based on the duration of application of the SPIS (in hours or days). This model can support a larger number of farmers to meet their irrigation requirements in an environmentally sustainable way as well as ensure efficient capacity utilisation of the SPIS. This is being piloted by solar energy companies and NGOs. For instance, In Madhya Pradesh, the BAIF development research foundation is providing support to women SHGs to lease 1 HP AC portable SIPs through a custom hiring centre (CHC). The SHGs have contributed 20% of the cost of the system with the rest being funded through a project by USAID. The farmers pay rent of INR 50 per day (i.e. INR 10/kWh) in advance at the time of leasing from the CHC.

FIGURE 13
Net-Metering Model



Net-metering model: The SPIS is connected to the grid and any excess energy after meeting irrigation pumping requirements is supplied to the DISCOM at a pre-decided tariff rate. The solar modules used for these SPISs are usually of higher capacity than stand-alone SPIS. The ownership of the SPIS lies with individual or community organisations (like SHGs, FPOs, cooperatives, water user associations etc). The owner of the SPIS signs a power purchase agreement (PPA) with the respective DISCOM in their area for sale of solar energy back to the grid. The PPA guides the import and export of the solar energy at prescribed rates over a specified time-period. For instance, In Gujarat, the Solar Pump Irrigators' Cooperative Enterprise (SPICE) acquired SPISs with a total solar PV capacity of 56.4 kWp generating 85,000 kWh/year. SPICE adopted a net-metering model to sell excess power (~45,000 kWh/year) to the local utility 'Madhya Gujarat Vij Company Limited' (MGVCL) at INR 4.6/kWh as per a 25-year PPA. This additional revenue stream reduced the payback period for the cooperative. Please find a video of the farmer's experience in this model.

FIGURE 14
Enterprise Model



Enterprise model: This is a multi-use SPIS whereby the excess solar energy is utilized for productive uses (such as milling, food processing, grinding etc.). This provides farmers with an additional source of income and ensures efficient utilisation of the solar module. For example, in West Bengal, GIZ supported Farmer Clubs (FCs) to improve the viability of SPISs by using a localized enterprise driven model. The SPISs had low energy utilization between 1-13%. These SPISs were connected to three productive use appliances (sewing machine, animal fodder machine, and water purification system) and supplied with electricity during non-pumping hours for irrigation. This resulted in higher income generation and improved energy utilization of SPISs. The FCs and GIZ contributed equity for procuring machines, modifying SPISs etc.

Group Exercise 4: Poster session on SPIS deployment models

The aim of this session is to enhance the understanding of agri-extension workers on different types of implementation models and their viability. This exercise would include the following steps:

1. The facilitator will display 3-4 posters with different SPIS deployment models across the classroom
2. Each LG will be given 20 minutes to read all the posters and gather key insights on the model w.r.t. implementation modality, stakeholders involved, impact on farmers, applicability in their respective and challenges. These insights would be documented on chart papers
3. The facilitator randomly selects one member from each LG to share their groups' findings
4. The facilitator will hold an open discussion/Q&A session at the end of this discussion

Group Exercise 5: Discussion on learnings derived from the field visit on Day 1

The aim of this group discussion is to gather insights from the trainees on their learnings from the first day of field visit and solve any queries/clarifications if any. The key process for implementing this discussion is:

1. Ask trainees to have an internal discussion within their LGs on the learnings derived during the field visit on different types of SPIS, irrigation technologies and basic do's and don'ts for installation and maintenance and collate the same on a chart paper along with any points of clarifications/queries
2. The facilitator randomly selects one member from each LG to share their top 5 findings with all the trainees
3. After documentation from each LG, the facilitator collates the distinct points of queries mentioned on the chart paper and opens the floor for discussion

Session Plan

for Day 2 of the Program

Table 10:
Outline of Day 2 of the Capacity Development Program

Duration	Sessions	Outcome
150 Minutes	Session 2.1: Schemes and Programs for acquiring SPIS	• Comprehend the scope of financial assistance for acquiring SPIS and the procedure of applying for the scheme
	Tea/Coffee Break	
150 Minutes	Session 2.2: Selection and Installation of SPIS	• Enhance understanding on the selection and installation process of SPIS based on varied parameters
	Lunch Break	
90 Minutes	Session 2.3 Visit to farmers' field, group discussion with farmers	• Develop practical skills on usage of SPIS
	End of Day 2	

2.1 Schemes and Programs for Acquiring SPIS

The key objectives of this session are to (i) generate awareness among agri-extension workers on salient features of the different national and state level schemes and (ii) explain the procedure for acquiring stand-alone SPIS through these schemes.

2.1.1 Session outline and delivery process/methodology

Table 11:
Day 2 Session 2.1 Outline and Delivery Process/Method

Session Outline				
Duration	Process	Learning Method	Outcome	Material
Component: Recap of Day 1				
10 minutes	Conduct a multiple-choice quiz on the topics covered in Day 1		Examine retention capacity	• Quiz sheet
10 minutes	Each participant will also share about MILLY (Most Important Lesson Learnt Yesterday)	Group Exercise 6		
10 minutes	Discuss the charts prepared by the learning groups during the field visit (if not done yesterday)			
Component: National and State Level Scheme/Programs Promoting SPIS – Guidelines and Procedure for Acquiring SPIS				

Session Outline				
Duration	Process	Learning Method	Outcome	Material
5 minutes	Distribute pamphlets/reading materials (sourced from govt. agencies/NGOs or prepared internally based on the content provided) on relevant policies at the national and state level with the learning groups		• Generate awareness on financial and non-financial incentives that can be accrued by beneficiaries • Develop ability to apply for different schemes/programs and acquire technology	• Pamphlets/reading material on national and state level schemes
20 minutes	Short videos – Farmers experience applying for KUSUM scheme (Link); Benefit to farmer through KUSUM scheme (Link)	Audio visual learning		• Video
40 minutes	Discussion within each learning group to understand the guidelines and application of their respective schemes/programs and display of chart explaining key components of policies/schemes with all trainees	Group Exercise 7		• Board/Chart paper
10 minutes	Interactive session with an expert from the state nodal agency on the entire procedure for acquiring SPIS	Interaction with Experts		• Guide for interaction with experts
Component: Financing mechanisms for acquiring SPIS				
10 minutes	Interaction with a financial institution on how to access finance for SPIS or with an organization deploying innovative financing mechanisms like PAYG/lease model/water-as-a-service	Interaction with Experts	Understand financial process and mechanisms to acquire SPIS	• Guide for interaction with experts
10 minutes	Showcase tool prepared by GIZ on subsidies available as per state for different sizes of pumps	Participatory learning		• Tool
25 minutes	Undertake a role play on step-by-step procedure for accessing finance (brief description of the role play given below)	Role Play		• Document capturing script of the role play
Time: Tea/Coffee Break				

2.1.2 Content for classroom training sessions

Recapof Day 1

Group Exercise 6: Discussion on learnings derived from Day 1 of the Capacity Building Program

The aim of this group discussion is to gather insights from the trainees on their learnings from the first day of the capacity building program, address any queries/clarifications, and gather feedback on the content and delivery process. The key process for implementing this discussion is:

1. The facilitator will ask all the trainees to state the MILLY (Most Important Lesson Learnt Yesterday) one by one and any challenge that they faced during Day 1 or any specific session
2. The facilitator will collate the key pointers on the board and open the floor for discussion
3. In case the discussion on the learnings from the field work is pending from Day 1, then the facilitator can ask each LG to discuss the findings they collated on the chart

National and State Level Scheme/Programs Promoting SPIS – Guidelines and Procedure for Acquiring SPIS

Group Exercise 7: Participatory learning exercise on the guidelines and application of national and state level schemes

The aim of this learning exercise is to inform the trainees about the key features of the national and state level schemes pertaining to SPIS and understand the procedure for accessing benefits under the specified scheme.

1. The facilitator will either distribute pamphlets sourced from the government agencies or reading material (note: content is provided below) on the KUSUM scheme and relevant policies/schemes at the state level with all the LGs
2. Ask trainees to have an internal discussion within their LGs on the key aspects of the scheme and prepare a chart defining key components of both the national level scheme i.e. KUSUM and the respective state scheme. The key components to be identified are salient features, eligible beneficiaries, nature and amount of assistance and process of application. The facilitator needs to make sure that the reading material does not have this information clearly delineated in the given reading material
3. The facilitator randomly selects one member from each LG to share key insights documented on their chart with all the trainees and opens the floor for discussion

NATIONAL LEVEL SCHEME

In 2019, the Ministry of New and Renewable Energy (MNRE) launched the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM – KUSUM) scheme to provide financial assistance to beneficiaries for generating renewable energy to pump water for irrigation purposes.[14] MNRE provides INR 34,035 crore of total central financial support with the aim of adding solar capacity of 30.8 GW by 2022-23.[15] The scheme has the following three components:

Component A: Set up of 10 GW of decentralized ground/ stilt-mounted grid-connected solar or other RE based power plants (REPP) with individual plant size up to 2 MW

Sanction for 2021-22[16] : MNRE has commissioned 4,910 MW of decentralized/grid connected renewable energy-based power plants against a target of 5,000 MW

14 Guidelines for Implementation of PM-KUSUM, MNRE, July 2019
15 Order on Scale-up and Expansion of PM-KUSUM scheme, MNRE, Nov 2020
16 Demand for Grants, Sixth Report, MNRE, March 2021

Value of financial assistance: A Procurement Based Incentive (PBI) at INR 0.40/kWh or INR 6.60 lakhs/MW/year (whichever is less) will be provided by MNRE to DISCOMs for the first five years from the commercial date of operation.

Salient features

- REPPs can be set up with a capacity between 500 kW to 2 MW by individual farmers, FPOs, group of farmers, panchayats, Water User associations (WUA), cooperatives; hereby referred to as Renewable Power Generator (RPG). The states or DISCOM can allow installation of REPPs of less than 500 kW capacity based on techno-commercial feasibility.[17]
- The above-mentioned entities can develop the REPP through the local DISCOM or developers if they are unable to provide the requisite equity financing. In this scenario, the landowner will receive lease rent (either in terms of INR per year per acre of land or INR per acre of land per unit of energy generated) from the developer of the REPP.
- A REPP should be preferably installed within a five-kilometre radius of the sub-station to avoid high costs and reduce transmission losses.
- The plants can be installed on barren/fallow land, pasturelands, agricultural land and marshlands of farmers. The preference is given to uncultivable land. Agricultural land is only permitted if the REPP is installed on a raised structure ensuring that agrarian activity is not affected.
- DISCOMs will notify sub-station wise surplus capacity which can be fed from REPPs to the grid and shall invite applications through a tendering process from interested entities to set up the power plants.
- The electricity generated from the REPPS will be sold to DISCOMs at a pre-determined feed-in-tariff determined by the respective State Electricity Regulatory Commission (SERC) of the state. The DISCOM will sign a Power Purchase Agreement (PPA) valid for a period of 25 years with the selected RPG.

Component B: Install 20 lakh stand-alone SPIS of total capacity of 9.6 GW of individual capacity up to 7.5 HP

Sanction for 2021-22: MNRE has allocated 3.74 lakh SPIS against a target of replacing 7 lakh existing diesel pumps/irrigation systems

Eligible beneficiaries: Farmers (especially small/marginal), WUAs, and community/cluster-based irrigation system, FPOs and Primary Agriculture Credit Societies (PACS)

Implementation agencies: DISCOMs, renewable energy department, agricultural department, minor irrigation department or any other department designated by the state

Value of financial assistance:

- MNRE will give Central Financial Assistance (CFA) of 30% of the benchmark or tender cost (whichever is lower) in general category states/UTs. In addition, a minimum state subsidy of 30% will be given by all the states to the beneficiaries. The remaining 40% of the cost needs to be contributed by the beneficiary of which 30% can also be availed as a

17 Office Memorandum on "Amendments/clarifications in the implementation Guidelines of PM-KUSUM scheme", MNRE, Nov 2020

bank loan. Each state independently decides the value of state subsidy under the KUSUM scheme.

- In the NE/Hilly/Island States the CFA is 50% and the minimum state subsidy is 30%, which further reduces beneficiary contribution to 20%

The benchmark cost for SPIS as per capacity and location for the year 2021-22 is given in the table below[18].

Table 12: Benchmark Costs for stand-alone SPIS by MNRE (2021-22)

Pump Capacity	Application of Universal Solar Pump Controller (USPC)	Benchmark Cost (INR per pump)[19]	
		General States/UTs	NE States/Hill States and UTs/Island UTs
1.0 HP	without USPC	1,05,500	1,14,900
2.0 HP	without USPC	1,34,700	1,46,800
3.0 HP	without USPC	1,81,100	1,97,300
	with USPC	2,17,300	2,36,800
5.0 HP	without USPC	2,55,500	2,78,400
	with USPC	3,06,600	3,34,100
7.5 HP	without USPC	3,55,100	3,87,000
	with USPC	4,08,300	4,45,000
10.0 HP	without USPC	4,44,200	4,84,100
	with USPC	5,10,800	5,56,700

SALIENT FEATURES

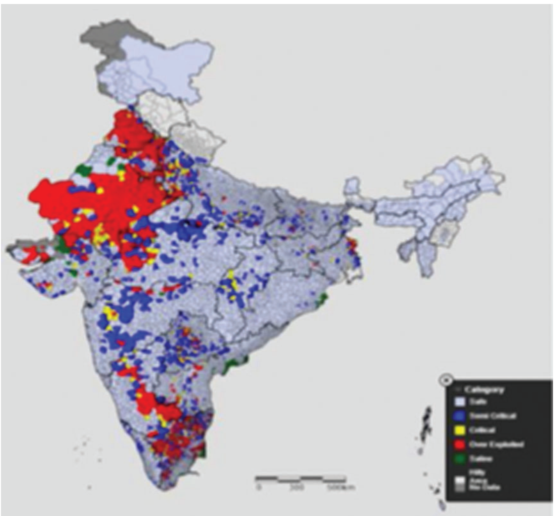


FIGURE 14 Enterprise Model Source: National Compilation on Dynamic Ground Water Resources of India, 2020, CGWB, June 2021

- This scheme also extends to installation of new SPIS in areas except dark/black zones. Dark zones are those areas with acute over-exploitation of groundwater resources (see figure 13 for reference[20]). In these areas, existing diesel pumps can be converted to stand-alone SPIS only with micro-irrigation systems.
- The beneficiary using micro-irrigation schemes will be given preference to minimize water usage for irrigation requirements
- The pump size is selected as per the area under agriculture, water table, and irrigation requirement.
- This scheme does not provide financial assistance for constructing a bore well in case of a submersible pump. It only covers the cost of the PV array and pump set.

18 Order on "Benchmark costs for Off-grid and Decentralized Solar PV System for the year 2021-2022", MNRE, Aug 2021
19 Note: This includes the cost of remote monitoring by MNRE
20 National Compilation on Dynamic Ground Water Resources of India, 2020, CGWB, June 2021

- A beneficiary can also install a universal solar pump controller (USPC) to optimize the capacity of the SPIS. This can allow the beneficiary to use solar energy for other purposes like flour mill, cold storage, battery charging etc. This additional cost of the USPC system is expected to be borne by the beneficiary. Though the states/UTs may bear this cost as per their respective guidelines.
- The manufacturer needs to provide an annual maintenance contract (AMC) for a period of five years from the installation date, including insurance coverage against theft and natural disasters.
- All SPIS should incorporate a remote monitoring system provided by the manufacturer. MNRE mandates the manufacturer to submit performance data online of the SPIS.
- The scheme also encourages innovative stand-alone SPIS solar pumps claiming better performance in terms of cost-effectiveness, efficiency, monitoring etc. These pumps will be tested in the field for a period of 1 year and assessed on comparative performance with MNRE specified technology. The pumps with considerable performance improvement may be scaled-up as per the scheme guidelines.[21]

Procedure for acquiring a stand-alone SPIS:

- MNRE will issue state-wise allocation of stand-alone SPIS on an annual basis as per the demand from the implementation agencies. MNRE will give the final sanction based on the online proposals submitted by the agencies.
- The central public sector units (like Energy Efficiency Services Limited (EESL)) will roll out the bids at a centralized level to select the manufacturers that follow the prescribed SPIS technical specifications as per MNRE guidelines. The bids rolled out at the regional/state level allow participation by only (i) manufacturers of SPIS or controllers or (ii) manufacturers of solar modules using domestically manufactured technology. The selected bidders (at least 3) that match the value of the lowest bid are allocated different districts for installation of SPISs based on their proposals.
- The eligible beneficiaries need to fill an application form either through online sources or as hard copy based on the guidelines of that specific state. For example, Jharkhand allows application through submission of a hard copy.
- Some of the key guidelines[22] prescribed for the beneficiaries are (i) SPIS can only be used for irrigation purposes and not sold/transferred to another applicant; (ii) availability of a permanent source of irrigation and water storage capacity; (ii) disconnection of the existing electric pump; and (iii) responsibility of maintenance and safety of the pump lies with the beneficiary.

An example of hard copy application for Component B of the KUSUM scheme in Jharkhand is given below:

Farmers can access three different sizes of pumps (2 HP, 3 HP and 5 HP) under the PM-KUSUM scheme from the Jharkhand Renewable Energy Development Agency (JREDA). In terms of contribution, 30% subsidy is given by the central government, 61-67% subsidy by the state government and 3-9% is the farmers' contribution. The costs of the SPIS to be paid by the farmers have been fixed at INR 5,000 for 2 HP, INR 7,000 for 3 HP and INR 10,000 for 5 HP.

21 Office Memorandum on "Guidelines for installation of innovative standalone solar pumps – reg", June 2020
22 User Manual for Application of Chief Minister Solar Pump Scheme, MPUVNL

Table 13: Costs of the SPIS to be paid by the farmers

क्रमांक	सोलर पम्प की क्षमता	बेरिंग का साईज	लाभुक अंशदान (रु० में)
1	2.0 एच.पी	4/6 ईंच	5,000/-
2	3.0 एच.पी	4/6 ईंच	7,000/-
3	5.0 एच.पी	6 ईंच	10,000/-

The step-by-by procedure for the farmer to access the benefits under this scheme is given below:

FIGURE 15 Step-by-step procedure for acquiring solar pumps in Jharkhand

FIGURE 16 Offline application form by JREDA

Jharkhand Renewable Energy Development Agency

(JREDA)

Application Format for Solar Water Pump Set

(Beneficiary Photo/

Attested

(Category)

Annexure 1

AC

DC

Signature of Beneficiary

Step 1: Farmers need to fill up an application form and prepare a demand draft in favour of "Director JREDA" and submit it to the concerned authority. A copy of the offline application form can be found here.

Step 2: The farmers' application and bank demand draft is further processed by the Block Agriculture Officer/ Block Development Officer/District Agricultural Officer, who are the nominated personnel from JREDA

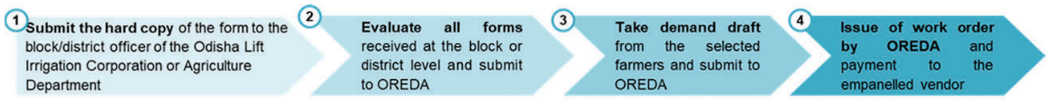
Step 3: The concerned persons accumulate all the application forms of their respective blocks and submit it to JREDA's head office in Ranchi

Step 4: After receipt of the application form with a recommendation from the concerned authority and bank demand draft (of farmers' contribution); the JREDA State Office issues a work order to the empanelled vendors. JREDA issues payments to the vendor after submission of the work completion report from the vendor

An example of hard copy application for Component B of the KUSUM scheme in Odisha is given below:

Farmers can access pumps of capacity 1 HP to 7.5 HP under the PM-KUSUM scheme from the Odisha Renewable Energy Development Agency (OREDA). The government is providing financial assistance amounting to 30% subsidy from the centre and 60% subsidy from the state. The farmers need to contribute only 10% of the cost of the SPIS to acquire a stand-alone SPIS under Component-B of the PM-KUSUM scheme in Odisha. The step-by-by procedure for the farmer to access the benefits under this scheme is given below:

FIGURE 17
Step-by-step procedure for acquiring solar pumps in Odisha



Step 1: Farmers collect and submit the hard copy of the application form at the block office of the Odisha Lift Irrigation Corporation or the Agriculture Department

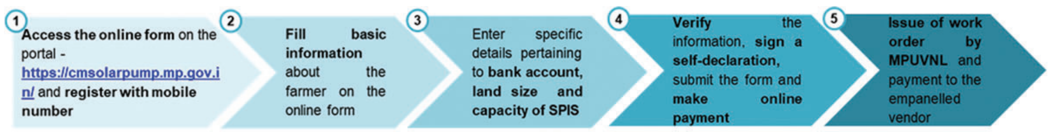
Step 2: The nodal officials at the block/district level process all the applications, prepare a list of eligible farmers and submit their recommendations to OREDA

Step 3: The officials at OREDA further evaluate the forms submitted by the block/district officials and select the final beneficiaries for the scheme. These beneficiaries are asked to submit demand drafts in favour of OREDA. The amount of beneficiary contribution is prescribed by OREDA as per the capacity of the pump

Step 4: After receipt of the bank demand draft (of farmers' contribution); the OREDA State Office issues a work order to the empanelled vendors. OREDA issues payments to the vendor after submission of the work completion report from the vendor

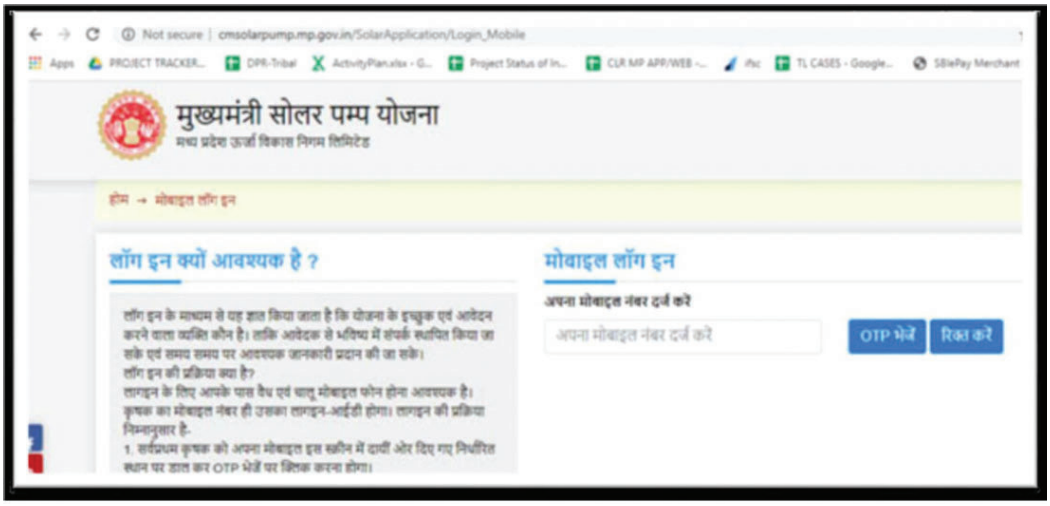
An example of online application for Component B of the KUSUM scheme in Madhya Pradesh (Hindi Manual Link):

FIGURE 18
Step-by-step procedure for acquiring solar pumps in Madhya Pradesh



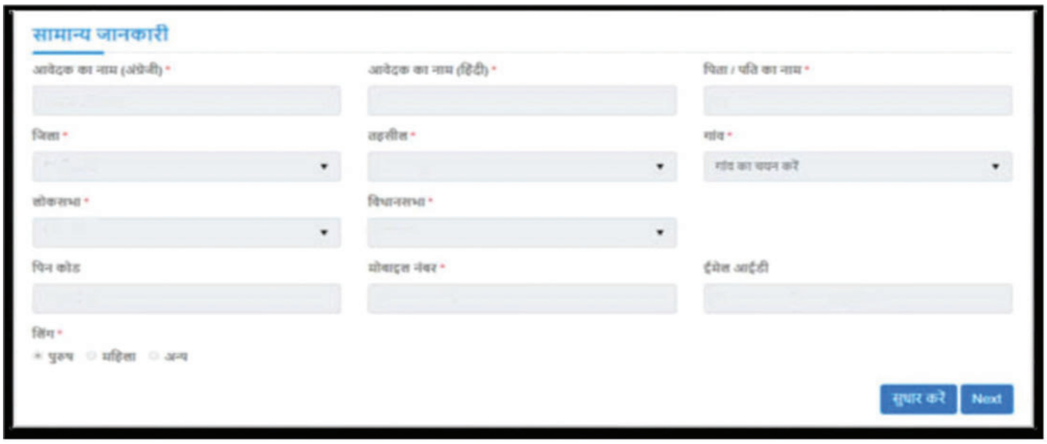
Step 1: Open the online portal - https://cmsolarpump.mp.gov.in/ and click on apply now to start the process. Submit your mobile number and access the application based on the generated OTP.

FIGURE 19
Online portal log-in screen



Step 2: Enter basic information like name of the beneficiary, gender, location (i.e. zilla, village, gram panchayat) and mobile number used for registration etc.

FIGURE 20
Screen for basicl information of the farmer



Step 3: The beneficiary needs to enter the Adhaar card number, bank account information, caste declaration, land details like khasra number and SPIS capacity and type. Each of these processes are defined below:

- Enter the Adhaar card details and conduct the KYC either through generation of OTP on registered mobile number or submission of biometrics. Adhaar based e-KYC is mandatory as per the guidelines of the scheme

FIGURE 21
Screen for entering Adhaar card details

- Fill in the bank details so that in case of non-approval of the scheme the money deposited for registration amounting to INR 5,000 is repaid to the beneficiary

FIGURE 22
Screen for submitting bank details

- Undertake a self-declaration regarding caste (General, OBC, Scheduled Caste and Scheduled Tribe)

FIGURE 23
Screen for stating case status

- Select the khasra based on the list provided on the online portal. Under the scheme provision, the benefit of the scheme can be availed only on agricultural land in the state. For verification of the agricultural land held, the beneficiary's Aadhaar number will be linked with the SPIS in any of the khasras that appear in the table on the portal. If the khasra number/ location is not accessible from the land records, the beneficiary can choose another khasra and proceed further. Other khasras selected may or may not be verified separately

FIGURE 23
Screen for stating case status

In case of non-linkage with Adhaar, select the button mentioning other khasras wherein the beneficiary provides information on the location and select the khasra accordingly

FIGURE 24
Screen for choosing khasra

Certify the khasra information and select the checkbox to proceed further

FIGURE 25
Screen for conducting self-certification of khasra

- Add details on SPIS such as khasra number, depth and size of bore well, water level, irrigation requirements, distance between the solar module and pump, type of pump etc.

FIGURE 26
Screen for adding details on SPIS

- After adding this information, the portal will show the amount of beneficiary's contribution based on the selection of the SPIS and display the water output of the SPIS

FIGURE 27
Screen showing beneficiary's contribution for acquiring SPIS

Step 4: The beneficiary verifies the information and signs the self-declaration agreeing to the conditions of the KUSUM scheme. After submitting the final application, the portal will display the application number and notify the beneficiary through SMS for online payment. The farmer will receive the application number and information through SMS post payment

FIGURE 28
showing submision of applicaton and receipt of relevant information on SMS

COMPONENT C: SOLARISATION OF 15 LAKH GRID-CONNECTED AGRICULTURAL PUMPS OF TOTAL CAPACITY OF 11.2 GW WITH INDIVIDUAL CAPACITY UP TO 7.5 HP INCLUDING THROUGH FEEDER LEVEL SOLARISATION[23]

I. Grid connected agricultural pumps

Sanction for 2021-22: MNRE has sanctioned 0.80 lakh grid-connected agricultural pumps

Eligible beneficiaries: Farmers (especially small/marginal), WUAs, and community/cluster-based irrigation system etc.

Implementation agencies: DISCOMs, GENCOs, or any other department designated by the state government

Value of financial assistance:

- MNRE will give Central Financial Assistance (CFA) of 30% of the benchmark or tender cost (whichever is lower) in general category states/UTs. In addition, a minimum state subsidy of 30% will be given by all the states to the beneficiaries. The remaining 40% of the cost needs to be contributed by the beneficiary of which 30% can also be availed as a bank loan.
- In the NE/Hilly/Island States the CFA is 50% and the minimum state subsidy is 30%, which further reduces beneficiary contribution to 20%

The benchmark costs for solarisation of grid-connected agricultural pumps as per capacity for the year 2021-22 is given in the table below.[24]

23 Office Memorandum on "Guidelines for Implementation of Feeder Level Solarisation under Component C of PM-KUSUM Scheme", MNRE, Dec 2020

24 Order on "Benchmark costs for Off-grid and Decentralized Solar PV System for the year 2021-2022, MNRE, Aug 2021

Table 14: **Benchmark costs for solarisation of grid-connected agricultural pumps by MNRE (2021-22)**

Capacity	Above 1 kW and up to 3 kW	Above 3 kW and up to 6 kW	Above 6 kW and up to 10 kW	Above 10 kW and up to 15 kW
Benchmark Cost (INR/kW)	48,300	47,100	44,300	41,000

Salient features

- This enables the beneficiaries to solarise existing pumps with PV capacity up to two times of pump capacity and use the SPIS for irrigation and sell excess solar energy supply to DISCOM.
- The beneficiary using micro-irrigation schemes will be given preference to minimize water usage for irrigation requirements. In dark/black zone areas, existing grid-connected pumps will be solarized only with micro-irrigation systems.
- DISCOM can opt for two modalities for solarisation of existing pumps; (i) net-metering wherein the pump will function at the rated capacity taking energy solar pumps and remaining deficit from the grid, in case of higher solar energy generation compared to the pump requirement, the excess supply will be fed into the grid, and (ii) pump to run only on solar energy without any grid availability for operation of the SPIS and any excess supply directly fed to the grid.
- DISCOMs will purchase excess solar energy supply from the beneficiaries at the rate decided by the respective State/SERC.

II. Feeder level solar plants

Sanction for 2021-22: MNRE has sanctioned 4.4 lakh feeder level solar plants

Eligible beneficiaries: DISCOMs/Power Department

Salient features:

- The beneficiaries can install a solar energy plant to cater to the annual energy demand of the agriculture feeder in its area, through a capital expenditure (CAPEX) or Renewable energy service company (RESCO) model.[25]
- The feeder level solar plant can be installed for a single or multiple agricultural feeders coming from a distribution sub-station with power at minimum voltage of 11 kV. There is no limit on the capacity of the solar energy plant. It depends on factors such as land availability, power requirement, technical feasibility etc.
- The project life of the solar energy plant should be 25 years and the operations/maintenance to be carried out by the implementation agency/EPC contractor.
- The implementation agency can install a feeder level solar energy plant with higher capacity than required for the agriculture feeder. The excess solar energy generated can be used to meet rural/urban loads during the day or stored in batteries for supply at night. In this scenario, the financial assistance will be limited for the solar capacity being utilised for the agriculture feeder.

25 Note: CAPEX model based projects are financed and owned by the implementation agency, whereas in a RESCO model the projects are financed, owned, and developed by third party investors or developers. In a RESCO model, the implementation agency will pay only for the electricity generated thereby reducing the investment cost.

Value of financial assistance

CAPEX model –

- MNRE will provide CFA of 30% for general states/UTs and 50% for NE/Hilly/Island states/UTs. The remaining 70% will be availed via concessional loans from NABARD/PFC/REC.
- An advance up to 40% of the eligible CFA will be provided to the implementation agency on completion of the procurement process and selection of the EPC contractor for construction of the solar energy plant. The balance amount will be released on generation of energy to the agriculture feeder(s).

RESCO model –

- The developer selected on the basis of lowest tariff for supply of solar energy will receive CFA of 30% of the total estimated cost (~INR 3.5 crore per MW) of the solar energy plant, amounting to INR 1.05 crore per MW
- In addition, the states can provide an upfront subsidy in the form of viability gap funding (VGF) to supply energy to farmers at existing subsidised rates.
- The developer needs to provide a bank guarantee up to the amount of the CFA to avail the subsidy. The developer will get 100% of the eligible CFA through the implementation agency on successful commissioning and declaration of Commercial Operation Date (COD) of the solar energy plant.

State level schemes

This capacity building program is focused in the six states of Assam, Bihar, Jharkhand, Madhya Pradesh, Odisha and Uttar Pradesh. Since 2018, majority of these states have converged schemes on solar irrigation with the national level KUSUM scheme. The table below showcases the component-wise allocation and achievement under the KUSUM scheme for the given six states as of December 2020[26].

Table 15: KUSUM Scheme State-Wise Allocation and Achievement as of Dec 2020

State	Component A (Decentralized REPPs)		Component B (Stand-alone SPIS)		Component C (Grid-Connected Agricultural Pumps)	
	Sanctioned	Achievement	Sanctioned	Achievement	Sanctioned	Achievement
Assam	-	-	-	-	-	-
Bihar	-	-	-	-	-	-
Jharkhand	10 MW	No progress reported	10,000	130	500	No progress reported
Madhya Pradesh	100 MW	Applications being invited	25,000	5,343	15,000	No progress reported
Odisha	No demand	-	2,500	48	No demand	-
Uttar Pradesh	75 MW	No progress reported	8,000	950	1,000	No progress reported

A few additional state level policies or schemes promoting solar irrigation have been briefly described in the section below.

26 Demands for Grants, Sixth Report, MNRE, March 2021

Assam

Rural Infrastructure Development Fund by the Department of Agriculture, Assam: Launched in 2016-17, this scheme aims to install 1,000 solar powered shallow tube wells (STW) for individual/group farmers having a minimum of 2 hectares of cultivable land.[27] In 2017, NABARD sanctioned INR 3,091 lakhs. The subsidy is as follows:

Table 16: Subsidy for solar powered shallow tube wells under RIDF by Govt. of Assam

Pump Capacity and Type	Component	Maximum Unit Cost (INR)	Subsidy (%)
STW with 2 HP SPV water pumping system (SPIS) with surface pump	STW including boring materials	INR 31,430	75%
	SPIS with surface pump	INR 1,87,489	85%
	Water storage tank (10,000 litre)	INR 74,000	85%
STW with 2 HP SPV water pumping system (SPIS) with submersible pump	STW including boring materials	INR 73,295	75%
	SPIS with submersible pump	INR 2,09,449	85%
	Water storage tank (10,000 litre)	INR 74,000	85%

Assam Solar Energy Policy: Launched in 2017, this policy targets installation of 1,200 solar pumps for micro-irrigation and drinking water supply with a total capacity of 6 MW by 2020-21. The state provides a maximum subsidy up to 30% of the capital cost of the SPIS.

Bihar

Bihar Saur Kranti Sinchai Yojana (BSSY) by the Bihar Renewable Energy Development Agency (BREDA): Launched in 2012, the scheme aims to increase irrigated area by providing 2 kW decentralized SIPs to farmers having 1-5 acres of land-holding and a functional bore well. The government provides a capital subsidy of 90% and the remaining 10% of the capital cost is borne by the farmers. The cost for an AC pump is INR 28,000 and for a DC pump is INR 29,700.[28]

Bihar Policy for Promotion of New and Renewable Energy by BREDA: Launched in 2017, this policy targets installation of 10,000 solar powered irrigation pumps by 2022.[29]

Odisha

Soura Jalanidhi Scheme by the Odisha Renewable Development Agency: Launched in 2017-18, this scheme aims to provide 5,000 SIPs with capacity of 0.5 HP to farmers having minimum 0.5 acres of cultivable land holding and a dug well or farm pond in owned land. This is a dug-well based solar pump irrigation scheme in convergence mode with the Department of Agriculture and Farmers' Empowerment (DA&FP). The state will provide a capacity subsidy (~90%) which entails a contribution of INR 36,000 from the DA&FP and INR 18,000 from the Department of Science and Technology (DST). The remaining cost will be contributed by the farmer through either self-financing or availing a bank loan.[30] In 2019-20, 230 SIPS (0.5 HP capacity each) were installed across the state.[31] This scheme has been converged with the PM-KUSUM scheme from 2020-21 onwards.

27 Schemes & Programs, Department of Agriculture & Horticulture, Govt. of Assam
28 Mapping Policy for Solar Irrigation Across the Water-Energy-Food (WEF) Nexus in India, IISD, Aug 2019
29 Ibid
30 Dug well Based Solar Pump Irrigation System in Convergence Mode, Department of Agriculture & Farmers' Empowerment
31 Mapping Policy for Solar Irrigation Across the Water-Energy-Food (WEF) Nexus in India, IISD, Aug 2019

Financing mechanisms for acquiring SPIS

Brief Note: Role play on procedure to access finance

The overall objective of the role play is to provide practical demonstration of the procedure to avail financing for SPIS. The trainees will be divided into two groups, one playing the role of the borrower (i.e. farmer) and the other playing the role of lender (i.e. banker). The script of the role play will define the typical procedure and questions and answers between a banker and farmer for accessing a loan under the PM-KUSUM scheme.

The borrower will ask questions about financing of SPIS to the lender on the typical loan terms (such as amount of loan, tenure, rate of interest and security) and pre-requisites for availing finance. The lender will respond to these answers and share a list of responses with the borrower (this list will be distributed among all trainees that they can use during their discussion with farmers at the field). The facilitator should encourage the borrowers and lenders to ask their own set of questions and get clarity on the entire procedure for availing loans for SPIS through banks. Any of the unanswered questions can be posed to the expert during the interactive session.

This discussion will help the trainees understand different questions which need to be answered to complete the formalities with banks and take decisions on the loan proposal. It will help the agri-extension workers to describe the entire process of availing loans to farmers by preparing them on the possible questions that could be posed by banks, as well as having a ready list of information to be shared with the farmers.

Detailed process and content of the tool is given in Section 5 of the guide.

2.2 Selection and Installation of SPIS

The two-fold objective of this session is to (i) enable the trainees to select the appropriate type, size and location of the SPIS based on various factors, and (ii) inform trainees about the installation and maintenance procedure of SPIS to increase efficiency of their system.

2.2.1 SESSION OUTLINE AND DELIVERY PROCESS/METHODOLOGY

Table 17: Day 2 Session 2.2 Outline and Delivery Process/Method

Session Outline				
Duration	Process	Learning Method	Outcome	Material
Component: Selection of SPIS – Type and Size				
5 minutes	Share a comprehensive list of factors used for selection of SPIS type/size such as cropping system, location, water level, soil type, land area, TDH, water source, daily evapotranspiration etc.	-	Develop skills on selection/ sizing of SPIS through visual learning tools	• List of factors for selection of SPIS
30 minutes	Demonstrate the tool prepared by BISA on selection/ size of SPIS based on a situational analysis game with the learning groups	• Situational Analysis Game • Online tool on sizing/selection of SPIS		• Web /Mobile Tool • Chart paper/ marker/ game cards
10 minutes	Hold an open discussion/Q&A session to discuss the outcome of the learning tool	-		-

Session Outline				
Duration	Process	Learning Method	Outcome	Material
Component: Installation Guidelines and Procedures for SPIS				
10 minutes	Deliver a short PPT with pictorial representation of guiding principles on installation of SPIS	Classroom Training	Explain the step-by-step procedure for installation of SPIS	• PPT
10 minutes	Show videos on installation of SPIS (Link)	Audio Visual Learning		• Video
30 minutes	Deliver a pictorial game on installation of SPIS with the learning groups	Pictorial Game on Installation		• Pictures for the game
10 minutes	Hold an open discussion/Q&A session	-		-
Component: Maintenance of SPIS				
10 minutes	Lead a session designed as FAQs to gather perspective from the trainees on the key problems they foresee regarding operation/maintenance of SPIS and provide requisite solutions	Group Exercise 8	Explain the maintenance plan and generate awareness on typical terms of contracts	• Board/Chart Paper
15 minutes	Distribute a maintenance schedule that includes the procedure and frequency and explain the schedule			• Maintenance schedule of SPIS
5 minutes	Show videos on proper maintenance and cleaning of SPIS (Link)	Audio visual learning		• Video
15 minutes	Interactive session with a progressive farmer or solar company on maintenance of SPIS, AMCs, and weather factors	Interaction with Experts		• Guide for interaction with experts
Time: Lunch Break				

2.2.2 CONTENT FOR CLASSROOM TRAINING SESSIONS

Selection of SPIS – Type and Size

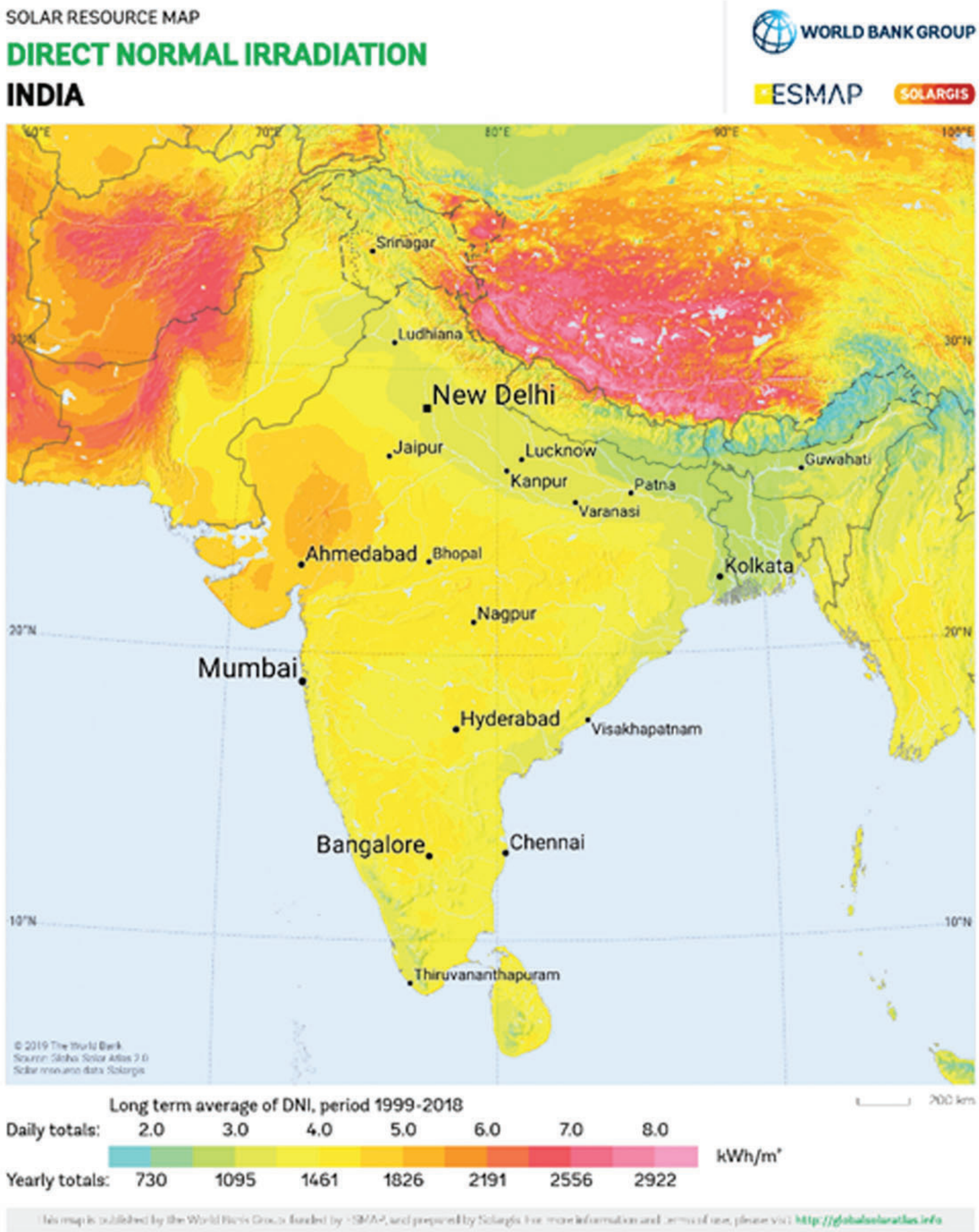
The selection of the type, size and location of the SPIS depends on various factors related to climatic conditions, agricultural practices and water resource availability, affordability and technology attributes. Some of the key input parameters across each of these factors are listed below:

Climatic conditions

Solar irradiation: The water output from a SPIS varies based on the solar irradiation which is dependent upon the time of day, month and location of the solar module. The size of the PV array needs to factor in the average solar irradiance during a month and peak irrigation requirements. Solar irrigation is advisable in locations with medium to high levels of solar irradiation (4-8 kWh/m^2).

Temperature: The water discharge from a SPIS depends on solar irradiation and not temperatures. The power generated from solar modules may decrease slightly with rise in solar module temperature

FIGURE 29
Direct Normal Solar Irradiation Map of India
Source: Solar Map for India, ESMAP



above 25 degree Celsius; thereby reducing the water outflow from the SPIS.[32] Also, higher temperature can lead to drying up of natural water resources resulting in increased water demand for irrigation and correspondingly higher capacity of SPIS for pumping water from greater depths.

Humidity: Humidity content can lower efficiency of solar modules as water droplets can collect on the PV array and reflect/refract sunlight away from the solar cells. This can reduce the generation of electricity. In addition, crop water requirements (CWRs) also depend on the level of humidity in a region. CWR is high in areas which are dry (i.e. low humidity) and low in areas which are relatively more humid.[33] This affects the capacity utilisation and size of the SPIS.

32 Solar pumping for water supply: harnessing the power of the Sun, The Solar Hub, 2020
33 Toolbox on Solar powered irrigation system (SPIS), GIZ, March 2018

Agricultural practices and water resource availability

Land area: Typically, farmers irrigating 2-3 acres of land install 2-3 HP capacity SPISs.[34] As a general thumb rule, every 1,000 Wp of PV array approximately requires 10 square metre of land.

Table 18: Time required for irrigation

SPIS Capacity	Approx. Time Required for Irrigation
1 HP	14 hours
2 HP	7 hours
3 HP	5 hours
5 HP	3 hours

Note: The time taken for irrigation would change based on the crop grown, soil type and irrigation method

Source: FAQs on Solar Powered Irrigation Pumps, GIZ, March 2018

Cropping pattern: The type of crop sown (as per season) and corresponding crop water requirements (CWRs) ascertain the capacity and efficiency of the SPIS. For instance, a higher proportion of area under horticulture crops would indicate better capacity utilization of SPIS (allowing for multi-cropping). The capacity of the irrigation pump depends on the peak daily water requirements in a specific area of land. For example, peak daily water needs of crops such as onions are 20% lower than that of sugarcane or paddy. The adequate capacity of SPIS based on time required for irrigation per acre of land is given in the corresponding table. The CWRs are also influenced by water holding capacity of the soil and other climatic factors like evapotranspiration rate and humidity. The table below provides daily water requirements[35] and total water demand per acre (i.e. 4,000 m2) of common crops grown in India.

Table 19: Crop Water Requirements of Common Crops Grown in India

Crop Type	Growing Period (No. of Days)	Daily Water Requirement (in mm)	Total Water Requirement (in 1,000 litres/acre)	Crop Type	Growing Period (No. of Days)	Daily Water Requirement (in mm)	Total Water Requirement (in 1,000 litres/acre)
Sugarcane	365	6.50	9,500	Maize	100	4.50	1,780
Cotton	202	5.25	4,220	Wheat	88	4.25	1,480
Rice	93	10.75	4,180	Oat	88	4.00	1,440
Tobacco	132	7.50	3,920	Linseed	88	3.50	1,268
Onion	120	6.25	3,000	Potato	88	7.50	1,200
Ragi	127	5.75	2,980	Pea	88	3.50	1,200
Groundnut	124	5.25	2,610	Mustard	88	3.00	1,008
Jowar	114	5.75	2,570	Barley	88	4.00	1,008

Soil type: It is generally more difficult to obtain a high uniformity of water distribution in long fields on coarse textured soil (gravels and sand) than on fine textured soils (loamy to clay). Further, the foundation and structural strength of the mounting structure for the solar module varies based on type of soil. For example, areas with loose/marshy soil may require concrete structures.

Soil water holding capacity: A SPIS can be used for a lesser number of hours daily if the water holding capacity of the soil is high.

34 Frequently Asked Questions on Solar Powered Irrigation Pumps, GIZ, March 2018
35 PIE Training Module, JOHAR, TRIF

Type of water source: The type of irrigation pump (submersible/surface) depends on the type of water source i.e. surface or ground water.

Depth or distance from water source: The capacity of pump is also determined by the pumping head, which in turn depends on the distance from or the depth of the water source. A higher capacity pump is required to extract water from lower water levels. Water depth is also factored in selecting the type of the pump. A surface pump is installed within 10 m water depth, while a submersible pump is preferred at deeper depths.

Affordability

Revenue: It is important to assess the monthly per capita expenditure of the farmer and crop revenue per unit of land. The amount of disposable income with the farmer does influence the type and capacity of the SPIS due to the relative cost-differential between different types of SPISs.

Financing: Financial assistance schemes (like subsidies on capital cost) by the government and innovative end-user financing options (like water-as-a-service, pay-as-you-use etc.) also improve affordability for farmers and influence uptake of SPIS.

Technology attributes

Total dynamic head: This is defined as the total amount of pressure when water is flowing in a system. This is calculated based on the vertical distance between the point of discharge and point of obtaining water (i.e. static head) and the effective head due to transfer of water through pipes from the pump to the storage tank (i.e. frictional head). The size of the pump and flow rate depends on the total dynamic head. The indicative technical specifications by MNRE are given in the table.

Table 20: Indicative Technical Specifications of Different SPV by MNRE

Capacity	Pump Type	Total Head (m)	PV array (Wp)	Water Output (Litres per day)
1.0 HP	DC Surface	10 m	900 Wp	99,000 LPD
	AC Surface	10 m	900 Wp	89,100 LPD
	DC Submersible	30 m	1,200 Wp	45,600 LPD
	AC Submersible	30 m	1,200 Wp	42,000 LPD
2.0 HP	DC Surface	10 m	1,800 Wp	1,98,000 LPD
	AC Surface	10 m	1,800 Wp	1,78,200 LPD
	DC Submersible	30 m	1,800 Wp	68,400 LPD
	AC Submersible	30 m	1,800 Wp	63,000 LPD
3.0 HP	DC Surface	10 m	2,700 Wp	2,97,000 LPD
		20 m	2,700 Wp	1,48,500 LPD
	AC Surface	10 m	2,700 Wp	2,67,300 LPD
		20 m	2,700 Wp	1,32,300 LPD
	DC Submersible	30 m	3,000 Wp	1,14,000 LPD
		50 m	3,000 Wp	69,000 LPD
		70 m	3,000 Wp	45,000 LPD
	AC Submersible	30 m	3,000 Wp	1,05,000 LPD
		50 m	3,000 Wp	63,000 LPD
		70 m	3,000 Wp	42,000 LPD

Capacity	Pump Type	Total Head (m)	PV array (Wp)	Water Output (Litres per day)
5.0 HP	DC Surface	10 m	4,800 Wp	5,28,000 LPD
		20 m	4,800 Wp	2,64,000 LPD
		30 m	4,800 Wp	1,82,400 LPD
	AC Surface	10 m	4,800 Wp	4,75,200 LPD
		20 m	4,800 Wp	2,35,200 LPD
		30 m	4,800 Wp	1,68,000 LPD
	DC Submersible	50 m	4,800 Wp	1,10,400 LPD
		70 m	4,800 Wp	72,000 LPD
		100 m	4,800 Wp	50,400 LPD
	AC Submersible	50 m	4,800 Wp	1,00,800 LPD
		70 m	4,800 Wp	67,200 LPD
		100 m	4,800 Wp	43,200 LPD

Brief note: Demonstration of tool prepared by BISA on selection/size of SPIS based on a situational analysis game

BISA will build capacity of the learning groups on how to use a web/mobile based SPIZ sizing tool and develop an understanding on how different input parameters can influence sizing of a particular SPIS. The key steps are:

1. Prepare and share cards providing details on different parameters that are used for selecting type and size of SPIS such as area of land, types of crops with irrigation requirements, type of water resource, water level, soil type, topography etc.
2. The learning group members will create their own scenarios based on these parameters on their charts
3. BISA will help the trainees input information as per their scenario on the web/mobile based tool
4. The learning group members will note down the result on the sizing/location of the SPIS on their chart papers

Detailed process and content of the tool is given in Section 6 of the guide

Installation Guidelines and Procedures for SPIS

Pre-Installation and Planning

The customer places an order to install a SPIS with the manufacturer. Generally, a manufacturer collects the following information[36] :

- **Customer details:** Name, Phone Number and Address
- **Pump details:** Type of Irrigation Pump (Surface/Submersible/Open Well), motor (AC/DC), location of the pump, daily water requirement (in LPD), vertical height (in m), length of the pipeline from point of water discharge to delivery area, and type of irrigation system (drip or sprinkler)

The key criterion for selecting a **suitable location of the solar module** states:

36 Bringing Reliable Water Supply with Solar Water Pump Solutions, Tata Power Solar System Limited

- **Topography:** A flat surface should be identified for mounting the solar module
- **Shading:** The solar module should be located in a shade-free area through the hours of 8 am to 4 pm. The power output of the modules reduces in shaded/covered areas
- **Minimal distance:** The PV array should be installed at the least possible distance from the water source and pump
- **Easily accessible:** The solar module should be easily accessible for cleaning of the system and should have sufficient space around the structure for unobstructed tracking movement

The key criterion for selecting a suitable location of the pump includes:

- **Topography:** A central/higher location within the irrigated area should be selected for setting up the pump
- **Minimal distance:** The pump should be installed at minimal distance from the solar module
- **Water table:** The area with the highest water table should be selected for installation of the pump in case of availability of multiple water sources
- **Suction lift:** The preferred location should have the shortest vertical distance between the surface pump and water surface

Installation Procedure

The manufacturer undertakes the installation of the SPIS in two specific stages that include (i) establishment of the mounting structure and PV array; and (ii) integration of the pump and other components. Typically, it takes around 3-4 days to replace a diesel pump with an already existing bore well; while an additional 5-7 days in case of construction of a bore well along with the SPIS. This timeline may vary depending on the site conditions.

Orientation and tilting of the PV array: The location of the mounting structure and its alignment is based on the tilting angle of the PV array to ensure optimum utilisation. The orientation and tilt angle of the PV array should be equal to the latitude of the location. A minimum 10 degree tilt angle is required to maximize efficiency and output, as well as allow runoff of rainwater from the solar module. The PV array is typically oriented towards the equator. This implies that the solar module would point southwards as India lies in the northern hemisphere.[37] The PV array can have a fixed, manual or automatic solar tracking system.

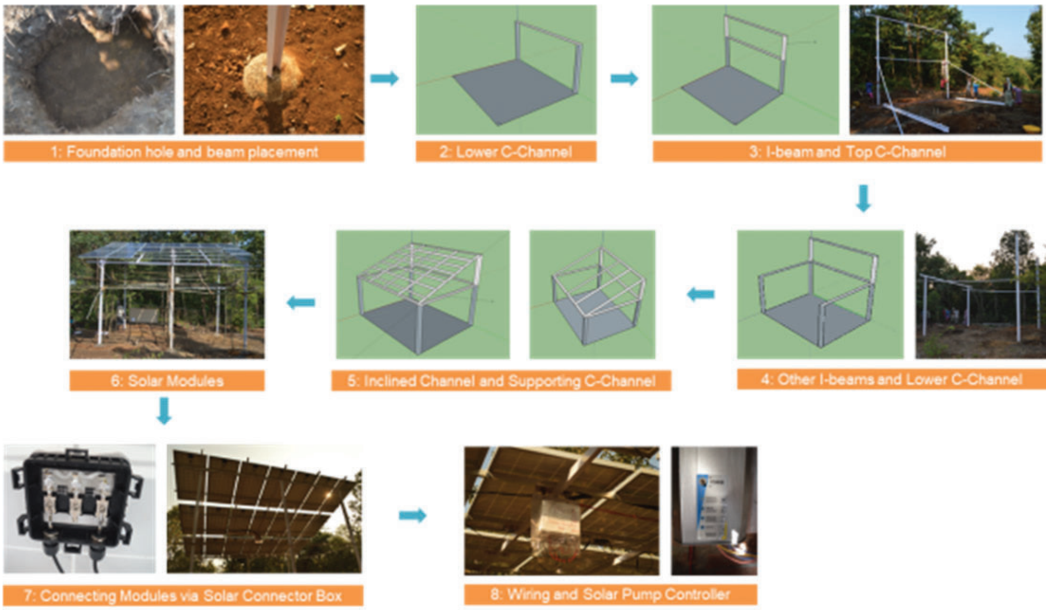
Construction of the mounting structure: The key steps involved in construction of the mounting structure[38] are placing the beam of the structure and strengthening the foundation with concrete (Step 1); placing the beams and channels of the aluminium structure as per the layout diagram or the guidelines given in the manufacturer's installation manual (Step 2-5); affixing the solar modules on the array structure at a prescribed distance by using clamps/bolts (Step 6); connecting the solar modules in series/parallel with the solar connector boxes (Step 7); and setting up the electrical connections and the solar pump controller with the PV array (Step 8). The pictorial description of the step-by-step procedure is given below:

Installation of the pump and system integration: The process for installation of the pump involves affixing the AC/DC motor assembly and screwing it to the pump; attaching the water

37 Solar water pumping system- System design, selection and Installation guide, SEIAPI, 2019

38 Solar Water Pump, Instructable workshop

FIGURE 30
Pictorial representation of installation of SPIS



outlet pipe or any other pipelines with the water storage system; connecting the cables with the pump controller; and configuring the solar pump controller with the pump/motor. The SPIS can also be integrated with micro-irrigation systems (like drip and sprinkler) for efficient water management.

Safety and security of the SPIS: The solar modules have tamper-proof hardware, and the mounting structure also uses anti-theft bolts/nuts to protect the PV array system from theft. Also, the system is placed within a fenced structure/compound which can only be accessed by the operator or owner of the SPIS.

Brief note: Pictorial game on installation of SPIS

The facilitators will explain the step-by-step procedure of installing all components of SPIS through a pictorial game. The key steps are:

1. Share photographs attached on cards showcasing all installation steps and components of the SPIS
2. Each learning group will arrange the photographs sequentially based on the procedure
3. The facilitator will note down the order of installation identified by each learning group, discuss the key steps and showcase the correct sequence (if needed)

Detailed process and content of the tool is given in Section 7 of the guide

Maintenance of SPIS

Group Exercise 8: Discussion designed as a FAQ session on maintenance of SPISs

The objective of this discussion is to gather perspective from the trainees on the key problems they foresee regarding operation and maintenance of SPIS and provide requisite solutions.

1. Ask trainees to have an internal discussion within their LGs and prepare 4-5 questions on operations and maintenance of SPIS on chart paper.
2. The facilitator randomly selects one member from each LG to share the questions for its LG and documents the distinct questions across all LGs on a chart paper/board.

3. The facilitator reads out each question and seeks response from the trainees on what they think is the appropriate maintenance process or solution. The same is documented on the chart paper/board.

After this initial discussion, the facilitator distributes the maintenance schedule (content given in this section) among all the trainees and explains the procedure and its frequency.

MAINTENANCE SCHEDULE

The manufacturer explains the key processes regarding maintenance and simple repairs of the SPIS at the time of installation. The operator/owner of the SPIS is expected to prepare a maintenance schedule highlighting the procedure and its frequency. This schedule can be maintained in a logbook. An indicative list of regular maintenance activities are given in the table below.

Table 21: Indicative Maintenance Schedule for SPISs

Category	Key Activities	Frequency
Solar Array	Undertake manual solar tracking to maximise water output. The tracking positions for the PV array based on the time of the day are east facing during morning, horizontal at noon, and west facing during the afternoon.	Daily
	Clean modules to remove accumulated dust and other debris with soft sponge and water or pressurized spray washer in the late evening or early morning when the modules are cool. Solar modules that have not been cleaned for a week can result in reduction in power output by 25-30%	Weekly
	Check the array output voltage and current (if the pump controller has a data reader)	Weekly
	Assess the amount of energy being generated by the PV system based on the reading of the controller	Weekly
	Inspect inter-module cables and other cables for any mechanical damages or loose connections	Monthly
	Check for any other technical damages like broken glass, damaged solar cells, spoilage of insulation cables etc.	Monthly
	Inspect the solar array structure for loose mounting connections	Quarterly
	Identify any structural damage such as corrosion/oxidation	Quarterly
Pump	Measure the depth of the water resource before running the pump	Daily
	Undertake priming of the suction pipe of a surface pump by putting some water in the pipe before operating the motor	Daily
	Inspect the pump performance or pumping rate	Weekly
	Check if the pump inlet is free from any debris, mud or sand and clean it	Weekly
	Examine the carbon brushes in surface pumps and replace them if required	Half-Yearly
Pump Controller	Read fault lights on the invertor or controller (if any)	Daily
	Clean the unit and minimise the possibility of dust	Weekly
	Ensure all electrical connections are tight	Weekly
Pipeline	Inspect for any leakages or blockages in the pipes	Weekly
	Remove debris within the system	Tri-Monthly
	Check all valves for inflow and outflow	Monthly
Storage Tank	Secure lids on tanks to avoid infestation	Monthly
	Disinfect and clean tank	Half-Yearly

Category	Key Activities	Frequency
Compound	Clear the area around the solar array and the water source from debris	Monthly
	Trim trees around the PV array to ensure that maximum sunlight is absorbed by the solar modules	Quarterly/ Half-Yearly
	Examine the fencing of the PV array system for any damages	Quarterly/ Half-Yearly

A pictorial representation of some common DO's and DONT's for operation and maintenance of SPIS

Table 22: **DO's and DONT's for Operation/Maintenance of SPIS**

Description	DO'S	DONT'S
Exposed Control Box The control box should be safely mounted onto a solid structure with insulated wires		
Exposed Wires Electric wires must be insulated and not exposed to outside weather con-ditions		
Mounting of solar panel Ensure solar modules are securely fastened on the array frame with rein-forcement to mitigate risk of damage or theft		
Unsecured solar panel All components of the SPIS must be secured by a lockable fenced and guarded by security personnel at night		

Description	DO'S	DONT'S
Trimming of trees Regular trimming of trees around the solar modules to ensure that they are not in a shaded area and receive maximum sun rays		
Clearing the area around bore hole and PV array system		
Completed name plate Ensure system details are displayed on the nameplate of the bore hole. This information is required for pump repair or replacement		

2.3 Visit to farmers' field, group discussion with farmers

The expected outcome of this session is to develop practical skills among trainees on usage of technology and understand field level challenges and impact of technology.

2.3.1 SESSION OUTLINE AND DELIVERY PROCESS/METHODOLOGY

Table 23: Day 2 Session 2.3 Outline and Delivery Process/Method

Session Outline				
Duration	Process	Learning Method	Outcome	Material
Component: Introduction to the Visit and Objectives				
15 minutes	Explain the objective of the visit and define any rules/procedures for the trainees	Discussion	-	-
Time: Travel to Field Site				
Component: Field Visit Day 2 – Deployment of SPIS at Farmers' Field				

Session Outline				
Duration	Process	Learning Method	Outcome	Material
60 minutes	Conduct a focus group discussion (FGD) among the trainees and farmers to understand the usage of technology, its benefits and challenges	Group exercise 9	Understand field level challenges and impact of SPIS technology	• FGD Guide
15 minutes	Hold an open discussion/Q&A session	-		-
End of Day 2				

2.3.2 CONTENT FOR CLASSROOM TRAINING SESSIONS

Field Visit Day 2: Practical Usage of SPIS at Farmers' Field

Group Exercise 9: Focus Group Discussion on Usage and Impact of SPIS

The aim of this focus group discussion is to gather the farmer's perspective on SPIS and solve any queries/clarifications on the application of SPIS if any. The key process for implementing this discussion is:

1. The facilitator will start the discussion by asking the group of farmers on the reason for deploying a SPIS and the process of acquiring it. This will help the trainees and group of farmers familiarise with the topic of discussion
2. After a basic introduction to the topic through this exercise, the facilitator will ask open-ended questions to the group of farmers from the FGD guide. Few thematic areas may include application of SPIS, operation and maintenance process, impact of the SPIS on cropping system/income/livelihoods etc., affordability of the SPIS, benefits of the pump vis-à-vis traditional pumping systems, challenges in acquiring and usage of SPIS, application of new and innovative technologies (like IoT sensors, Agri-voltaics etc.), and any recommendations for stakeholders or users of SPISs
3. The facilitator will hold an open discussion/Q&A session at the end of this discussion

Detailed FGD guide given in Annexure A

Session Plan

for Day 3 of the Program

Table 24: Outline of Day 3 of the Capacity Development Program

Outline of Day 3 of the Capacity Development Program		
Duration	Sessions	Outcome
135 Minutes	Session 3.1: Efficient use of SPIS and Scaling/Protmotion of Solar Irrigation Systems	• Enhance knowledge on climate smart strategies and showcase best practices for scaling/promoting SPIS
	Tea/Coffee Break	
90 Minutes	Session 3.2: Interactive Session with Experts	• Gather learnings from key ecosystem players on SPIS technology, it's usage and impact
	Lunch Break	
135 Minutes	Session 3.3: Open Discussion, Training Feedback, Closing	• Enable agri-extension workers to create awareness among farmers on SPIS • Seek feedback on the capacity building program
	End of Day 3	

3.1 Efficient use of SPIS and Scaling/Promotion of Solar Irrigation Systems

The two-fold objective of this session are to (i) enhance knowledge about climate smart and efficient water management practices aligned with SIPS, and (ii) share best practices on scaling/promoting of SPIS.

3.1.1 SESSION OUTLINE AND DELIVERY PROCESS/METHODOLOGY

Table 25: Day 3 Session 3.1 Outline and Delivery Process/Method

Session Outline				
Duration	Process	Learning Method	Outcome	Material
		Component: Recap of Day 2		
10 minutes	Conduct a multiple-choice quiz on the topics covered on Day 1 and Day 2	-	Examine retention capacity	• Quiz Sheet
10 minutes	Each participant will also share about MILLY (Most Important Lesson Learnt Yesterday)	Group Exercise 10		-
10 minutes	Hold an open discussion/Q&A session	Group Exercise 10		-
	Component: Efficient Use of SPIS - Water Management and Climate Smart Agriculture Practices			

Session Outline				
Duration	Process	Learning Method	Outcome	Material
15 minutes	Showcase videos on efficient water management practices and climate smart agriculture practices	Audio visual learning	Facilitate development of climate smart strategies/ plans based on different scenarios	• Videos
45 minutes	Conduct a scenario-based game on efficient use of SPIS with the learning groups	Scenario based game		• Meta – Cards • Coloured tokens • Chart paper • Markers
15 minutes	Hold an open discussion/Q&A session	=		
Component: Scaling of SPIS				
10 minutes	Deliver a PPT on scaling of SPIS in terms of key actors, cropping systems, private and development sector engagement	Classroom Training	Enhance knowledge on implementation of scaling strategies through field experiences	• PPT
10 minutes	Interaction with an expert from the govt. agency/manufacturer/ distributor to share experiences of rapid scaling of SPIS in their respective area	Interaction with Experts		• Guide for interaction with experts
10 minutes	Hold an open discussion/Q&A session	-		-
Tea/Coffee Break				

3.1.2 CONTENT FOR CLASSROOM TRAINING SESSIONS

Recap of Day 2

Group Exercise 10: Discussion on learnings derived from Day 2 of the Capacity Building Program

The aim of this group discussion is to gather insights from the trainees on their learnings from the second day of the capacity building program, address any queries/clarifications, and gather feedback on the content and delivery process. The key process for implementing this discussion is:

1. The facilitator will ask all the trainees to state the MILLY (Most Important Lesson Learnt Yesterday) one by one and any challenge that they faced during Day 2 or any specific session
2. The facilitator will collate the key pointers on the board and open the floor for discussion

Efficient Use of SPIS - Water Management and Climate Smart Agriculture Practices

Definition

Climate Smart Agriculture (CSA) is defined as a strategy for reorienting and transforming agricultural practices to cope with the negative impacts of climate change. The Food and Agricultural Organization of the United Nations (FAO) has defined CSA as '*agriculture that sustainably* *increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals*'.

Common CSA Practices

CSA practices can be classified as: (a) Improved agricultural practices that would help in soil nutrient management, improve crop yields, arrest surface run-off and increase soil moisture retention capacity; and (b) Water efficient irrigation practices such as drip irrigation/sprinklers in place of flood irrigation. The aim of these practices is to minimise the water stress situation in the given state based on the cropping pattern, and also build climate resilience and adaptive capacity of the farming community. A book documenting case studies of innovative CSA practices deployed in India can be accessed here.

Some of the common practices that can be deployed by farmers are listed below:

Ridge and Tied Furrow Practices (RTFP): The system of ridge and tied furrow practice in planting of crops may be particularly advantageous in areas where groundwater levels are falling, and herbicide-resistant weeds are becoming a problem. The dimensions of the furrows, ridges depend on several factors like means used to create them, soil type, rainfall and groundwater conditions, salinity and irrigation water quality and requirements of crops grown in rotation. Ridges and ties furrow are commonly made in the contour line with spacing of usually 1 to 2 metres. In this system, irrigation water is applied to the bottom of the furrows. Also, runoff is collected from the uncultivated strip between ridges and stored in a furrow just above the ridges with crop plantations on both the sides of the furrow. Thus, the water demand for irrigation is lowered due to the furrows collecting the water efficiently instead of spreading it over the whole surface (border irrigation). This has an added advantage in irrigation of rabi crops. The yield of runoff from the very short catchment lengths is extremely efficient and when designed and constructed correctly there should be no loss of runoff out of the system.

Dry Sowing System: This method is usually practiced for rain fed and deep-water ecosystems. In this method the farmers sow the seed onto dry soil surface, and then incorporate the seed either by ploughing or harrowing. This CSA practice helps save water in drought prone areas and resists climate variability i.e., hails, storm and wind effects. It also reduces the cost of crop cultivation and carbon emission into per square metre area. Thus, making it a dual climate adaptation strategy – resist climate variability and reduce carbon emissions.

Broad Bed and Furrow System (BBF): The Broad Bed and Furrow system has been developed at the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in India as an in-situ soil and water conservation and drainage technology for deep black soils. The recommended system consists of broad beds about 1 m wide separated by sunken furrows about 0.5 m wide with sowing of crop at a row spacing of 0.3 m. BBF system helps for safe disposal of excess water through furrows when there is high intensity rainfall with minimal soil erosion, while at the same time it serves as land surface treatment for in-situ moisture conservation. It also makes weeding easier, contributes to good pod formation and leads to proper aeration in the seedbed and root zone. Further, rainwater conserved in the furrows helps in better performance of crops during dry spells. A video on the preparation of bed and plantation of crops can be viewed here.

Soil Nutrient Management: Maintaining or improving soil organic matter is a pre-requisite to ensuring soil quality, productivity and sustainability. Increased organic matter in soil improves soil aggregation which in turn improves aeration, water storage, improves infiltration and surface and ground water quality. Soil nutrient management minimizes risk of climate change and enables adaptation to the conditions by managing organic matter content in the soil through application of vermi-compost. It is encouraged to use bio-degradable Tetra Vermi-Compost as its non-toxic, easy to use, and consumes low energy input for compositing. Additionally, green manure crops such as Sesbania/Sunhem are proposed to be grown during the South West Monsoon (SWM) period with minimum rainfall and incorporated into the soil at the age of 40 days when the crop is at peak flowering stage. This will increase the water holding capacity of the soil by increasing organic matter content. Further, these supplements of micro-nutrients and organic content will enhance the soil health and improve the overall crop production. This will lead to soil moisture conservation through enhancing soil water retention capacity and drought resilience by promoting increased biomass at farm level by cultivation of green manure field crops and improved composting.

Micro-Irrigation Systems: In drip and sprinkler irrigation, water is discharged under pressure in the air through a set of nozzles attached to a network of High Density Poly Ethylene (HDPE) pipes. These micro-irrigation systems are engineered to apply water to the crop as per requirement, thus enhancing the water application and use efficiency and improving the production per unit of water (and energy for drawing water) drawn/lifted. These are mostly suitable for high density crops such as onion and garlic. These micro-irrigation systems use less water and energy than flood irrigation thus improving water efficiency. They also decrease soil erosion which is common in flood irrigation and make the farming system more sustainable. Few benefits of drip irrigation systems can be viewed here.

System of Rice Intensification (SRI) and System of Crop Intensification (SCI): SRI involves transplanting young seedlings (typically 8-14 days old) of rice plants in a square grid pattern (25x25 cm) on a widely spaced bed (i.e. one plant per hill).[39] This system does not require irrigating the rice field up to a depth of 5 cm, it is sufficient to keep the soil moist through alternative wetting and drying method. The farmers need to frequently aerate the soil (every 7-10 days) and apply organic matter (such as compost, mulch etc.). SRI supports adaptation to climate change by saving water by 30-50% per hectare through controlled irrigation instead of flood irrigation, improving crop tolerance to biotic (diseases/pest attack) and abiotic (e.g. droughts, heat waves, high winds etc.) stresses, and increasing productivity by 20-50% compared to traditional cropping system of rice.[40][41] Furthermore, it also leads to a reduction in carbon emissions and enhances the nitrogen content of the soil. Videos explaining the process of SRI across India can be accessed here.

This method when used for other crops such as wheat, sugarcane, pulses, millets etc.; is called system of crop intensification (SCI). SCI can be used for plantation of crops with low height (less than 50 cm) that can grow in areas with shade close to the PV array of a SPIS. Some of the suitable vegetable crops may be chilli, cabbage, onion and garlic.[42] SCI for vegetables is proposed on raised bed cultivation with raising a bed of 0.30m x 1m wide bed. The plant to plant and row to row distance for planting the saplings will be 45x45 cm and the seedling will be prepared on non-soil media with pro-tray and coco peat technology. The documented advantage under this method is that vegetable production increases by 1.5 times the normal cultivation. Further, the crop water requirements (CWR) of such vegetables are lower which promotes the climate resilient malleability.

39 SRI METHODOLOGIES, Cornell University- College of Agriculture and Life sciences
40 System of Rice Intensification, Climate, Energy and Tenure Division (NRC), FAO, Dec 13
41 The System of Rice Intensification (SRI), Cornell university
42 Agri-voltaic system: Crop production and photovoltaic-based electricity generation from a single land unit, ICAR, Jan 2018

Crop Diversification and Agro-Forestry System: Crop diversification reduces the risk of crop failure and is recognized as a cost-effective solution to build resilience into an agricultural production system. Diversification also brings stability in soil fertility by cultivating legumes with cereals in rotation or in an intercropping system. Further, implementation of an agro-forestry or agro-horti model with plantation of perennial trees (e.g. fruits, timber etc.) along with existing crops can improve resilience of farmers. These models enhance resilience to climate change by promoting sequestration of carbon, minimising carbon emissions, increasing income generation and creating favourable micro-climate for other crops. A farmer's experience in Bihar on crop diversification from wheat to vegetables due to lack of water for irrigation can be viewed here.

Laser Land Levelling: This method involves using a laser land leveller machine to level the land before cropping; resulting in water saving due to reduced water-logging and minimal run-off. The farmer uses a leveller machine equipped with a laser guided drag bucket to create the desired level or slope of the land. Precise levelling of land has multiple benefits such as uniform soil moisture distribution, improvement in irrigation efficiency, reduction in nutrient loss, higher crop productivity and crop tolerance to abiotic stresses.[43] For instance, using laser land levelling technique for rice and wheat plantation lowers irrigation time by 47-69 hours per hectare per season for rice and by 10-12 hours per hectare by season for wheat; improves yield by 8%; and saves electricity amounting to 755 kWh per hectare per year due to reduced irrigation requirement.[44] A video on usage of laser land levelling technique and its benefits can be found here.

Brief note: Scenario based game on efficient use of SPIS

The overall aim of this game is to inform the trainees about the implications of efficient water management and climate smart agriculture (CSA) practices and understand its benefits through collaborative learning. The key steps are:

1. Give each learning group a particular amount of financing resources to be used for irrigation and agriculture practices in a specific piece of land with a defined cropping system
2. Provide cards with different practices and costs of implementing efficient water management/CSA practices
3. Ask the groups to create a strategy for land management based on the given information
4. Deliver different scenarios to each group for example occurrence of a drought, heat wave, pest attack etc. and relay the impact of the scenario in terms of monetary/environmental/productivity parameters
5. Ask the groups to identify the problems in their strategy based on the scenario that was given to them and prepare an improved plan/strategy considering the possible implications

Scaling of SPIS

Market drivers and challenges of scaling SPIS

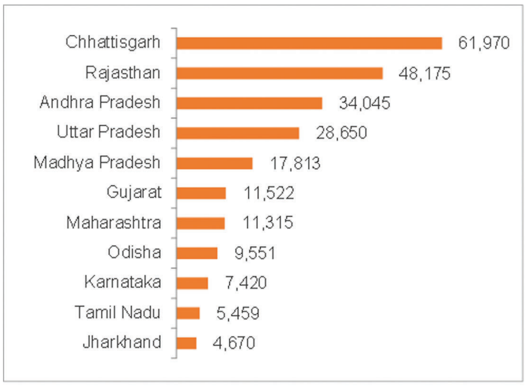
By December 2020, there were only 2,56,156 solar powered irrigation systems deployed across India. Around 94% of these stand-alone SPISs are concentrated across 11 states as given in the

43 Laser land leveling – a precursor technology for resource conservation, IRRI-CIMMYT alliance Cereal Knowledge Bank, 2007

44 Laser Land Levelling: How it Strikes all the Right Climate-Smart Chords, CGIAR, March 2015

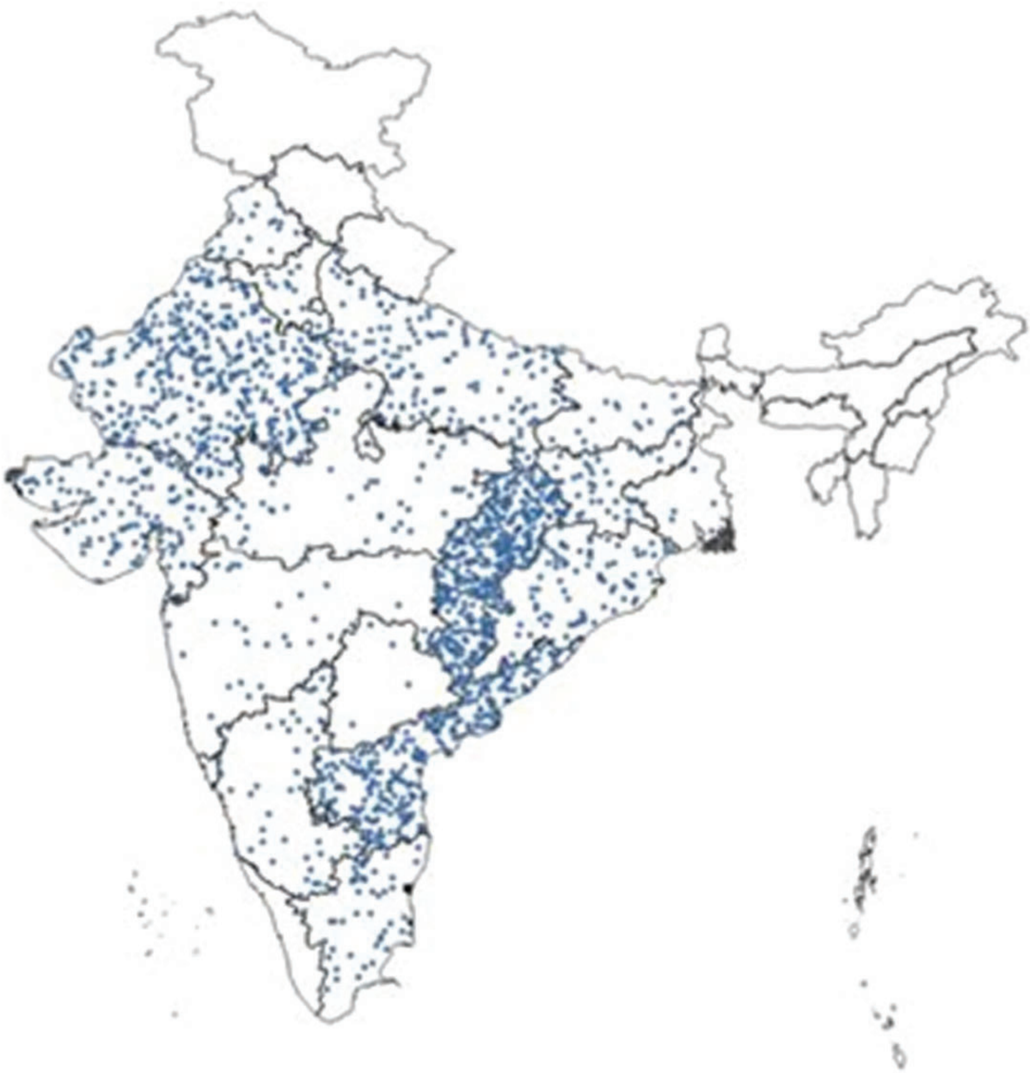
map[45] and chart[46]. Chhattisgarh, Rajasthan and Andhra Pradesh are the states with the highest installation of stand-alone SPISs.

FIGURE 31
Pictorial representation of installation of SPIS



The market for SPIS in India is mostly driven by government subsidies as mandated under the PM-KUSUM scheme. The other drivers leading to progress of the sector are decreasing prices of solar modules (by ~80-90% in the last two decades), increasing demand for irrigation by farmers, and the growing impetus by the government on domestic manufacturing of solar components/systems. Despite these factors, there hasn't been significant scaling of SPIS in India due to the following demand-side and ecosystem-level challenges:

FIGURE 32
Distribution of SPIS (1 dot = 100 pumps)



45 India – Solar Irrigation for Agricultural Resilience, IWMI
46 Energy Statistics India 2021, MOSPI

Table 26: Demand-Side Challenges related to SPIS Application in India

Parameters	Demand-Side Challenges
Affordability	High capital cost for farmers compared to the low capital cost of conventional (i.e. electric/diesel) pumps
Willingness to Pay	Low willingness to pay compared to conventional pumps varying from 12-30% of the market price, especially for small and marginal farmers
Consumer Awareness	Poor awareness and understanding among beneficiaries on usage and benefits of SPISs especially cost savings over lifetime, reliable energy supply and potential to generate additional revenue (through crop diversification, integration with applications for productive uses etc.). A survey conducted in Uttar Pradesh in 2017 found that only 27% of the farmers had heard about SPISs and a mere 2% had any information regarding government schemes.
Consumer Confidence	Limited after-sales service network in the rural regions, poor quality assurance and danger of theft of solar panels impacts consumer confidence.
Technology	Limited knowledge on operations and maintenance of the SPISs (like cleaning of solar panels) can lower the solar output and reduce water discharge

Table 27: Ecosystem-Level Challenges Related to SPIS Application in India

Parameters	Ecosystem-Level Challenges
Awareness	Limited awareness among key stakeholder groups such as financial institutions on aspects related to technology and economics of SPIS
Technology	Limited research and development on innovative technologies (e.g. IOT based SPIS) and lack of turnkey solutions as per individual farmers' specific needs
Capacity Building	Lack of training of extension workers, local government officials, technicians and farmers on application (like installation, maintenance, repairs etc.) and financing of SPISs (e.g. subsidies, low-interest loans by financial institutions, water-as-a-service, rental/lease models etc.)
Market Infrastructure	Lack of relevant infrastructure support such as after-sales service centres in remote locations and networks for market promotion.

Key recommendations for agri-extension workers to support scaling SPIS

Generate awareness on application of SPIS technology among farmers at a gram-panchayat level to promote uptake of SPISs: The agri-extension workers can conduct monthly awareness sessions with farmers highlighting critical aspects on technology, market, policies/schemes and financing of SPISs. They can also collaborate with the local Krishi Vigyan Kendra (KVK) or a research institute to conduct technology demonstrations. This will help the farmers gather an in-depth understanding of the SPIS and provide a discussion forum to seek clarifications on usage of SPISs.

Promote innovative deployment strategies/business models to improve affordability and scalability of SPISs: The agri-extension workers should promote and scale innovative deployment models catering to locale specific conditions, especially among small and marginal farmers. Some of the promising models are (i) water-as-a-service by village level solar entrepreneurs, (ii) community-based ownership and rental of SPIS to small and marginal farmers, and (iii) enterprise model focused on using excess solar energy for other productive uses by the farmer.

Collaborate with rural banks branches to improve understanding on the cost viability and economic benefits of SPIS and potentially promote off take: Banks and other financial institutions need to be trained so that they can take effective advantage of various government initiatives for promotion of SPISs. Training programs or awareness sessions by agri-extension workers focusing on technical specifications as well as benefits of SPIS need to be facilitated, along with mechanisms to ensure proper liaison with implementing agencies.

Engage with manufacturers to train local community members as solar technicians for conducting simple repair and maintenance of SPISs: After-sales service is a major issue in rural regions. In the absence of timely service, people lose trust in the product which discourages them from purchasing the product again. Technical faults often emerge due to lack of awareness/training on usage and maintenance of SPISs. The agri-extension workers can support manufacturers to design and implement a training program for community members on proper usage and handling of minor faults at the site. Local manufacturers may also provide some financial incentive to these solar technicians for uptake of any after-sales service.

3.2 Interactive Session with Experts

The two-fold objective of this session is to (i) gather learnings from key ecosystem players (i.e. solar energy experts, agrarian researchers, and private sector agencies) on usage and benefits of SPIS technology, and (ii) disseminate information on existing knowledge resources for further learning.

3.2.1 SESSION OUTLINE AND DELIVERY PROCESS/METHODOLOGY

Table 28: Day 3 Session 3.2 Outline and Delivery Process/Method

Session Outline				
Duration	Process	Learning Method	Outcome	Material
Component: Engagement with Experts in the SPIS Sector				
20 minutes	Interactive session with a technical research institute on the design of a SPIS followed by FAQs	Interaction with Experts	Enable interaction with key ecosystem players and experts to clarify queries regarding technology application, impact, challenges etc.	• Guide for interaction with experts
20 minutes	Interactive session with a NGO/CSO supporting farmers access SPIS followed by FAQs			
20 minutes	Interactive session with an agricultural research institute on applicability of SPIS and best practices for water management/CSA followed by FAQs			
Component: Knowledge Sharing on SPIS - Resources, Forums, Tools and Institutions				
20 minutes	Disseminate information on existing knowledge platforms/resources on SPIS	Group Exercise 11	Enable knowledge sharing and peer-to-peer learning	• List of resources
10 minutes	Hold an open discussion/Q&A session	-		-
Lunch Break				

3.2.2 CONTENT FOR CLASSROOM TRAINING SESSIONS

Knowledge Sharing on SPIS - Resources, Forums, Tools and Institutions

There are various resources/tools that are published by government agencies and development sector partners on SPIS and its application. Some of the most relevant resources for further reading have been listed below:

Table 29: **List of Knowledge Resources/Tools on SPIS**

Knowledge Resource/Tool and Brief Description	Link
Benchmark costs for off-grid and decentralized solar PV systems for 2021-22 by MNRE (18 August 2021): Provides details on the benchmark costs of stand-alone SPIS and solarisation of agricultural pumps mandated for the PM-KUSUM scheme	https://mnre.gov.in/img/documents/uploads/file_f-1629354435111.pdf
PM-KUSUM scheme guidelines and technical specifications by MNRE: Provides updated information on all guidelines of the national scheme on SPIS along with technical specifications regarding the solar components of the SPIS	https://mnre.gov.in/solar/schemes/
Compendium on solar powered irrigation systems in India by CCAFS (1 Sep 2020): Documents the different deployment models of SPISs and examines the key factors that affect scalability of SPISs in India	https://ccafs.cgiar.org/resources/publications/compendium-solar-powered-irrigation-systems-india
Energypedia: Documents information/data on different energy technologies and their application across different countries	https://energypedia.info/wiki/Main_Page
Toolbox on solar powered irrigation systems (SPIS) on energypedia: Consists of all resources and tools regarding financial, operational, technical and market aspects of SPIS	https://energypedia.info/wiki/Toolbox_on_SPIS
India water portal: Provides information on efficient water management practices deployed in India including FAQs on SPISs	https://www.indiawaterportal.org/ https://www.indiawaterportal.org/faqs/solar-water-pumps https://www.indiawaterportal.org/topics/solar-irrigation
Solar pump tools by CEEW: It is an online map-based, interactive decision support tool to categorize India's 613 districts as per their potential for the deployment of SPISs	https://portal.ceew.in/

There are various stakeholder groups (i.e. government agencies, NGOs/CSOs, financial institutions and research institutes etc.) that are supporting promotion of SPISs across India. Few of the most relevant stakeholders are given below:

Table 30: **Relevant Stakeholders Promoting SPIS in India**

Stakeholder Type	Name	Role
Central Government Agency	Ministry of New and Renewable Energy (MNRE)	Designs policies/regulations related to renewable energy (RE) at the national level including the PM-KUSUM scheme
Government Agency	State Nodal Agencies for Component B – Assam Energy Development Agency (AEDA); Bihar Renewable Energy Development Agency (BREDA); Jharkhand Renewable Energy Development Agency (JREDA); Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL); Odisha Renewable Energy Development Agency (OREDA); and Agricultural Department, Uttar Pradesh Govt.	Implement policies/regulations on RE projects and supports installation of SPISs under the PM-KUSUM scheme at the state level
Joint venture of Public Sector Undertakings'	Energy Efficiency Services Limited (EESL)	Invite bids from manufacturers and procure stand-alone SPISs at a centralized level under the PM-KUSUM scheme
Central Public Sector Undertaking	Solar Energy Corporation of India Ltd. (SECI)	Facilitate the MNRE to implement RE projects including SPISs
Financial Institutions	Select Banks – Bank of Baroda; Bank of India; Bank of Maharashtra; Union Bank of India etc.	Provide loans for installation of SPISs

Stakeholder Type	Name	Role
Foundations/ NGOs/ CSOs	Select Foundations/NGOs – Transform Rural India Foundation (TRIF), SwitchON Foundation, SELCO Foundation, BAIF Development Research Foundation; Tata Trusts etc.	Generate awareness on SPISs, support installation of SPISs through innovative deployment approaches, undertake policy advocacy and conduct research on solar irrigation and efficient water management practices
Research Institutes	Few examples – CGIAR, International Water Management Institute (IWMI); ICAR Indian Agricultural Research Institute; Council on Energy, Environment and Water (CEEW) etc.	

3.3 Open Discussion, Training Feedback, Closing

This session is designed to enable agri-extension workers to effectively deliver training on SPIS through a simulation exercise, assess the learnings derived from the three day capacity building program and gather feedback on the process and methodology of implementing the program.

3.3.1 SESSION OUTLINE AND DELIVERY PROCESS/METHODOLOGY

Table 31: **Day 3 Session 3.3 Outline and Delivery Process/Method**

Session Outline				
Duration	Process	Learning Method	Outcome	Material
Component: Simulation Exercise with Agri-Extension Workers				
90 minutes	Conduct a practical simulation exercise with each learning group on how they would deliver the content of this program to farmers	Simulation Exercise	Enable agri-extension workers to effectively deliver the content learnt in the capacity building program	-
Component: Evaluation of the Capacity Building Program				
15 minutes	Ask trainees to fill a post-training questionnaire based on self-assessment of knowledge and practice	Questionnaire	Evaluate the effectiveness of the program	• Post-training questionnaire
Tea/Coffee Break				
Component: Feedback on the Capacity Building Program				
15 minutes	Hold an open discussion/feedback session	Group Exercise 12	Improve the content and delivery mechanism of the program	-
30 minutes	Gather written feedback on the entire capacity building session, covering the relevance of content delivered, processes followed, logistics and teaching pace etc.			• Feedback template
Certificate Distribution and Closing of Capacity Building Program				

3.3.2 CONTENT FOR CLASSROOM TRAINING SESSIONS

Simulation Exercise with Agri-Extension Workers

Brief note: Simulation exercise on actual delivery of information by agri-extension workers to farmers

This practical exercise will help the trainers to assess whether the agri-extension workers can effectively deliver the content learnt through the capacity building program and evaluate the learning outcomes of the capacity building program. This will also help the trainers to understand the gaps in learning and identify the key challenges that may be faced by agri-extension workers on the field. This activity can be undertaken with the trainees or with actual farmers from nearby areas.

Around 5-6 trainees from each learning group can be given the role of agri-extension workers, while the others can be farmers. The trainees playing the role of agri-extension workers will be asked to deliver the content that they have learnt and answer the questions posed by the farmers. The outcome of this simulation exercise will be fed into design and delivery of the final capacity building program.

Detailed process and content of the tool is given in Section 9 of the guide

Feedback on the Capacity Building Program

Group Exercise 12: Discussion on the content and learning method of the capacity building program

The aim of this open discussion/feedback session is to gather detailed insights from the trainees on the entire capacity building program; covering the relevance of content delivered, processes followed, logistics and teaching pace etc.

1. Ask trainees to have an internal discussion within their LGs to discuss the relevance of the content and the learning methodology. The trainees document the best practices and challenges faced across the three day capacity building program on a chart paper
2. Select one member from each LG to share the key insights documented on their chart with all the trainees and open the floor for a feedback session
3. Distribute the detailed feedback template and ask all trainees to rank each session across a few aspects like relevance of content, ease of learning, level of interaction, teaching pace etc.; as well as have few open-ended questions on the overall program. This will be anonymous feedback.

An example of the feedback template is given in Annexure C of the guide

Adult Learning Tools

This section details out all the adult learning tools to be deployed by the facilitator during the capacity building program.

Game on Economics of SPIS and diesel pumps

Duration:	30 minutes
Purpose:	To explain the cost-benefit assessment of SPIS vis-à-vis diesel pumps **through a resource economics game**
Name of Session:	Solar irrigation technologies and application
Name of Component:	Benefits of SPIS: Disaggregated at two levels – (i) by type of pump and (ii) by crop and cropping systems

4.1 Methodology

The key steps to deliver the game along with the role of the trainees and facilitator are given below:

Step 1: Provide multiple-coloured tokens valued with a specific financial amount (in tens, hundreds and thousands) to each learning group (LG).

Step 2: Provide meta-cards with different cost components of SPIS and diesel pumps along with the time of its incurrence (e.g. one-time cost, annually, 5-yearly etc.) including the capital cost of each component, installation cost, operating/maintenance cost, replacement cost of any component, insurance cost, after-sales service cost etc.

Step 3: Create a chart showcasing a life cycle of 25 years for both the category of pumps and ask the trainees to put the requisite tokens based on the cards for each type of the pump

Step 4: Pick different scenarios and hold discussions with the learning groups. A few scenarios could be:

i. Increase in diesel price by 5% annually due to depleting fossil fuels in the country: In this scenario, the facilitator will ask the LGs to assess the impact of this scenario on direct fuel costs for diesel pumps and indirect costs such as transportation for fetching fuel. The facilitator will explain how the change in fuel prices leads to an increase in operational cost of the diesel pumps annually, thereby making it costlier than SPIS

ii. Decrease in water levels due to over-extraction of ground water vis-à-vis installation of a drip irrigation system with SPIS: The facilitator can explain how decreasing water levels will require constant increase in the power capacity of a pump to extract water resulting in increased capital costs year-on-year. While, adding a drip irrigation system along with the

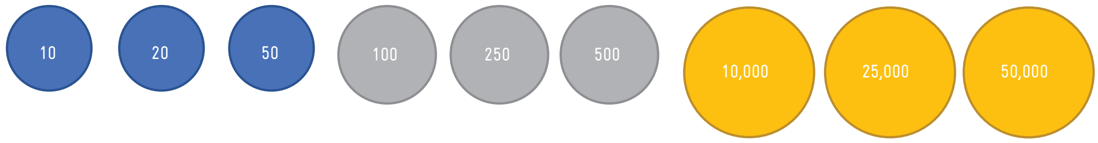
SPIS may yield higher initial capital cost but enable saving of irrigation of water, resulting in lower lifetime cost of the system

Step 5: Demonstrate the change in cost on the chart by placing or removing additional tokens based on the different scenarios

Outcome: This will enable the trainees to visually comprehend the benefit of a SPIS based on cost-economics. This game can be easily replicated by the agri-extension workers with the farmers using easily available material on the field such as pebbles and map it on the ground.

4.2 Content of the tool

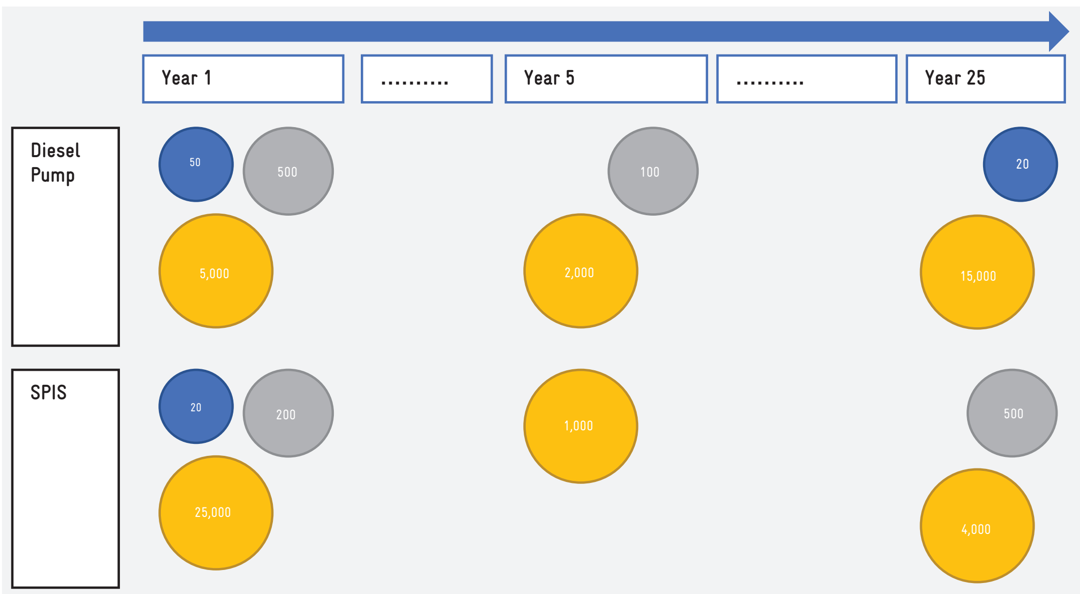
Coloured tokens with a specific colour defined for values in tens, hundreds and thousands



Illustrative examples of meta-cards displaying varied cost components for SPIS and diesel pumps

Diesel Pump	Diesel Pump	Diesel Pump	Diesel Pump
Capital cost of 5 HP pump INR 55,000	Maintenance Cost INR 2750	Fuel Cost INR 89000	Replacement of pump INR 25000
One-time Cost	Annual Cost	Annual Cost	Annual Cost
SPIS	**SPIS**	**SPIS**	**SPIS**
Capital cost of 5 HP system INR 266,950	Maintenance Cost INR 2670	Fuel Cost INR 0	Replacement of pump INR 35000
One-time Cost	Annual Cost	Annual Cost	Annual Cost

Design of the chart paper with lifecycle of 25-years with blocks for adding the costs (*indicative values assigned for diagrammatic representation) of both the pumps5.1Methodology



Role play

on procedure to access finance

Duration:	25 minutes
Purpose:	To ensure that borrowers (i.e. farmers) understand the key considerations and pre-requisites from banks to avail loans for SPIS and also prepare themselves with required document/information when they approach the bank
Name of Session:	Schemes and Programs for acquiring SPIS
Name of the Component:	Financing mechanisms for acquiring SPIS

5.1 Methodology

The trainees will perform the role of a borrower (i.e. farmer) and a lender (i.e. bank manager) among themselves and pose questions to understand financing under the KUSUM scheme, and evaluate data to inform borrowing and lending decisions. The step-by-step methodology for implementation of the role play is as follows:

Step 1: Divide the entire capacity building group into two groups of which one will be the 'lenders' and the other will be 'borrowers'

Step 2: Ask these two groups to internally discuss (for 5-7 minutes) and frame some key questions that they would like to pose to each other to understand the procedure of availing loans from a bank. The 'borrowers' will think of questions/concerns that they would like to understand from the 'lenders' and vice-versa for the lenders. These specific questions will be written by the facilitator on the board

Step 3: Prepare and distribute two separate questionnaires, one each for 'lenders' and 'borrowers', detailing the key questions that need to be posed by the borrower and the answers provided by the lenders. These handouts provide the narrative description of the entire role play. The facilitator will highlight any additional questions that may have been posed by either of the groups on the board for consideration during the role play

Step 4: Explain the role of the borrower in this role play is to:

a. Seek a loan for a SPIS

b. Interview lenders in hopes of obtaining an understanding of loan offer under the specific PM-KUSUM scheme

c. Answer the questions posed by the lender and record the details of any offers they receive from a lender on a separate sheet

d. Examine the critical aspects pertaining to accessing the loan such as eligibility criteria, interest rate, tenure, type of loan, security requirements, and documentation among others

e. Reflect on their experience with the lenders by documenting the key findings

Step 5: Explain the role of the lender in this role play is to:

a. Answer all the questions asked by the borrower accurately from the lender sheet

b. Make sure that the type of loan the borrower is requesting matches the loan provided by the bank

c. Determine the risk associated with each potential borrower

d. Ensure that all the information is provided towards the end in case the borrower misses out any particular question during the role play

Step 6: Create multiple sub-groups consisting of 3-4 borrowers and 2-3 lenders to conduct the role play in groups. Each borrower will ask a minimum of 2 questions from the 'borrower questionnaire', while the lenders can alternatively respond to the questions. The facilitator should encourage the borrowers and lenders to ask their own set of questions and get clarity on the entire procedure for availing loans for SPIS through banks

Outcome: This role play will help the trainees understand different questions which need to be answered to complete the formalities with banks and take decisions on the loan proposal. It will also help the agri-extension workers to describe the entire process of availing loans to farmers by preparing them on the possible questions that could be posed by banks, as well as having a ready list of information to be shared with farmers during their outreach activities.

5.2 Content of the tool

The narrative description of the role play is provided below:

5.2.1 BORROWER QUESTIONNAIRE

The borrower needs to understand the following information from the lender:

1. **Purpose for which the bank will provide the loan:**

   Question to the bank manager - I am here to take a loan under the PM-KUSUM scheme. I heard that there are different components of the scheme. Can you please explain the different components for which I can avail a loan under the PM-KUSUM scheme? What is the amount of subsidy provided by the government? What percentage of contribution do I need to make?

2. **Eligibility criteria for availing the loan:**

   Question to the bank manager - I am here to apply for a loan for a SPIS as an individual farmer, will I be eligible to get a loan? Are there any other groups who can also get loans under this scheme? Do I need to submit some documents or information for getting the loan?

3. **Nature of loan:**

   Question to the bank manager – What is the type of loan? Will I get a term loan or working capital loan?

4. **Maximum project cost and loan amount:**

   Question to the bank manager – What is the value of the loan that I can get? Does this change depending on the capacity/size of the SPIS? What is the maximum capacity/size of the SPIS that can be financed under this scheme?

5. **Tenure and repayment period:**

   Question to the bank manager – What is the maximum duration of loan? What will be the payment cycle (monthly, quarterly, yearly, etc.)?

6. **Rate of interest:**

   Question to the bank manager – What is the interest rate at which loan will be provided? What EMI would I need to pay for different scenarios of the payment cycle?

7. **Security:**

   Question to the bank manager – Do I need to provide any security against the loan on SPIS? What type of security needs to be provided? What percentage of the loan needs to be covered by security?

5.2.2 LENDER QUESTIONNAIRE

The answers to each of the questions posed by the borrower are given below *(Note: The answers may slightly differ based on the bank. For the role play, an illustrative example is given based on the Bank of Baroda guidelines[47]):*

1. **Purpose for which the bank will provide the loan:**

   Answer - There are three components for which you can take/apply for loan under the PM KUSUM scheme. These are

   A. Setting up of decentralized ground/ stilt mounted grid-connected solar or other renewable energy based power plants of individual plant size from 500 kW to 2 MW

   B. Installation of stand-alone SPIS of individual pump capacity up to 7.5 HP

   C. Solarisation of grid-connected agricultural pumps

   The central and state government provides a subsidy up to 60% of the benchmark or tender cost (whichever is lower) for Component B and C in general states/UTs; and up to 80% in NE/Hilly/A&N Island states/UTs. The farmer has to pay around 10% of the total cost as a contribution, while the remaining is covered by the loan provided by the bank.

2. **Eligibility criteria for availing the loan:**

   Answer - If you apply for the loan as any one of the following categories of beneficiaries you can get a loan under the PM-KUSUM Scheme. These are - Farmers, Group of farmers, Co-Operative of farmers, Panchayat, Farmer Producer organizations (FPOs) and Water users Associations (WUA) who have their own or lease land

47 Application of PM-KUSUM Scheme, Bank of Baroda

3. Nature of loan:

Answer – The loan will be provided as a Term Loan under this scheme

4. Maximum project cost and loan amount:

Answer – The financing from loan under this scheme differs based on the components and may also vary across states as per the benchmark/tender cost of the SPIS for that state. The maximum loan amount which can be financed under different components is explained below *(Note: The lender can show the sheet to the borrower and point out the different project cost and loan amount on the sheet):*

Table 32: Maximum project cost and loan amount under PM-KUSUM scheme

Particulars	Maximum Project Cost (INR)	Maximum Loan Amount (INR)
Component A	INR 3.5 Crores/ MW Maximum: INR 7.00 Crores for 2 MW	INR 490.00 Lakhs
Component B	INR 3.25 lakhs per pump	INR 0.97 lakhs
Component C	INR 4.50 lakhs per pump	INR 1.35 lakhs

5. Tenure and repayment period:

Answer – There are different tenure periods and repayment schedules disaggregated as per the components of the scheme. These are defined below (*Note: The lender can show the sheet to the borrower and point out the different tenure and repayment schedules for each component on the sheet):*

Table 33: Loan tenure and repayment schedule under PM-KUSUM scheme

Particulars	Maximum Period of Loan	Repayment Schedule
Component A	Maximum period 15 year including moratorium period of 6 months	Monthly/ Bi-monthly/ Quarterly based on Cash Flow
Component B	Maximum period of 10 years including maximum moratorium period of 6 months	Monthly/ Quarterly/Half-Yearly installment based on income generated from power unit and harvesting season.
Component C	Maximum period of 10 years including maximum moratorium period of 6 months	Monthly/ Quarterly/Half-Yearly installment based on income generated from power unit and harvesting season

6. Rate of interest:

Answer – The interest rate varies based on the loan amount taken by the individual borrower. The interest rate slabs as per the categorization are given below (*Note: The lender can show the sheet to the borrower and point out the variable rate of interest based on the loan amount on the sheet):*

Table 33: Minimum payable interest rate based on loan amount under PM-KUSUM scheme

Particular	Minimum Interest Rate (%)
For limit up to INR 3.00 lakhs	7.45%
For limit above INR 3.00 lakhs and less than INR 25.00 lakhs	8.70%
For limit of INR 25.00 lakhs and above	9.45% - 10.40%
Note: The interest rate may increase based on the credit history of the borrower and product specific factors	

7. Security:

Answer – The amount of security varies across the different component of the scheme as highlighted below (*Note: The lender can show the sheet to the borrower and point out the security requirements as per the different components of the scheme on the sheet):*

Table 35: Security requirements to avail loans under PM-KUSUM scheme

Component A	Component B	Component C
Demand promissory (DP) note	DP Note	DP Note
Offering asset as collateral	Offering asset as collateral	Offering asset as collateral
Mortgage of land or third-party guarantee	Mortgage of land or third-party guarantee applicable as per security norms for agriculture accounts	Mortgage of land or third-party guarantee applicable as per security norms for agriculture accounts

Demonstration of tool prepared by BISA on selection/size of SPIS based on a situational analysis game

Duration:	25 minutes
Purpose:	To ensure that borrowers (i.e. farmers) understand the key considerations and pre-requisites from banks to avail loans for SPIS and also prepare themselves with required document/information when they approach the bank
Name of Session:	Schemes and Programs for acquiring SPIS
Name of the Component:	Financing mechanisms for acquiring SPIS

6.1 Methodology

The key steps to deliver the game along with the role of the trainees and facilitator are given below:

Step 1: Prepare and share meta-cards with the LGs providing details on various factors such as climatic conditions, agricultural practices and water resource availability, affordability and technology attributes. The corresponding parameters include types of crops, type of water source, land area, capacity of pump, solar irradiation, financing options etc. Each crop card will have information on growing period and crop water requirements (refer to Section 2.2.2 Table 17 for details)

Step 2: Undertake a discussion within each LG for around 10 minutes to select different factors and create scenarios on a chart paper. The facilitator will ensure that each LG selects at least one parameter from each type of factor

Step 3: Support the trainees to input information as per their scenario on the web/mobile based SPIS sizing tool

Step 4: Analyse and record the result on the sizing of the SPIS based on the tool on the chart paper

Step 5: Pick different scenarios (such as decrease in rainfall, change in irrigation requirements, change in cropping pattern and increase in depth of water level) and assess the impact on sizing of the SPIS based on the tool

Step 6: Hold an open discussion with the LGs

Outcome: This will enable the trainees to understand all the factors that need to be considered before deciding the size and type of SPISs.

6.2 Content of the tool

Each factor will have a different coloured card for ease of reference. Illustrative examples of meta-cards displaying multiple parameters across each factor relevant for sizing a SPIS:

Climate	Climate	Climate	Climate	Climate
4 kWh/m^2	6 kWh/m^2	8 kWh/m^2	$25\,^{0}C$	$30\,^{0}C$
Solar Irradiation	Solar Irradiation	Solar Irradiation	Temperature	Temperature
Agri & Water	Agri & Water	Agri & Water	Agri & Water	Agri & Water
1 acre	2 acre	3 acre	5 acre	7 acre
Land Area	Land Area	Land Area	Land Area	Land Area
Agri & Water	Agri & Water	Agri & Water	Agri & Water	Agri & Water
Cotton 202 days 42,20,000 lts/acre p.a.	Rice 93 days 41,80,000 lts/acre p.a.	Onion 120 days 30,00,000 lts/acre p.a.	Maize 88 days 14,80,000 lts/acre p.a.	Potato 88 days 12,00,000 lts/acre p.a.
Cropping Pattern	Cropping Pattern	Cropping Pattern	Cropping Pattern	Cropping Pattern
Agri & Water	Agri & Water	Agri & Water	Agri & Water	Agri & Water
Black Soil	Clayey Soil	Bore Well	Open Well	Pond
Soil Type	Soil Type	Water Source	Water Source	Water Source
Agri & Water	Agri & Water	Agri & Water	Agri & Water	Agri & Water
2 m	4 m	7 m	12 m	15 m
Water Depth	Water Depth	Water Depth	Water Depth	Water Depth
Technology	Technology	Technology	Technology	Technology
10 m	20 m	30 m	50 m	70 m
Total Dynamic Head	Total Dynamic Head	Total Dynamic Head	Total Dynamic Head	Total Dynamic Head
Affordability	Affordability	Affordability	Affordability	Affordability
80% subsidy	60% subsidy	INR 40,000 per acre	INR 3,00,000 per acre	INR 7,00,000 per acre
Financing	Financing	Crop Revenue	Crop Revenue	Crop Revenue

Design of the chart paper for the LGs to input information across all factors as well as showcase the output based on the online sizing tool

Input Parameters

Climate

- Solar Irradiation: XYZ
- Temperature: XYZ
- Rainfall: XYZ

Technology

- Total dynamic head: XYZ
- Static head: XYZ

Agri and Water

- Land Area: XYZ
- Crop 1: XYZ
- Crop 2: XYZ
- CWR of Crop 1: XYZ
- CWR of Crop 1: XYZ
- Type of water source: XYZ
- Water Depth: XYZ
- Soil Type: XYZ

Affordability

- Crop revenue per acre : XYZ
- Monthly per capita expenditure: XYZ
- Financial assistance scheme: XYZ

Output from Tool

1. SPIS Capacity (HP): XYZ
2. PV Array Size (kWp): XYZ
3. PV Array Surface Area (m^2): XYZ
4. Water Discharge (LPD): XYZ

Pictorial game on installation of SPIS

Duration:	30 minutes
Purpose:	To enable trainees to understand the step-by-step procedure for installation of a SPIS
Name of Session:	Selection and Installation of SPIS
Name of Component:	Installation Guidelines and Procedures for SPIS

7.1 Methodology

The key steps to deliver the game along with the role of the trainees and facilitator are given below:

Step 1: Print images of all components of a SPIS and the pictorial representation of the 9 installation steps. Affix these images on small cards without any names of the components on the card or any serial numbers/stages of installation. The steps are:

i. Placing the foundation hole and beam

ii. Installing the lower C-Channel

iii. Installing the I-beam and top C-Channel

iv. Installing other remaining I-beams and lower C-Channel

v. Installing the inclined channel and supporting C-Channel

vi. Mounting the solar modules on the PV array structure

vii. Connecting modules via solar connector box

viii. Wiring and linking the solar pump controller

ix. Fitting the pump/motor, attaching the water pipelines and integrating with micro-irrigation systems

Step 2: Distribute cards identifying all the components and installation steps with each LG

Step 3: Provide each LG with 10 minutes to arrange the photographs sequentially based on the procedure explained by the facilitator during the classroom training. Ask different LGs to display the procedure for installing varied types of pumps. For example: LG 1 – AC submersible pump with drip irrigation system; LG 2 – DC surface pump with sprinkler irrigation system; and LG 3 – only AC surface pump with no micro-irrigation system etc.

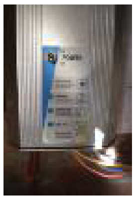
Step 4: Facilitator notes down the order of installation identified by each LG, discusses the key steps and showcases the correct sequence (if needed)

> **Outcome:** This will enable the trainees to identify the different components of the SPIS and comprehend the step-by-step procedure for installation of a SPIS.

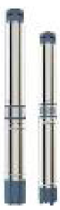
7.2 Content of the tool

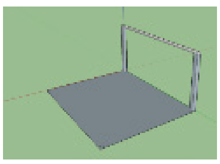
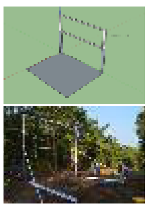
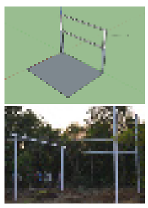
Cards with images of different components of the SPIS *(Note: Name of the components are given only for reference to the facilitator. It should not be mentioned on the cards given to the LGs.)*

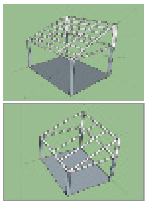
Cards displaying different steps involved in installation of the SPIS (Note: Name of the steps are given only for reference to the facilitator. It should not be mentioned on the cards given to the LGs.)

Solar Array	Solar Pump Controller	Solar Connector Box
		

Drip Irrigation	Sprinkler Irrigation
	

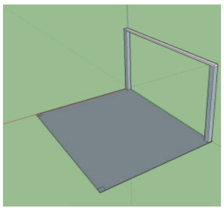
DC Pump	AC Pump	Submersible Pump	Surface Pump
			

Foundation & Beam	Lower C-Channel	I-beam &Top C-Channel	Other I-beams & Lower C-Channel
			

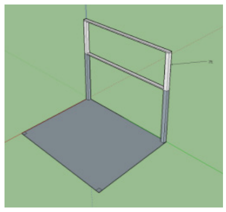
Inclined Channel & Supporting C-Channel	Solar modules on structure	Connecting Modules	Wiring
			

Pictorial representation of the step-by-step installation procedure for a DC submersible pump with drip irrigation system *(only for reference to the facilitator to cross-check the sequence of the LGs)*

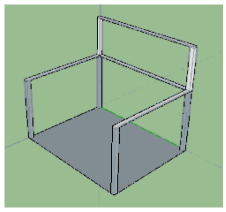

1: Placing the foundation hole and beam



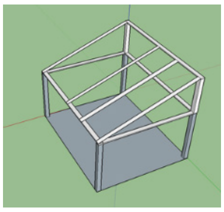
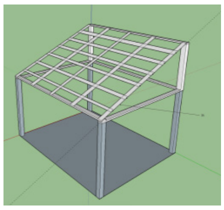
2: Installing the lower C-Channel




3: Installing the I-beam and top C-Channel




4: Installing the I-beam and top C-Channel

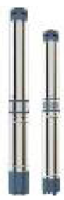



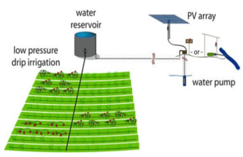
5: Installing the inclined channel and supporting C-Channel

6: Mounting the solar modules on the PV array structure


7: Connecting Modules via Solar Connector Box


8: Wiring and Solar Pump Controller



9: Fitting the pump/motor, attaching the water pipelines and integrating with micro-irrigation systems

Scenario game based on efficient use of SPIS

Duration:	45 minutes
Purpose:	To inform the trainees about the implications of efficient water management and climate smart agriculture (CSA) practices and understand its benefits through collaborative learning
Name of Session:	Efficient Use of SPIS - Water Management and Climate Smart Agriculture Practices
Name of Component:	Installation Guidelines and Procedures for SPIS

8.1 Methodology

The key steps to deliver the game along with the role of the trainees and facilitator are given below:

Step 1: Provide multiple-coloured tokens valued with a specific financial amount (in tens, hundreds and thousands) to each LG

Step 2: Define different cropping systems for each LG on one acre of land, like wheat and maize; cotton, soya bean and black gram; banana and garlic; maize and gram etc. The facilitator should provide a cropping pattern based on the location of the trainee. They can also ask each LG to choose a cropping pattern based on the crop cards available.

Step 3: Distribute the crop cards with each LG containing information on growing period and crop water requirements (*refer to Section 2.2.2*) as per the defined cropping pattern

Step 4: Share two lists a list with each LG on (i) average yield, per unit cost of production and average price for each of the crops; and (ii) change in yield for different CSA/efficient water management practices

Step 5: Provide meta-cards with the annual per unit (i.e. acre) cost of different CSA and efficient water management practices that can be implemented along with the SPIS

Step 6: Ask each LG to create their own strategy for land management based on the given information by placing the relevant meta-cards on a chart paper

Step 7: Ask the LGs to estimate the net profit in the usual scenario (w/o implementing any CSA/water management practices) by subtracting the cost of crop production from the revenue (i.e. multiplying the price with the estimated production of each crop). This should be documented on the chart

Step 8: Ask the LGs to also estimate the net profit of their land management strategy (including CSA/water management practices) whereby the additional cost of implementing the interventions will be added. This should be documented on the chart

Step 9: Deliver different scenarios to each LG and relay the impact of the scenario in terms of monetary/productivity parameters. A few scenarios with indicative impacts only for the purpose of this game (*Note: These are not scientifically assessed quantifiable impacts*) are given below:

i. Drought year will lead to 80% reduction in the revenue of the LG if no CSA cards on drought resistant measures have been selected for 1 acre of land

ii. Increase in rainfall will lead to spoilage of all rain-fed crops and decrease yield by 20% thereby reducing revenue of the LG in the same proportion, if crop diversification practices have not been selected in the land management strategy

iii. Decrease in ground water table will reduce water for irrigation purposes and thereby reduce crop yield by 40% compared to application of micro-irrigation systems

iv. Usage of flood irrigation technique can lead to removal of fertile top soil and decrease yield of crops by 30%

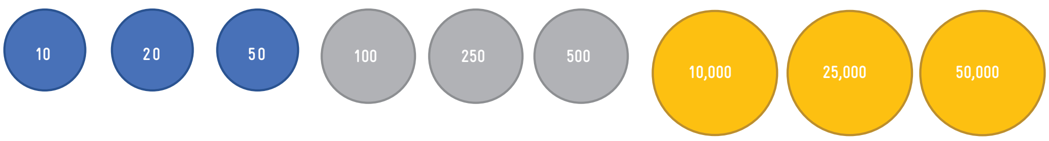
v. Implementation of system of crop intensification (SCI) will increase yield by 1.5 times of the normal cultivation resulting in improved income per unit of land cultivated

Step 10: Ask the groups to document the change in productivity or revenue based on the scenario that was given to them and prepare an improved plan/strategy considering the possible implications

> Outcome: This will enable the trainees to understand the need and benefit of implementing efficient water management and CSA practices along with a SPIS.

8.2 Content of the tool

Coloured tokens with a specific colour defined for values in tens, hundreds and thousands



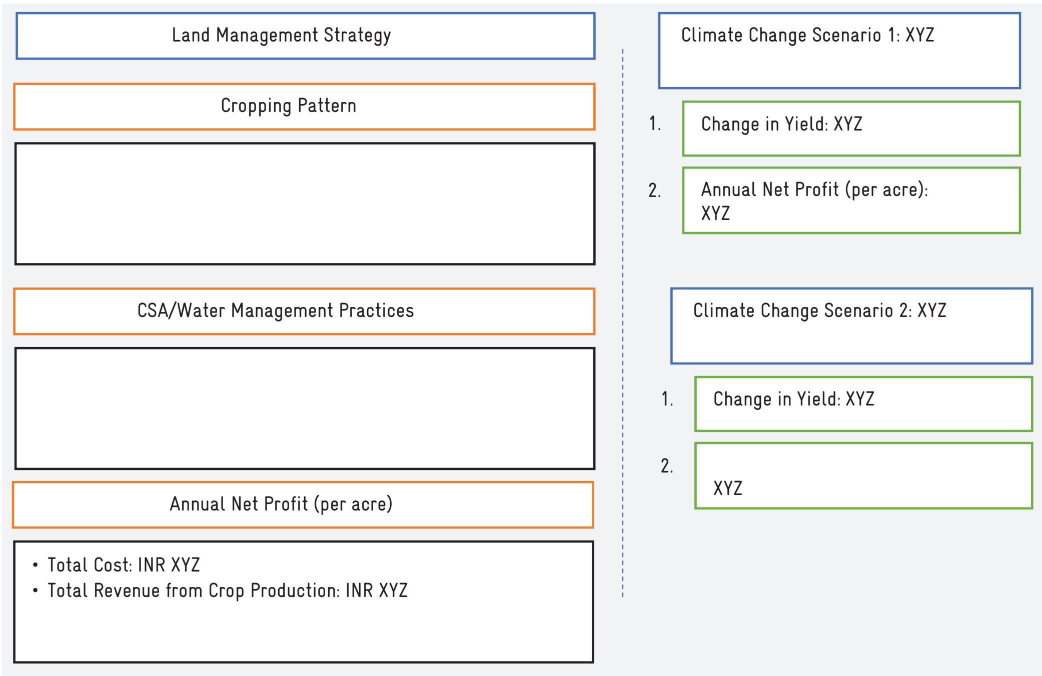
Illustrative examples of meta-cards displaying the cost of cultivating different crops and per unit cost of implementation of CSA/water management practices annually

Agri & Water	Agri & Water	Agri & Water	Agri & Water	Agri & Water
Cotton 202 days 42,20,000 lts/acre p.a.	Rice 93 days 41,80,000 lts/acre p.a.	Onion 120 days 30,00,000 lts/acre p.a.	Maize 88 days 14,80,000 lts/acre p.a.	Potato 88 days 12,00,000 lts/acre p.a.
Cropping Pattern	Cropping Pattern	Cropping Pattern	Cropping Pattern	Cropping Pattern

CSA Practices	CSA Practices	CSA Practices
Ridge and Tied Furrow Practices INR XYZ/acre	Dry Sowing System INR XYZ/acre	Broad Bed and Furrow System INR XYZ/acre
Annual Cost	Annual Cost	Annual Cost

CSA Practices	CSA Practices	CSA Practices
Drip Irrigation INR XYZ/acre	System of Crop Intensification INR XYZ/acre	Laser Land Levelling INR XYZ/acre
Annual Cost	Annual Cost	Annual Cost

Design of the chart paper for the LGs to design their land management strategy as well as showcase the impact on productivity/economics based on differing scenarios



Indicative example of the tables – (i) cost of cropping, productivity and price per unit; (ii) annual cost per acre of implementing CSA/water management practices and change in yield

Simulation exercise

on actual delivery of information by agri-extension workers to farmers

Duration:	90 minutes
Purpose:	To enable agri-extension workers to effectively deliver the content learnt in the capacity building program
Name of Session:	Open Discussion, Training Feedback, Closing
Name of the Component:	Simulation Exercise with Agri-Extension Workers

9.1 Methodology

The trainees will perform the role of an agri-extension worker and a farmer among themselves and pose questions to understand the technical, operational and economical aspects of the SPIS technology. The step-by-step methodology for implementation of the simulation exercise is as follows:

Step 1: Divide the entire capacity building group into two groups of which one will be the 'agri-extension workers' and the other will be 'farmers'

Step 2: Ask the group of farmers to internally discuss (for 5-7 minutes) and frame some key questions that they would like to pose to the agri-extension workers to understand the functionality and implementation of SPIS. These specific questions will be written by the facilitator on the board

Step 3: Prepare and distribute a list of FAQs/probes (with both the groups) that could be posed by a farmer during an actual extension exercise undertaken by the agri-extension workers. The facilitator will also highlight any additional questions that may have been posed by the group of farmers on the board for consideration during the simulation exercise

Step 4: Explain the role of the farmer in this simulation exercise is to (i) gather awareness on the SPIS technology in terms of its design, usage, benefits and implication and understand the process of financing of the SPISs in their respective state; and (ii) document the questions that remain unanswered by the agri-extension workers

Step 5: Explain the role of the agri-extension workers in this simulation exercise is to introduce the topic of discussion and answer all the questions posed by the farmer accurately based on the learnings derived during the capacity building program. The trainees could be allowed to refer to the capacity building guide or any other reading material for responding to the farmers

Step 6: Create multiple sub-groups consisting of 3-4 farmers and 2-3 agri-extension workers to conduct the simulation exercise in groups. The exercise may follow as below:

i. Agri-extension workers will lead the discussion by explaining the need for SPIS and describing the technology

ii. Each farmer will ask questions based on the FAQ list, while the agri-extension workers can alternatively respond to the questions. The facilitator should encourage the farmers to ask their own set of questions and get clarity on feasibility, functionality and benefits of SPIS technology

iii. Agri-extension workers will close the discussion by providing information on efficient usage of SPIS by integrating CSA/water management practices

Outcome: This practical exercise will help the trainers to assess whether the agri-extension workers can effectively deliver the content learnt through the capacity building program and evaluate the learning outcomes of the capacity building program. This will also help the trainers to understand the gaps in learning and identify the key challenges that may be faced by agri-extension workers on the field. This activity can be undertaken with the trainees or with actual farmers from nearby areas.

9.2 Content of the tool

The FAQs/probes to steer the discussion during the simulation exercise are given below:

Overview of Solar Powered Irrigation System (SPIS) Technology

- What is a solar powered irrigation system (SPIS)?
- How does a SPIS function? What are the different components?
- How is it different from a diesel or electric pump?
- What are the different types of SPIS available in the market? How much does it cost?
- Why should we use SPIS? What are its benefits?
- Are SPIS suitable only for specific crops, e.g., vegetables, which require to be watered either early in the morning or late in the evening, or can it be used to irrigate all kinds of crops?
- Will SPISs affect the yield of my crops? How do I irrigate my field during cloudy/rainy days?

Acquisition and Financing of SPIS

- How can I acquire/purchase a SPIS? What are the deployment models available? Can I purchase a SPIS on rent or lease?
- Are there any schemes/programs being implemented by the national or state government? Is there any subsidy support from the government on SPISs? What is the value

of the subsidy? How much do I need to contribute? What type of SPIS can be purchased under this scheme?

- Who are the beneficiaries under this scheme? Can my FPO or SHG also get support?
- What is the procedure that I need to follow to avail this government subsidy? What government department should I visit to submit my application?
- Do banks also provide loans for a SPIS? What are the general terms and conditions of the loan? What is the interest rate and repayment period?

Installation and Maintenance of SPIS

- How do I select between different types of SPIS? What size of SPIS do I need to deploy? What would be most suitable for my farm?
- What is the water discharge/outflow of a 2 HP SPIS?
- How many panels are required for a 2 HP SPIS?
- What is the land area required for installation of a 2 HP pump? How does the amount of land required vary based on the capacity of the pump?
- How do I choose a location for installation of my SPIS?
- What are the key steps for installation of a SPIS? Who will install the system? Does the manufacturer send a technician? How long does it take to install a SPIS with and without a bore well?
- What is the life of a SPIS? Is there any warranty on the SPIS? Does the manufacturer provide any after-sales service?
- What kind of maintenance is required for SPIS? What is the frequency of these activities?
- What are the precautionary methods to protect the panels against cyclones or floods?

Annexures

Annexure A: Focus Group Discussion Guide

Duration:	75 minutes
Name of Session:	Visit to Farmers' Field and Group Discussion with Farmers
Name of the Component:	Field Visit Day 2 – Deployment of SPIS at Farmers' Field

Objective and key considerations for the FGD

The aim of the FGD with the trainees and farmers is to gather the farmer's perspective on solar powered irrigation systems in terms of technology design, application, benefits, financing, market and any challenges. This will provide a platform to the trainees to seek any clarifications/ queries regarding application of SPIS from an end-user. The FGD will help the trainees gather information on (i) application of a SPIS, (ii) acquisition and financing of the SPIS, (iii) maintenance of the SPIS, and (iii) benefits and impact of the SPIS.
Few considerations for the FGD are given below:

- **Group size and duration of the FGD:** The FGD group should consist of 2-3 progressive farmers who have implemented SPISs at their farms and all trainees of the capacity building programs. This FGD group can also be divided into sub-groups as per the LGs depending on the number of participants. The duration of the FGD should ideally not exceed 60 minutes followed by 15 minutes for open discussion/Q&A. There are various thematic areas to be covered in the FGD; however, there is no prescribed duration for each of these sections. Thematic areas should be prioritized by the trainees as they would be leading the discussion.
- **Opening and closing questions:** Each thematic session should have an opening and a closing question. The opening question should be open ended, which would yield unique dimensions at the beginning of the FGD. This should be further explored during the discussion. The closing question should be focussed on capturing the participants' expectations and inputs regarding future interventions.

- **How to use the questions given in this guide:** The questions provided for each of the thematic areas are probes that will help the facilitator and trainees of the capacity building program explore the details of certain scenarios that emerge from the FGD. These questions do not necessarily need to be asked verbatim but to be used as pointers to explore key dimensions on critical points.

Introduction to the FGD

The facilitator should introduce the purpose of the FGD to the progressive farmers and the trainees. She/he should provide overall guidelines for conducting the FGD and explain the role of the participants. The trainees will pose questions to the progressive farmers, who will respond to the questions based on their practical experience of application of SPISs.

The facilitator will start the FGD by gathering general information from progressive farmers such as:

- Area of agricultural land and cropping pattern
- Area of land under solar irrigation and rain-fed landholding size
- Water source used for irrigation and level of water
- Farm assets owned by the farmer (e.g. any other irrigation pump apart from a SPIS, drip/sprinkler system, thresher, power tiller, tractor etc.)
- Any alternative livelihood options (e.g. dairy farming, flour milling etc.

Specific probes as per thematic areas

ACQUISITION AND FINANCING OF SPIS

Opening question: How did you acquire the SPIS? What was the key process of acquisition?

Probes

1. *Availability:* Who was the first point of contact for purchase of the SPIS? What is the waiting period for acquiring the SPIS? How far is the manufacturer/distributor located from the village?
2. *Access to government schemes:* Are you aware of any government schemes that provide financial support for SPISs like the PM-KUSUM scheme? Have you applied for the PM-KUSUM scheme or any other state level scheme? What is the process of applying for these schemes? What documentation is required for these schemes?
3. *Subsidy:* Did you get any subsidy under the PM-KUSUM scheme? What was the amount of subsidy received? How much did you contribute for purchasing the pump? When did you get the subsidy (before or after purchase of the SPIS) and how much time did it take you to get the subsidy?
4. *Access to loans*: Did you avail any loan from a financial institution? What were the terms and conditions of the loan? What is the entire process for availing loans from a financial institution?

Closing question: What are your key recommendations for improving financing for SPISs – both in terms of ease of accessing subsidy from the government and availing loans by financial institutions?

APPLICATION OF A SPIS

Opening question: What was your source for gathering information about SPIS and what is the main reason for purchasing a SPIS?

Probes

1. *Installation:* When was the SPIS installed? How many days did it take to install the SPIS? Who installed the SPIS?
2. *Type and size:* What is the type and capacity of SPIS you own? What is the size of the solar array? How much land is being used to set up the solar module?
3. *Selection:* What were the key factors for selection of the SPIS? How did you choose the location for setting up the SPIS?
4. *Components:* What are the different components of the SPIS? Do you use a DC or AC pump and why? Do the solar modules have a sun tracking system? Do you also have a water storage system?
5. *Affordability:* What was the total cost of installing the SPIS? What is the monthly expenditure incurred on repairs and maintenance of the SPIS?
6. *Utilization:* Which crops are irrigated by using the SPIS? How many days in a year do you use the SPIS for irrigation? How do you maximize the usage of the SPIS – do you use excess solar energy for any other productive uses?
7. *Deployment approaches:* Are there any innovative deployment approaches of SPISs (like water-as-a-service or rental/lease) implemented in your area? Who are the market players supporting these approaches?

Closing question: What are your suggestions for promoting and scaling SPIS in your area?

MAINTENANCE OF THE SPIS

Opening question: What are the main issues (e.g. cleaning, breakdown etc.) of SPIS maintenance? For each issue mentioned by the farmer, please mention the process of maintenance and frequency.

Probes

1. *Warranty:* What is the warranty provided by the manufacturers on the solar module and pump? Do you also have an annual maintenance contract (AMC) for the SPIS? How much does it cost and what is the validity of the AMC?
2. *Training*: Did you receive training for operation and maintenance of the SPIS? If yes, who gave you training and what all did you learn? If not, do you feel the need for training and on what aspects?

3. *Availability of after*-sales service: What repair and maintenance services are provided by the manufacturer? How do you submit your request for maintenance? What is the turnaround time by the manufacturer?
4. *Safety and Security:* What steps have you implemented to ensure safety and security of the SPIS? What are the precautionary methods to protect the panels against lightning, strong winds or any other natural disasters (like flooding etc.)?
5. *Insurance:* Have you taken any insurance for the solar modules? If yes, what is the premium paid per year? If not, why not?

Closing question: What are the key challenges faced in operation and maintenance of the SPIS? Are you satisfied with the after-sales service? Please provide some recommendations on proper operation and maintenance of the SPIS.

BENEFITS AND IMPACT OF THE SPIS

Opening question: What are the key benefits of the SPIS vis-à-vis traditional pumping systems?

Probes

1. *Costing:* Is a SPIS more cost-effective than diesel/electric pumps? What is the difference in the cost in terms of initial capital and operations/maintenance?
2. *Cropping:* Has there been any change in the area of land under irrigation after using the SPIS? Have you started cultivating different crops after using a SPIS? Has there been any noticeable change in the productivity of the crops compared to traditional pumping systems?
3. *Efficiency:* What is the irrigation efficiency of the SPIS vis-à-vis electric or diesel pump? Do you get sufficient water from the SPIS? If not, what is the source of irrigation other than SPIS?
4. *Revenue:* Has there been any change in revenue after using the SPIS? If yes, how has implementation of a SPIS led to enhancement of income (e.g. sale of water, improved yield of crops, energy/fuel cost savings, other livelihood activities etc.)?
5. *Durability and Reliability:* Is a SPIS more durable than electric or diesel pumps? Does it provide a more reliable source of electricity compared to grid connectivity? Would you still prefer using a SPIS after improvement in grid connectivity – why and why not?

Closing question: What are the limitations of a SPIS compared to the traditional pumping systems?

Annexure B: Guide for Interactive Sessions with Experts

Expert from the state nodal agency on the entire procedure for acquiring SPIS

Duration:	10 minutes
Name of Session:	Schemes and Programs for acquiring SPIS
Name of the Component:	National and State Level Scheme/Programs Promoting SPIS – Guidelines and Procedure for Acquiring SPIS

The FAQs/probes to steer the discussion with a representative from the government agency are given below:

- What are the key components of the PM-KUSUM scheme? Are there any other schemes/ programs being implemented by the state government?
- What are the key government departments implementing these schemes?
- Is there any subsidy support from the government on SPISs? What is the value of the subsidy? What is the value of the beneficiary's contribution for purchase of a SPIS?
- Who are the eligible beneficiaries under these schemes? Are there any basic requirements that need to be met to be eligible as a beneficiary?
- What is the step-by-step procedure for applying for these schemes/programs – both online and offline? What documentation needs to be submitted to access the PM-KUSUM scheme or any other state level scheme on SPIS?
- How long does it take to acquire a SPIS under this scheme? What type and capacity of SPIS can be availed? Are there any government guidelines on technology specifications of SPISs?

- Does the government have a grievance redressal forum to support the farmers?
- How can the farmers avail updated data/information about these government schemes/programs especially PM-KUSUM?

Financial institution on how to access finance for SPIS

Duration:	10 minutes
Name of Session:	Schemes and Programs for acquiring SPIS
Name of the Component:	Financing Mechanisms for acquiring SPIS

The FAQs/probes to steer the discussion with a financial institution are given below:

- What types of loans are provided by the banks for solar powered irrigation systems?
- Who can avail these loans? What is the minimum eligibility criterion for borrowers?
- What is the step-by-step process for applying for a loan for SPIS? What documentation needs to be submitted by the borrower?
- What amount of loan can be availed by the borrower? Does this change depending on the capacity/size of the SPIS? What is the maximum capacity/size of the SPIS that can be financed by the financial institution?
- What are the terms and conditions of accessing a loan for a SPIS? What is the rate of interest and payment schedule? Does the borrower have to give any collateral? What type of collateral is accepted by the financial institution?
- What type of financial support is provided by financial institutions for other decentralized renewable energy products? Is there any additional incentive provided by the financial institution for purchase of these products?

Organization deploying innovative financing mechanisms like PAYG/lease model/water-as-a-service

Duration: 10 minutes
Name of Session: Schemes and Programs for acquiring SPIS
Name of the Component: Financing Mechanisms for acquiring SPIS

The FAQs/probes to steer the discussion with an organization deploying innovative financing mechanisms to promote SPISs are given below:

- What kind of support does your organisation provide farmers in adopting solar irrigation? What are the different programs being implemented by your organisation and at what locations?
- What are the different innovative financing mechanisms deployed by your organisation for improving affordability of SPIS? Please describe each approach in detail explaining the implementation modality, capacity and type of SPIS, eligibility criterion, access, affordability, availability etc.

- What are the benefits of these deployment approaches? Has this improved access and affordability for the farmers?
- What are the key challenges hindering uptake of SPISs by farmers?
- What are your suggestions for promoting and scaling SPISs?

Progressive farmer or solar company on installation and maintenance of a SPIS

Duration: 15 minutes
Name of Session: Selection and Installation of SPIS
Name of the Component: Maintenance of SPIS

The FAQs/probes to steer the discussion on installation and maintenance of a SPIS is given below:

- What are the key factors to consider for selecting the size of a SPIS? How does the peak power of the solar array vary based on the capacity of the SPIS? How much area of land is required for installation of the solar modules?
- Can a farmer also plant crops below the solar modules? What are the suitable crops that can be grown in the shade of the solar modules?
- What are the key steps for installation of a SPIS? Who will install the system? Does the manufacturer send a technician? How long does it take to install a SPIS with and without a bore well?
- What are the main issues (e.g. cleaning, breakdown etc.) of SPIS maintenance? For each issue, please mention the process of maintenance and frequency.
- What repair and maintenance services are provided by the manufacturer? How can a farmer submit their request for after-sales service? What is the turnaround time by the manufacturer?
- What is the warranty provided by the manufacturers on the solar module and pump? Does the manufacturer also provide an annual maintenance contract (AMC) for the SPIS? How much does it cost and what is the validity of the AMC?
- What are the precautionary methods to protect the panels against lightning, strong winds or any other natural disasters (like flooding etc.)?
- What steps need to be taken to ensure safety and security of the SPIS? Does the farmer need to take some insurance for the solar modules? What is the cost and what is the process for getting insurance?
- What are the key challenges faced in operation and maintenance of the SPIS?

Technical research institute on the design of a SPIS

Duration: 15 minutes
Name of Session: Interactive Session with Experts
Name of the Component: Engagement with Experts in the SPIS Sector

The FAQs/probes to steer the discussion on solar technology and design of a SPIS are given below:

- What is a solar powered irrigation system (SPIS)?
- How does a SPIS function? What are the different components?
- How is it different from a diesel or electric pump?
- What are the different types and capacities of SPIS available in the market? How much does it cost?
- What is the irrigation efficiency of the SPIS vis-à-vis electric or diesel pump?
- Why should a farmer use a SPIS? What are its benefits? Is a SPIS more durable than electric or diesel pumps? Does it provide a more reliable source of electricity compared to grid connectivity?
- How can a farmer measure the amount of electricity produced from solar energy and utilised by the pump? How can the farmer use this excess solar energy?

NGO/CSO supporting farmers access SPIS

Duration: 15 minutes
Name of Session: Interactive Session with Experts
Name of the Component: Engagement with Experts in the SPIS Sector

The FAQs/probes to steer the discussion with the NGO/CSO supporting promotion of SPIS among farmers are given below:

- What kind of support does your organisation provide farmers in adopting solar irrigation? What are the different programs being implemented by your organisation and at what locations?
- What are the different financing options that can be availed by the farmer (such as subsidy under PM-KUSUM, loans etc.? What is the process for accessing finance through the varied options?
- What are the innovative deployment approaches for acquisition of SPIS? Please describe the entire implementation mechanism and the role of different stakeholders.
- Does your organisation provide any training to farmers on operations and maintenance of SPISs? How can farmers participate in these training sessions?
- What are the key challenges hindering uptake of SPISs by farmers?
- What are your suggestions for promoting and scaling SPISs?

Agricultural research institute on applicability of SPIS and best practices for water management/CSA

Duration: 15 minutes
Name of Session: Interactive Session with Experts
Name of the Component: Engagement with Experts in the SPIS Sector

The FAQs/probes to steer the discussion with an agricultural institute are given below:

- What support does the agricultural research institute provide farmers to access and implement solar irrigation technologies?
- What are the different types of solar irrigation technology as per agro-ecological zones?
- What are the advantages and disadvantages of solar irrigation?
- Are SPIS suitable only for specific crops, e.g., vegetables, which require to be watered either early in the morning or late in the evening, or can it be used to irrigate all kinds of crops? What are the most suitable crops for solar irrigation?
- What is the impact of the SPIS on the area of land under irrigation, crop productivity and revenue generation?
- Can a farmer also plant crops below the solar modules? What are the suitable crops that can be grown in the shade of the solar modules?
- What are the most relevant climate smart agricultural and water management practices that farmers can deploy along with the SPIS? What steps should farmers take to reduce over-extraction of ground water in their area?

Annexure C: Quiz Sheets

Quiz Sheet 1 – Overview of Solar Powered Irrigation Systems

1. Basic Information

Day and Date	
Name of the Trainee	
Mobile No. of the Trainee	
Registration No. for the Capacity Building Program	

2. List of Questions

Questions – Quiz 1	Options	Answer (only for facilitator)
1) What is energy converted from sun into mechanical or thermal energy called?	A. Solar energy B. Electrical energy C. Mechanical energy D. Thermal energy	A
2) What is solar irrigation?	A. Irrigation that uses the electric pump to power a pump water to the crops B. Irrigation that uses the sun's energy to power a pump that supplies water to crops C. Irrigation that uses diesel energy to power a pump that supplies water to crops A. None of the above	B

Questions – Quiz 1	Options	Answer (only for facilitator)
3) What is the basic difference between a solar pumps and traditional pumping systems?	A. SPIS can lift water but diesel pump cannot B. SPIS doesn't require any fuel C. SPIS cannot be deployed in the fields D. All of the above	B
4) Can a solar pump operate only on DC current?	A. Yes B. No C. Maybe D. Don't know	B
5) Can solar pumps operate at different speeds during varied times of the day?	A. Yes B. No C. Maybe D. Don't know	A
6) What is the unit of measurement of solar energy consumed over a period of hour?	A. kWp B. Watts C. kWh D. Don't know	C
7) Can a solar pump be connected to the grid?	A. Yes B. No C. Maybe D. Don't know	A
8) What types of costs are included for calculating the levelized cost of energy for a solar pump?	A. Only installation price B. Only operations and maintenance cost including energy costs C. Both A and B D. Neither of the above	C
9) What is the definition of peak watt (Wp)?	A. A standard unit of electrical power equal to 1,000 watts or to energy consumption at a rate of 1,000 joules per second B. A unit of power used to rate the performance of solar cells or arrays C. The number of hours per day when solar irradiance averages 1,000 watt/m^2 D. It is a unit of energy measured as 1,000 watts consumed over a period of 1 hour	B

Questions – Quiz 1	Options	Answer (only for facilitator)
10) What is the definition of alternating current (AC)?	A. A type of electricity transmission and distribution by which electricity flows in one direction through the conductor, usually relatively low voltage and high current B. A type of electric current that is only generated from the sun C. A type of electrical current of which the direction is reversed at regular intervals or cycles D. None of the above	C

Quiz Sheet 2 – Recap of Day 1

1. BASIC INFORMATION

Day and Date	
Name of the Trainee	
Mobile No. of the Trainee	
Registration No. for the Capacity Building Program	

2. LIST OF QUESTIONS

Questions – Quiz 2	Options	Answer (only for facilitator)
1) What are the key components of a solar powered irrigation system (SPIS)?	A. Solar array B. Universal Solar Pump Controller (USPC) C. Pump A. All of the above	D
2) What are the additional components required in an AC pump?	A. PV array B. Invertor C. Controller D. Pump	B
3) What is the function of automatic solar tracking system?	A. Senses the water requirement B. Controls the voltage C. Aligns the solar module in the direction of maximum solar irradiation D. None of the above	C
4) What is the maximum level of depth for drawing water by a surface pump?	A. 5 m B. 10 m C. 15 m A. 20 m	B

Questions - Quiz 2	Options	Answer (only for facilitator)
5) What is the average capacity of a portable solar pump?	B. Less than 0.5 HP C. 0.5 HP to 2 HP D. 2 HP to 5 HP E. 5 HP to 7 HP	B
6) Which practice is associated with multi-use solar pump?	A. Agrivoltaics B. Microvoltaics C. Farmvoltaics F. Watervoltaics	A
7) What is the life expectancy of a solar pump?	A. 10 years B. 15 years C. 20 years D. 25 years	D
8) What amount of fuel cost needs to be incurred for running a solar pump?	A. Zero B. ~INR 10,000 per year C. ~INR 25,000 per year D. ~INR 50,000 per year	A
9) Which irrigation method/ system is the most suitable (efficient) with solar pumping?	A. Flood irrigation B. Open canals C. High pressure drip irrigation D. Low pressure drip irrigation	D
10) Which irrigation pump has the lowest operation and maintenance cost?	A. Electric pump B. Diesel pump C. Solar pump D. Kerosene pump	C
11) Which is the most polluting irrigation pump?	A. Electric pump B. Diesel pump C. SPIS D. None of these	B
12) Which state has the maximum number of stand-alone solar pump installed?	A. Chhattisgarh B. Rajasthan C. Andhra Pradesh D. Uttar Pradesh	A
13) What deployment approach is most suitable for a small or marginal farmer who cannot afford to purchase a solar pump?	A. Upfront Purchase B. Net-metering C. Pay-As-You-Go D. None of the above	C

Questions – Quiz 2	Options	Answer (only for facilitator)
14) Is solar energy directly used to run the pump in a centralized system?	A. Yes B. No C. Maybe D. Don't know	A
15) What is the net-metering model?	A. Solar pump is connected to productive use appliances and any excess energy after meeting irrigation pumping requirements in used for running the appliances B. Solar pump is connected to the grid and any excess energy after meeting irrigation pumping requirements in supplied to the DISCOM at a pre-decided tariff rate C. Both A & B D. None of the above	B

Quiz Sheet 3 – Recap of Day 1 and Day 2

1. BASIC INFORMATION

Day and Date	
Name of the Trainee	
Mobile No. of the Trainee	
Registration No. for the Capacity Building Program	

2. LIST OF QUESTIONS

Questions – Quiz 3	Options	Answer (only for facilitator)
1) Which national level government scheme is associated with acquiring solar pumps?	A. Saubhagya B. NREGA C. PM-KUSUM D. UDAY	C
2) What is the main objective of the national level scheme?	A. Reduce usage of fossil fuels by farmers for pumping water B. Reduce farmer's dependence on moneylenders for credit C. Increase income generation for farmers by utilizing barren land D. None of the above	A

Questions - Quiz 3	Options	Answer (only for facilitator)
3) What are the different types of systems supported under this national level scheme?	A. Stand-alone solar water pumps B. Decentralized ground/ stilt mounted grid connected solar power plants C. Solarise existing grid connected agricultural pumps D. All of the above	D
4) Who are 'not' eligible as beneficiaries under the KUSUM scheme for installation of stand-alone solar water pumps?	A. Individual Farmers B. Water User Associations C. Community Based Irrigation Systems D. DISCOMS	D
5) How many stand-alone solar water pumps does the government plan to install in the country?	A. 17.5 lakhs B. 20 lakhs C. 22.5 lakhs D. 25 lakhs	B
6) What is the level of subsidy available from the central government for installation of stand-alone solar water pumps in general states and Hilly/ NE/ Island states?	A. 30% in general states, 40% in hilly/NE/ island states B. 40% in general states, 50% in hilly/NE/ island states C. 50% in general states, 30% in hilly/NE/ island states D. 30% in general states, 50% in hilly/NE/ island states	D
7) What is the minimum level of subsidy available from the state government for installation of stand-alone solar water pumps in all states of the country?	A. 30% B. 40% C. 50% D. 60%	A
8) What is the maximum percentage of contribution that beneficiaries may need to make for purchase of the solar water pump across all states after availing loans from banks?	A. 10% B. 20% C. 30% E. 40%	A
9) In what zones can new solar water pumps be installed under this scheme?	A. All zones in the country B. All zones except dark zones C. Only dark zones D. None of the above	B
10) What is the capacity range of Renewable Energy based Power Plants (REPPs) allowed under the national level scheme on solar pumps?	A. 100 kW to 1.5 MW B. 300 kW to 2 MW C. 500 kW to 2 MW D. 200 kW to 3 MW	C

Questions - Quiz 3	Options	Answer (only for facilitator)
11) What percentage of the cost of solar water pump can be availed as bank loan by the beneficiaries in all states apart from Hilly/NE/Island states of the country?	A. 20% B. 30% C. 40% D. 50%	B
12) What cannot be considered as collateral for availing a loan from a bank for solar pump?	A. Asset B. Mortgage of Land C. Agricultural Produce D. Demand Promissory Note	C
13) What is the time period of the annual maintenance contract provided by vendors for the solar water pumps?	A. 2 years B. 3 years C. 4 years D. 5 years	D
14) Which of these factors do not affect selection of type and size of a solar pump?	A. Temperature B. Land Area C. Cropping Pattern D. Occupation	D
15) What parameters are critical for deciding the size of the solar pump?	A. Only head (m) B. Only flow rate (m3/hour) C. Both flow rate (m3/hour) and head (m) D. Neither flow rate (m3/hour) nor head (m)	C
16) How much land is required for installing every 1,000 Wp of PV array?	A. 10 m^2 B. 15 m^2 C. 20 m^2 E. 25 m^2	A
17) Which criterion is not important for selection of a suitable location of the solar module?	A. A flat surface should be identified for mounting the solar module B. The solar module should be easily accessible for cleaning of the system C. The PV array should be installed at the least possible distance from the water source and pump D. The solar module should be located in an area surrounded by trees and buildings	D
18) What is the minimum tilting of PV array to maximize efficiency and power output?	A. 5 degree B. 10 degree C. 15 degree D. 20 degree	B

Questions – Quiz 3	Options	Answer (only for facilitator)
19) What is the frequency of cleaning solar modules?	A. Weekly B. Monthly C. Quarterly D. Yearly	A
20) What is the ideal frequency for checking the solar pump for technical damages like broken glass, damaged solar cells, spoilage of insulation cables etc.?	A. Weekly B. Monthly C. Quarterly D. Yearly	B
21) Which of these maintenance steps do not need to be undertaken daily?	A. Measure the depth of the water resource before running the pump B. Undertake manual solar tracking to maximise water output C. Trim trees around the PV array to ensure that maximum sunlight is absorbed by the solar modules D. Read fault lights on the invertor or controller	C

Post-Training Quiz

1. BASIC INFORMATION

Day and Date	
Name of the Trainee	
Mobile No. of the Trainee	
Registration No. for the Capacity Building Program	

2. LIST OF QUESTIONS

Questions – Post-Training Quiz	Options	Answer (only for facilitator)
1) What is the maximum level of depth for drawing water by a surface pump?	A. 5 m B. 10 m C. 15 m D. 20 m	B
2) What is the function of automatic solar tracking system?	A. Senses the water requirement B. Controls the voltage C. Aligns the solar module in the direction of maximum solar irradiation D. None of the above	C
3) What amount of fuel cost needs to be incurred for running a solar pump?	A. Zero B. ~INR 10,000 per year C. ~INR 25,000 per year D. ~INR 50,000 per year	A
4) Which of the following systems is not one of the deployment approaches for solar pumps?	A. Grid-Connected System B. Stand alone System C. Solar Agricultural Feeders D. Roof Top System	D
5) What deployment approach is most suitable for a small or marginal farmer who cannot afford to purchase a solar pump?	A. Upfront Purchase B. Net-metering C. Pay-As-You-Go G. None of the above	C
6) Which irrigation method/ system is the most suitable with solar pumping?	A. Flood irrigation B. Open canals C. Drip Irrigation D. Furrow Irrigation	C

Questions – Post-Training Quiz	Options	Answer (only for facilitator)
7) What is the net-metering model?	A. Solar pump is connected to productive use appliances and any excess energy after meeting irrigation pumping requirements in used for running the appliances B. Solar pump is connected to the grid and any excess energy after meeting irrigation pumping requirements in supplied to the DISCOM at a pre-decided tariff rate C. Both A & B D. None of the above	B
8) Who is not directly eligible as beneficiaries under the KUSUM scheme for installation of stand-alone solar water pumps?	A. Individual Farmers B. Water User Associations C. Community Based Irrigation Systems D. DISCOMS	D
9) What is the level of subsidy available from the central government for installation of stand-alone solar water pumps in general states and Hilly/ NE/ Island states?	A. 30% in general states, 40% in hilly/NE/island states B. 40% in general states, 50% in hilly/NE/island states C. 50% in general states, 30% in hilly/NE/island states D. 30% in general states, 50% in hilly/NE/island states	D
10) What is the maximum percentage of contribution that beneficiaries may need to make for purchase of the solar water pump across all states after availing loans from banks?	A. 10% B. 20% C. 30% D. 40%	A
11) What parameters are critical for deciding the size of the solar pump?	A. Only head (m) B. Only flow rate (m3/hour) C. Both flow rate (m3/hour) and head (m) D. Neither flow rate (m3/hour) nor head (m)	C
12) What is the frequency of cleaning solar modules?	A. Weekly B. Monthly C. Quarterly D. Yearly	A

Questions – Post-Training Quiz	Options	Answer (only for facilitator)
13) What is the definition of peak watt (Wp)?	A. A standard unit of electrical power equal to 1,000 watts or to energy consumption at a rate of 1,000 joules per second B. A unit of power used to rate the performance of solar cells or arrays C. The number of hours per day when solar irradiance averages 1,000 watt/m2 D. It is a unit of energy measured as 1,000 watts consumed over a period of 1 hour	B
14) Which of these is <u>not</u> a consideration for selection of crops under a SPIS?	A. Low height B. Higher crop water requirements C. Shade tolerance D. Low sunlight requirement	B
15) How can the land around/under the mounting structure of solar panels be utilized efficiently by farmers?	A. They can grow crops with short height under them B. They can use the shade for relaxing C. They can put their cattle under and around the panels D. No use of land under solar panel	A
16) Which of these is true about proper water management practice for farming under solar irrigation?	A. Solar saves energy so it can be used all the time B. Solar pumps can be used non-stop during day-time C. Overuse of solar pumping can lead to degradation of water table D. None of the above	C
17) What is the function of a controller in a SPIS?	A. It maintains and cleans the solar panels regularly B. It automatically starts or stops a water pump when irrigation is done C. It optimizes the performance of the SWP by maintain its power at peak efficiency throughout the day D. It controls the circulating pump in a solar hot water system to harvest as much heat as possible from the solar panels and protect the system from overheating.	D
18) What is the average capacity of a portable solar pump?	A. Less than 0.5 HP B. 0.5 HP to 2 HP C. 2 HP to 5 HP D. 5 HP to 7 HP	B

Questions – Post-Training Quiz	Options	Answer (only for facilitator)
19) From the following list which crop needs maximum number of irrigation?	A. Wheat B. Bajra C. Pea D. Sugarcane	D
20) What is the efficiency of a drip irrigation system?	A. Below 50% B. 50 – 60% C. 60 – 70% D. More than 90%	D

Annexure D: Pre and Post-Training Questionnaire

Pre-Training Questionnaire

1. BASIC INFORMATION

Name of the Trainee	
Name of Village	
Name of District	
Name of State	
Mobile No. of the Trainee	
Gender	☐ Female ☐ Male
BPL Card	☐ Yes ☐ No
Age Group	☐ Under 25 ☐ 25 to 30 ☐ 31 to 39 ☐ 40 to 49 ☐ Above 50
Educational Qualification	☐ No formal education ☐ Not finished primary school ☐ Completed primary school (grade 6) ☐ Completed secondary school (grade 9) ☐ Completed high school (grade 12) ☐ Graduate
Occupation/Job Title	
Years of Experience	

2. AGRICULTURAL ACTIVITIES (ONLY TO BE FILLED IF OCCUPATION IS FARMING)

How many years of farming experience do you have?	☐ Less than 3 years ☐ 3 to 5 years ☐ More than 5 years
What is the size of all your agricultural land (in hectares)?	☐ No land ☐ Less than 1 ha (marginal) ☐ 1 to 2 ha (small) ☐ 2 to 4 ha (semi-medium) ☐ 4 to 10 ha (medium) ☐ 10 ha and above (large)
What area of your land is under irrigation (in hectares)?	
What area of your land is rainfed (in hectares)?	
What agricultural activities do you engage in for revenue generation? (multiple responses)	☐ Agricultural labour on other farmers' field ☐ Crop production ☐ Vegetable production ☐ Fruit harvesting ☐ Livestock production ☐ Fisheries ☐ Food processing (please specify) ________________ ☐ Other (please specify) ________________
What crops do you grow annually? (List down all crops)	*Rabi Crops* *Kharif Crops* Zaid Crops *Perennial Crops*
What are the different sources of irrigation you use? (multiple responses)	☐ Canal ☐ Open Wells ☐ Borewells ☐ Tank ☐ River/ponds/lakes ☐ Other (please specify) ________________

What is the groundwater level/depth in your area (in metres)?	
What type of irrigation pump do you own?	☐ Diesel Pump ☐ Kerosene Pump ☐ Electric Pump ☐ Solar Powered Irrigation System ☐ Other (please specify) ______________
What is the capacity of the irrigation pump (in HP)?	
What type of irrigation system do you own?	☐ Pipelines for flood irrigation ☐ Drip system ☐ Sprinkler system ☐ Other (please specify) ______________

3. KNOWLEDGE AND AWARENESS

What according to you are the main challenges faced by farmers?	
Are you aware about solar powered irrigation systems (SPISs)?	☐ Yes ☐ No
If yes, what was the source of information about SPIS?	☐ Media (TV, radio, mobile) ☐ Newspaper ☐ Krishi Vigyan Kendra ☐ Farmer Fairs ☐ Interaction with NGO worker ☐ Interaction with Government Official ☐ Interaction with Private Company ☐ Other (please specify) ______________
Have you ever operated a SPIS?	☐ Yes ☐ No
Have you ever owned SPIS? If yes, who financed the pump and under what scheme/ program?	

Are you aware about any government schemes for promoting SPISs in your state?	☐ Yes *(please mention the schemes/programs)* ____________________ ____________________ ____________________ ☐ No
Have you previously received any training on SPISs?	☐ Yes *(please mention details about the training program)* ____________________ ____________________ ____________________ ☐ No
Have you previously received any training from BISA?	☐ Yes *(please mention details about the training program)* ____________________ ____________________ ____________________ ☐ No

4. TRAINING NEEDS

Please circle all the areas mentioned below in which you need training. Then tick your current proficiency in these areas and how importance you think the training need is.

Area	Current knowledge (competence)					Importance of area		
	None	Poor	Fair	Good	Excel-lent	Not Important	Important	Very Important
Design of solar powered irrigation system (SPIS) and its different components	☐	☐	☐	☐	☐	☐	☐	☐
Types of SPISs	☐	☐	☐	☐	☐	☐	☐	☐
Benefits and impact of SPISs	☐	☐	☐	☐	☐	☐	☐	☐
Innovative deployment approaches for SPIS	☐	☐	☐	☐	☐	☐	☐	☐
Procedure to acquire SPISs under government schemes/programs	☐	☐	☐	☐	☐	☐	☐	☐
Financing of SPISs	☐	☐	☐	☐	☐	☐	☐	☐
Selection of a SPIS – type and size	☐	☐	☐	☐	☐	☐	☐	☐
Step-by-step process for installation of a SPIS	☐	☐	☐	☐	☐	☐	☐	☐
Maintenance of a SPIS	☐	☐	☐	☐	☐	☐	☐	☐
Efficient use of SPIS - water management and climate smart agriculture practices	☐	☐	☐	☐	☐	☐	☐	☐

Area	Current knowledge (competence)					Importance of area		
	None	Poor	Fair	Good	Excel-lent	Not Important	Important	Very Important
Scaling and promotion of SPISs	☐	☐	☐	☐	☐	☐	☐	☐

What are your expectations from this capacity building program on solar powered irrigation systems?

Post-Training Questionnaire

1. BASIC INFORMATION

Name of the Trainee	
Mobile No. of the Trainee	
Registration No. for the Capacity Building Program	
Gender	▯ Female ▯ Male
Age Group	▯ Under 30 ▯ 31 to 39 ▯ 40 to 49 ▯ Above 50
Educational Qualification	▯ No formal education ▯ Not finished primary school ▯ Completed primary school (grade 6) ▯ Completed secondary school (grade 9) ▯ Completed high school (grade 12) ▯ Graduate
Occupation/Job Title	
Years of Experience	

2. SELF-ASSESSMENT OF KNOWLEDGE AND PRACTICE

Based on the learnings derived from the capacity building program, how would you assess your knowledge and capacity to train others across different areas?

Area	Current knowledge (competence)w					Capacity to train others				
	None	**Poor**	**Fair**	**Good**	**Excellent**	**None**	**Poor**	**Fair**	**Good**	**Excellent**
Design of solar powered irrigation system (SPIS) and its different components	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Types of SPISs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Area	Current knowledge (competence)w					Capacity to train others				
	None	Poor	Fair	Good	Excel-lent	None	Poor	Fair	Good	Excel-lent
Benefits and impact of SPISs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Innovative deployment approaches for SPIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Procedure to acquire SPISs under government schemes/ programs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Financing of SPISs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Selection of a SPIS – type and size	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Step-by-step process for installation of a SPIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Maintenance of a SPIS	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Efficient use of SPIS – water management and climate smart agriculture practices	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Scaling and promotion of SPISs	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Please mention any further training requirements related to solar powered irrigation systems or climate smart agriculture/water management practices.

Annexure E: Feedback Template

1. EVALUATION OF THE COURSE CONTENT

Please mark the most relevant option:

Course Content	Strongly Disagree	Disagree	Cannot Decide	Agree	Strongly Agree	Not Appli-cable
The objective of the training was clearly defined	☐	☐	☐	☐	☐	☐
The content of the sessions was aligned with the learning objectives	☐	☐	☐	☐	☐	☐
The content was structured and easy to follow	☐	☐	☐	☐	☐	☐
The capacity building program was relevant to improving the knowledge/skills related to my work	☐	☐	☐	☐	☐	☐
The information provided during the sessions was sufficient to understand the topic	☐	☐	☐	☐	☐	☐
The time allocated for each session was sufficient	☐	☐	☐	☐	☐	☐
What according to you was the most informative session and why?						
What according to you was the least informative session and why?						

2. METHODOLOGY AND TOOLS

Please mark the most relevant option:

Method and Tools	Strongly Disagree	Disagree	Cannot Decide	Agree	Strongly Agree	Not Applicable
The design of the course (i.e. material and learning activities) encouraged participation in the class	☐	☐	☐	☐	☐	☐
The quizzes improved learning of the course information	☐	☐	☐	☐	☐	☐
The learning aids (like pamphlets, brochures, PPT slides, role-playing exercises etc.) enhanced my learning	☐	☐	☐	☐	☐	☐
The games were easy to implement and helped improve understanding of the topic	☐	☐	☐	☐	☐	☐
The field demonstrations on installation and maintenance of SPIS, and FGD with farmers helped gain practical experience	☐	☐	☐	☐	☐	☐
The sessions with experts were interactive with clarifications/queries readily answered by the experts	☐	☐	☐	☐	☐	☐
The practical exercises were good simulations of the tasks that I would need to perform during my job	☐	☐	☐	☐	☐	☐
The time allocated for these adult-learning tools and field demonstrations was sufficient	☐	☐	☐	☐	☐	☐
The capacity building program had too many learning exercises which made it difficult to retain information	☐	☐	☐	☐	☐	☐
What learning methodology do you prefer	☐ Classroom training ☐ Participatory learning exercises ☐ Mix of both					

Method and Tools	Strongly Disagree	Disagree	Cannot Decide	Agree	Strongly Agree	Not Applicable
What learning exercise and game did you find as most useful to improve your understanding of the topic?						
What are you suggestions to further improve the delivery method and tools?						

3. EFFECTIVENESS OF THE FACILITATOR

Please mark the most relevant option:

Effectiveness of the Facilitator	Strongly Disagree	Disagree	Cannot Decide	Agree	Strongly Agree	Not Applicable
The facilitators were knowledgeable about the topics/ content	☐	☐	☐	☐	☐	☐
The facilitators were well prepared	☐	☐	☐	☐	☐	☐
The facilitators gave clear explanation of the topics	☐	☐	☐	☐	☐	☐
The speed of the lecture sections was appropriate	☐	☐	☐	☐	☐	☐
The facilitators welcomed questions and responded to them effectively	☐	☐	☐	☐	☐	☐
How can we improve our facilitation?						

Please provide any additional comments on the overall delivery of the capacity building program and suggestions for improvement