Technology Guidebook

A Compendium of Resources for End Users of Climate-Friendly Technologies

(1st Edition)

NRDC
NATURAL RESOURCES DEFENSE COUNCIL

SEWA
SELF EMPLOYED WOMEN'S ASSOCIATION

AREAS

About NRDC

With over 50 years of experience, the Natural Resources Defense Council (NRDC) combines the power of more than three million members and online supporters with the expertise of over 700 scientists, lawyers, and policy experts to drive climate and clean energy action, protect nature, and promote healthy people and thriving communities. NRDC works in the United States, China, India, and key geographies to advance environmental solutions. In India, NRDC partners with leading organizations on clean energy access, climate resilience, and clean air and healthy cities. For over 10 years, NRDC has also worked with government officials at the national, state, and city level partnering with local groups and businesses to combine scientific research and policy acumen to implement impactful climate solutions.

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About SEWA

Self Employed Women's Association (SEWA) is a member-based organization of poor, self-employed women workers in India. SEWA is spread across 14 states of India with deep penetration at grassroots level in villages. SEWA also works in Afghanistan, Nepal, Sri Lanka, and Myanmar. SEWA has membership reach of 1.7 million globally. SEWA organizes the women into self-help groups and cooperatives based on their respective trades and then channelizes information, awareness, health interventions, trainings for skill development, financial support (e.g. savings, insurance, credit, and pension), and market linkages to enable members to become self-sustainable in their trades, including salt production. SEWA's twin goals are "Full Employment" and "Self-Reliance." "Full employment" includes work security, income security, food security and social security (at least healthcare, childcare, nutrition, shelter) whereas "self-reliance" means making members autonomous economically and in decision-making.

www.sewa.org.

About AREAS

Association of Renewable Energy Agencies of States (AREAS) has been formed and registered as a society on 27 August 2014 under Society Registration Act 1860. Ministry of New & Renewable Energy (MNRE) is the nodal agency at the central level for promotion of grid-connected and off-grid renewable energy in the country. Ministry's programmes are implemented in close coordination with State Nodal Agencies (SNAs) for renewable energy (RE). Over the period the SNAs have developed considerable knowledge and experience in planning and implementation of RE programmes. In this background it is important that SNAs interact and learn from each other's experiences and also share their best practices and knowledge regarding technologies and schemes/programmes. All SNAs are members of the Association.

www.areas.org.in

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Disclaimer

This compendium presents a pool of resources for various climate friendly solutions as a reference document. NRDC, SEWA, and AREAS do not endorse any particular technology, product or organization.

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TECHNOLOGY GUIDEBOOK:

A Compendium of Resources for End Users of Climate-Friendly Technologies

AREAS

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Foreword

India has reaffirmed its climate commitments by updating the Nationally Determined Contributions (NDCs) and by developing a supportive policy ecosystem to enable low-carbon emission pathways. Through India's G20 presidency, the country has played a crucial role in fostering green development as well as inclusive and resilient growth. This has been done by focussing on identifying innovations to drive energy transition while ensuring energy security, accessibility, and affordability.

In parallel, the 'Lifestyle for the Environment (LiFE) Mission' announced at COP-26 in Glasgow focuses on adoption of traditions and values of conservation and moderation. While keeping energy security at the fulcrum, India has also enabled communities to adopt climate-friendly solutions particularly in rural areas through enhanced access to technical and financial resources under National Biomass Program, Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan (PM KUSUM) and such other schemes. In addition, several initiatives such as the Suryamitra and Vayumitra Skill Development Programmes, have been launched to develop the skilling ecosystem for clean technologies. Such initiatives play a significant role in enhancing livelihoods, creating jobs and reducing drudgery at the household level.

Knowledge products such as this *"Technology Guidebook - A Compendium of Resources for End Users of Climate-Friendly Technologies"* are essential, especially for stakeholders who have limited access to skilled technicians or repair and servicing support at the last mile. These resources have the potential to enable users to efficiently operate and maintain the technologies they have adopted. Consequently, it will also encourage more households to adopt clean technologies and transition to cleaner fuels. I congratulate Natural Resources Defense Council (NRDC) and Self-Employed Women's Association (SEWA) for releasing this compendium, which aims to equip the users of climate-friendly solutions with necessary information and resources to build their capacity to adopt climate friendly solutions.

J K Jethani
Executive Director

Preface

The window to limit global warming to 1.5 degree Celsius is rapidly closing, and access to energy remains an urgent developmental challenge in large parts of the world. Rural populations are especially vulnerable to the worst impacts of climate change, such as rising temperature and increasing frequency of natural disasters such as drought, floods and cyclones. At the same time, access to reliable and affordable energy is imperative for their growth and development. Natural Resources Defense Council (NRDC) and Self Employed Women's Association (SEWA) along with the Association of Renewable Energy Agencies of States under the Ministry of New and Renewable Energy (AREAS-MNRE) are implementing a unique initiative, called *Hariyali Gram (Green Villages)*, which aims to enhance accessibility and affordability of clean energy and climate-friendly solutions to improve livelihood opportunities at the household level in rural India.

As the use of clean energy and climate-friendly solutions increases across rural parts of the country, the workforce deficit and skill gaps in the clean energy sector remain barriers to the wider adoption of these new technologies. Capacity building and skilling initiatives, especially for early adopters in the rural context, are essential to enhance trust in these new technologies to ensure their long-term viability. This first-of-a-kind **Technology Guidebook** is a compendium of various clean energy and climate-friendly solutions and provides a detailed overview on the operation and maintenance of these technologies. The guidebook aims to bridge the knowledge gaps in last-mile service, repair, and maintenance of these technologies in rural areas. It equips the end-user with step-by-step information and mentions best practices to operate and maintain these technologies. By skilling and empowering rural households, especially women, to take greater ownership over the operation and maintenance of these technologies, this guidebook will serve as an important resource in enabling the creation of a holistic clean energy ecosystem at the grassroots level.

Dipa Singh Bagai

Country Head, NRDC India

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List of Abbreviations

AC	Alternating Current
BLDC	Brushless Direct Current Motor
BOS	Balance of System
CFL	Compact Fluorescent Lamp
CH_4	Methane
CO_2	Carbon Dioxide
DC	Direct Current
DRE	Distributed Renewable Energy
H_2O	Water
H_2S	Hydrogen Sulphide
HP	Horsepower
kg	Kilo Gram
kW	Kilo Watt
kWh	Kilo Watt Hour
l	Litres
LED	Light-emitting Diode
LLDPE	Linear Low-Density Polyethylene
LPG	Liquified Petroleum Gas
m	Meter
m^2	Square Meter
m^3	Cubic Meter
mm	Mili Meter
MNRE	Ministry of New and Renewable Energy
NRDC	Natural Resources Defense Council
PMB	Power Management Box
PV	Photovoltaic
PVC	Polyvinyl Chloride
RMS	Remote Monitoring System
SECI	Solar Energy Corporation of India
SEWA	Self Employed Women's Association
SIPS	Solar Irrigation Pump Sizing
Sq. Ft.	Square Feet
USPC	Universal Solar Pump Controller
V	Volt(s)
W	Watt(s)
Wp	Watt Peak

INTRODUCTION

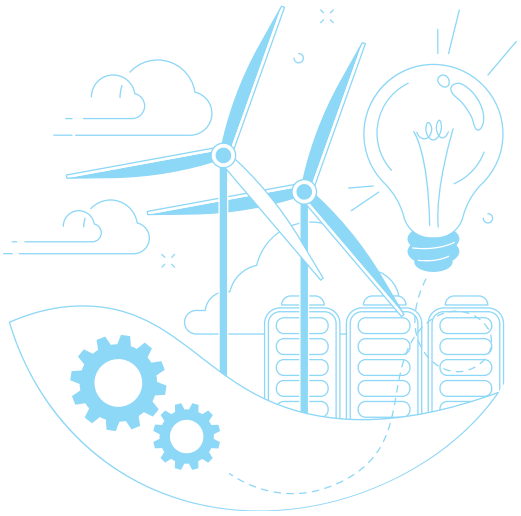
The world's energy systems are transitioning quickly to respond to the climate crisis. This is driving demand for climate friendly solutions, a trained workforce to enact those solutions as well as skilling and re-training programs to help grow that workforce.[1] Climate-friendly solutions include Distributed Renewable Energy (DRE) technologies, energy efficient appliances, sustainable cooling solutions, and more. These solutions are critical to the energy transition and are effective in providing reliable and affordable access to energy, especially to the rural and vulnerable communities.[2] Productive use of these solutions, especially DRE, benefits the environment and boosts livelihoods for better quality of life.[3]

Developing the workforce with the appropriate knowledge, competence and experience to enable a clean energy transition is essential for an environmentally sustainable and socially inclusive economy.[4] As the use of climate-friendly solutions expand across the country, rural areas often face the challenge of limited post sale services for timely maintenance and repairs. Similar experiences from other countries have also highlighted the shortage of skilled human resources for technology installation and maintenance.[5] To bridge this gap, it is crucial to increase end users' capacity to operate, maintain, and repair these technologies. This can assist in improving asset efficiency, increase its usability and enhance trust in the technology. And consequently, support long-term adoption and scaling up efforts for climate-friendly solutions. In addition, efforts can be directed towards building capacities of rural entrepreneurs who can lead the energy transition at the community level.

OBJECTIVE

The first step to scaling up the adoption of climate-friendly technologies in rural areas is technology identification: a specific technology must suit household needs; it should be a high-quality product; it should be financially feasible; and it must be easy to use. The next step is to ensure that users have been trained to ensure proper operation, repair, and maintenance of the equipment. This will make certain that households can efficiently use the implemented technologies. It will also address the challenge pertaining to limited capacities to repair and maintain assets especially in rural areas.[6]

This guidebook is the first of its kind reference document for rural households and rural entrepreneurs on climate-friendly solutions. The guidebook is designed to support efficient utilisation of these solutions and enables rural communities to adopt and maintain these technologies.



STRUCTURE OF THE GUIDEBOOK

The guidebook is divided into 11 modules. Each module introduces a climate-friendly solution, its key components, steps for installation/usage, operations & maintenance guide, troubleshooting steps, and a compendium of related resources, such as videos, handbooks, guidebooks, etc. The guidebook also provides relevant links and QR codes for easy accessibility of additional resources. These resources have been compiled based on secondary research that may belong to specific entities working in the domain. However, Natural Resources Defense Council (NRDC) and Self Employed Women's Association (SEWA) do not endorse any specific company's products and these resources have been provided solely for the reader's reference.

The module identifies specific instances where it is recommended or necessary to call a technician for repair and maintenance.

The 11 modules cover the following climate-friendly solutions: off-grid solar photovoltaic systems, biogas plants, solar water pumps, solar precision irrigation systems, solar fencing, solar fodder system, solar trap light, Light-emitting Diode (LED) bulbs, energy efficient fans, improved pellet cookstoves, and cool roofs.

Module 1:
Off-grid Solar Photovoltaic System

1.1. Introduction

Off-grid solar photovoltaic (PV) systems serve as a clean and green energy alternative to conventional grid power and polluting fuels such as diesel, kerosene, charcoal, firewood etc.[7] They can provide reliable electricity to rural households lacking access to grid power or dealing with intermittent electricity supply and are equally beneficial for industrial and agricultural applications.[8]

An off-grid solar PV system generates electricity directly from solar radiation through a phenomenon called photovoltaic effect. Solar PV cells contain a special 'semiconductor' material that can absorb incoming sunlight and convert it to an electric current. This energy generated can be stored in the battery ensuring continuous electricity supply, especially during night or overcast conditions making the system self-sufficient. To make this electricity usable for household appliances, an inverter transforms the generated direct current (DC) into alternating current (AC).

When an off-grid solar PV system is connected to the grid, it is called grid-interactive solar PV system. This arrangement can supply extra energy generated by the off-gird solar PV system to the grid depending on the metering arrangement with the distribution company. Thus, it can be used to earn additional income by the households depending on the state government regulations on net-metering, feed-in tariffs or generation linked incentives.[9]

Off-grid solar PV systems offer versatile installation options, whether on the ground or rooftop, provided certain conditions are met. To ensure the effectiveness of off-grid solar PV systems, installations require unshaded, dedicated spaces available for long term. For rooftop installations, the space must be structurally suitable for mounting rooftop solar PV modules securely.

1.2. Key Components

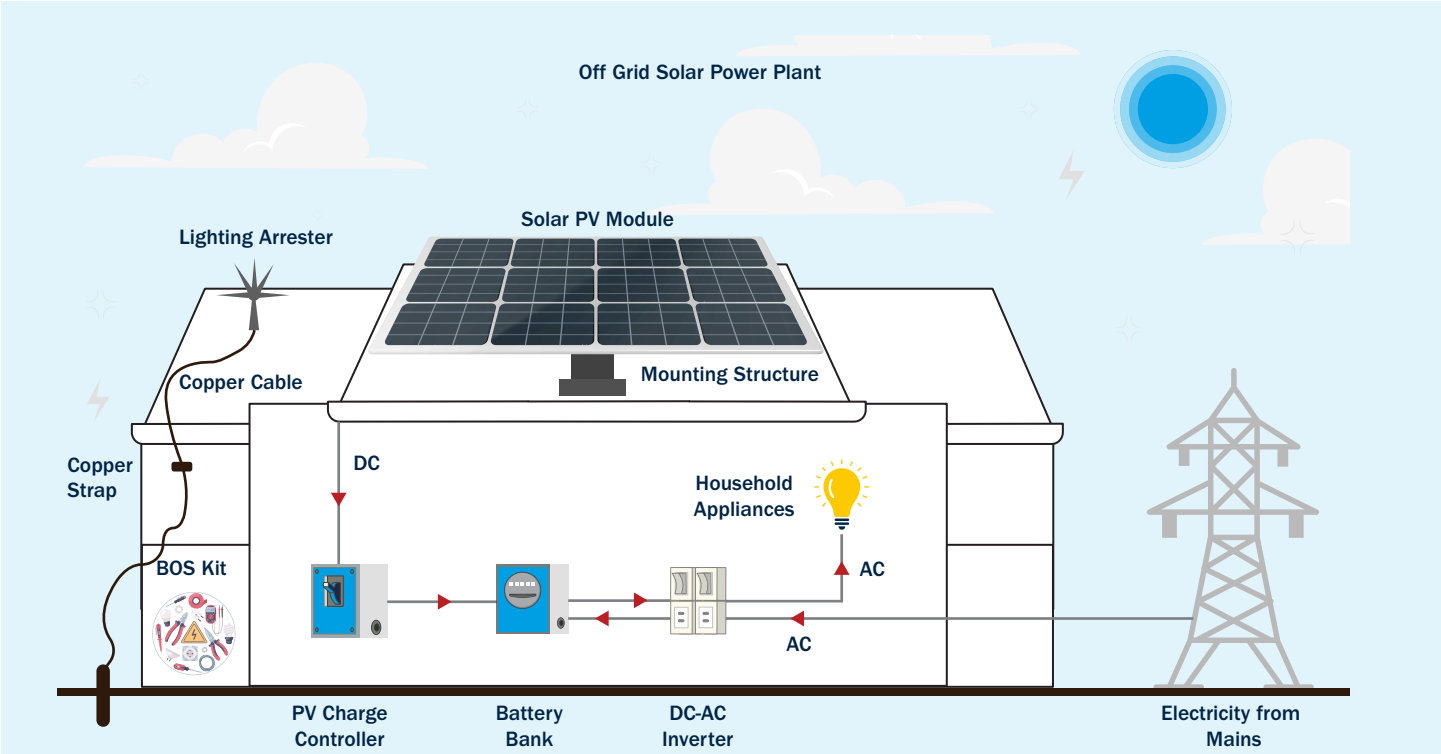


Figure 1: Schematic of an Off-grid Solar PV System

Figure 2: Solar PV Module[10]

Solar PV Module

The solar PV module absorbs light energy from the sun and uses it to generate an electric current.

DC - AC Inverter

The inverter converts DC electricity generated by solar PV modules to AC electricity required by the grid or appliances in the house.

Figure 3: DC-AC Invertor[11]

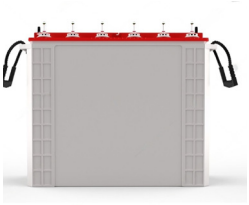


Figure 4: Battery Bank[12]

Battery Bank

A battery is added to the solar PV system to store excess electricity generated by the solar PV modules. This stored energy can be used to electrify appliances during non-generation periods such as nights and cloudy days.

PV Charge Controller

The PV charge controller is an electronic device that controls the power going from the solar module to the battery bank. It ensures that batteries are not overcharged during the day, and that the power does not flow back to solar PV modules overnight, thus draining the batteries. Controlling the power flow is the primary job of PV charge controllers. However, some charge controllers are available with additional capabilities, like lighting and load control.

Figure 5: PV Charge Controller[13]

Figure 6: Mounting Structure[14]

Mounting Structure

Mounting structures are the supporting pillars for solar PV modules. These structures are used to set the solar PV modules at an angle that can collect maximum solar radiation.

Balance of System (BOS) Kit

The BOS kit comprises of all other parts that contribute to the smooth functioning of the system, such as wiring, switches, junction boxes with fuses and relays, grounding/earthing, etc.

Figure 7: Balance of System Kit[15]

Figure 8: Lightning Arrester[16]

Lightning Arrester

Lightening arresters protects the solar PV systems from direct lightning strikes and surge damages by redirecting excess voltage surges to the ground.

1.3 Installation

Solar PV power plants must be designed depending on the energy consumption/requirement of the household and the roof space/land that is available for the installation. Table 1 below provides an illustrative list of panel sizing depending on the rooftop area in the state of Gujarat.[17] For more such iterations, the calculator link provided in section 1.6 can be used.

Table 1. Solar PV Sizing and Corresponding Roof Space Requirement (Source: MNRE)[18]

Total Rooftop Space Available for installation of Solar PV Panels (Sq. Ft)	Total System Size (kW)	Annual Electricity Generation (kWh)
100	0.9	1,350
200	1.9	2,850
300	2.8	4,200

The technicians will install solar PV modules on the ground or a rooftop – depending on availability of abundant sunlight, which is usually south facing in India for maximum sunlight absorption – and they will make the necessary electricity connections. Ensure that the solar PV module is correctly mounted in the south direction at a suitable angle based on geographic location of the site. A link for the calculator to find the most appropriate tilt angle based on the geography is provided in section 1.6.

1.4 Operations & Maintenance Guide

The technician will demonstrate key steps for operating and maintaining off-grid solar PV system while installing the same. However, the following key steps are important to be considered for day-to-day operations and maintenance of the system, as listed below:[19]

Solar PV Modules

- Clean the modules frequently using normal water or gentle soap water to get rid of dust, bird droppings, and other debris accumulated over time.
- Check for any kind of cracks and other mechanical defects. If found, call the technician immediately.
- Ensure that the angle of tilt is the same as installed.
- Inspect for any damaged or burnt wires and if found, replace it with the help of a technician.

Inverters

- Remove dust or dirt accumulation.
- Check if the inverter lights are working in accordance with the technician's description.
- Ensure wires are not loose, as described by the technician during installation.

Batteries

- Check for any electrolyte leaks, corrosion, or cracks at the terminals.
- If using lead acid batteries, check for the electrolyte level and use distilled water to top up the batteries, as demonstrated by the technician during installation.

Charge Controller

- Wipe away any accumulated dirt/dust using a dry cloth.
- Check if all the indicators such as LED lights are working.
- Check if the wires leading to and from the charge controller are not loose.

Mounting Structure

- Check if the mounting frame and modules are firmly secured.
- Check the junction boxes to ensure that the wires are not chewed by rodents or insects.
- Check for rusted bolts in the mounting structure and replace, if required.

Balance of System

- Check if all the fuses and switches are in working condition.
- Check the earthing (grounding) cable to see if there are any disconnections in between.

Do's and Don'ts

Note 1: Low current or voltage can have different causes as each system is designed differently. If the system is not performing normally after troubleshooting, it is best to hire a technician who knows how to perform the correct diagnostic steps.

Note 2: In homes, DC electricity is significantly more dangerous than AC power. Do not try to troubleshoot electrical problems by yourself and engage an electrician to resolve any issues.

Note 3: If there is any problem with the technology, it is helpful to record and communicate information to the service provider. Helpful information to record includes: error messages, the times when problems occurred or the technology stopped working, such as power disruptions.

Note 4: While installing the solar PV system, ensure that proper earthing of the system is provided to ensure safety of the system and the individuals operating it.

1.5 Troubleshooting

The following are some of the most common problems that arises with solar PV systems, and suggestions for how to address them:[20]

Problem 1: Modules are not generating electricity.

Possible Solutions

- **Check if wiring is loose:** Remember that the wiring in a solar PV system connects the modules to each other, to the battery bank, and to the inverter. As a result, the wiring connection could be broken at one or several places. Talk to a technician to fix any wiring problems. They will be able to repair damaged parts without affecting other parts of the system.
- **Check if the components of the solar PV system are overheating:** Check if any individual solar PV modules, battery, charge controller or inverter is overheating. Overheating may affect the efficiency of the solar PV modules.
- **Check for bad wire connections:** If the wire needs to be replaced, use the wire with thickest gauge that the system can handle. If wire replacement was not demonstrated during the installation phase, then call the technician. Do not attempt to tamper with the system without proper training and safety measurements in place.
- **If none of the above issues exist** then it may be due to problems associated with the inverter, charge controller, or battery. In such cases, reach out to a technician to determine the root cause and address the issue accordingly.

Problem 2: Electricity generation is lower than expected.

Possible Solutions

- **Check if the system is dirty:** Performance issues are frequently caused by accumulation of dirt, dust, pollen, leaves, and other debris—on the surface of the solar panels, which reduces module efficiency. Cleaning is an easy fix and should be done on a regular basis. If the dirt has hardened over certain sections of the solar PV module, use a soft broom to remove it.
- **Check if any module is damaged:** Modules can sustain small cracks and continue to function normally. However, in most cases, the cracks tend to grow larger over time, causing the performance to drop significantly. When this occurs, the module should be replaced by the authorised service provider.
- **Check if the batteries are malfunctioning:** If the batteries are taking an unusual amount of time to charge, experiencing frequent discharges, or showing significantly reduced backup power. If any of these issues arise, seek the assistance of a technician to address the problem.

1.6 Relevant Resources

Solar system for home: On-grid solar system vs. off-grid solar system in English (video)

Brief description about off grid solar system and its comparison with on grid system in Hindi (video)

On-grid solar rooftop Frequently Asked Questions by Solar Energy Corporation of India (SECI)

Step by step guide on installation of solar modules - images and videos

Calculator for finding the solar panel size

Calculator for finding tilt angle for solar panel according to geographical location

Basics of solar rooftop systems

Module 2:
Biogas Plant

2.1 Introduction

Biogas is a combustible gaseous fuel collected from the microbial degradation of organic matter in anaerobic (without oxygen) conditions, which can be used for cooking, lighting, and other applications. Biogas is principally a mixture of methane (CH_4) and carbon dioxide (CO_2) along with other trace gases. It is produced through anaerobic digestion of various biomass sources, including livestock manure, agricultural residue, and food waste.[21]

Biogas provides households with numerous social, environmental, health, and economic benefits.[22] For instance, it saves money, and reduces workload. Primarily for women – biogas reduces the drudgery and costs associated with firewood collection for cooking. There are numerous types of biogas plants, as well as different associated technologies, such as prefabricated balloon biogas plants made with Linear Low-Density Polyethylene (LLDPE), Polyvinyl Chloride (PVC) reactors, fixed-dome plants, and floating-drum plants.

For this guidebook, the discussion is limited to balloon biogas plants. Flexible PVC Models (balloon-type) involve much less civil work during construction and use, and is easy to install and repair in case of gas leakages.[23] These plants have a life span of 10 - 15 years, and due to their pre-fabricated nature, there is limited scope to involve local technician during installation phase of these plants.[24] However, local livelihoods can be generated by training the local youth on how to take care of repairs and maintenance.

Small scale biogas plants can be used at the household, farm, or community level. The minimum space requirement is 9 x 4 meters.[25] Biogas plants are primarily suitable for users who are engaged in animal husbandry related activities, which provide regular and sufficient supply of biomass sources. A by-product of biogas plants is organic fertilizer that can be used in the agriculture sector, thereby reducing dependency on the chemical fertilizers. Table 2 below summarizes the sizing of a biogas plant based on the number of cattle and correspondingly, the availability of wet dung. An average of 0.25 cubic meter ($m^{3)}$ of biogas is required to cook food for one person per day.[26]

Table 2. Sizing of Biogas Plant (Source: MNRE)[27]

Size of Biogas Plant (m^3/day)	Amount of Wet Dung Required Daily (kg)	Approximate Number of Adult Cattle		Sufficient for Daily Cooking Fuel Need (number of people)
		Local	Cross Breed	
1	25	2-3	1-2	3-4 people, 3 meals
2	50	4-5	2-3	4-6 people, 3 meals
3	75	6-7	3-4	Up to 8 people, 3 people
4	100	8-10	4-5	10-15 people, 3 meals
6	150	12-14	6-8	15-20 people, 3 meals

2.2 Key Components

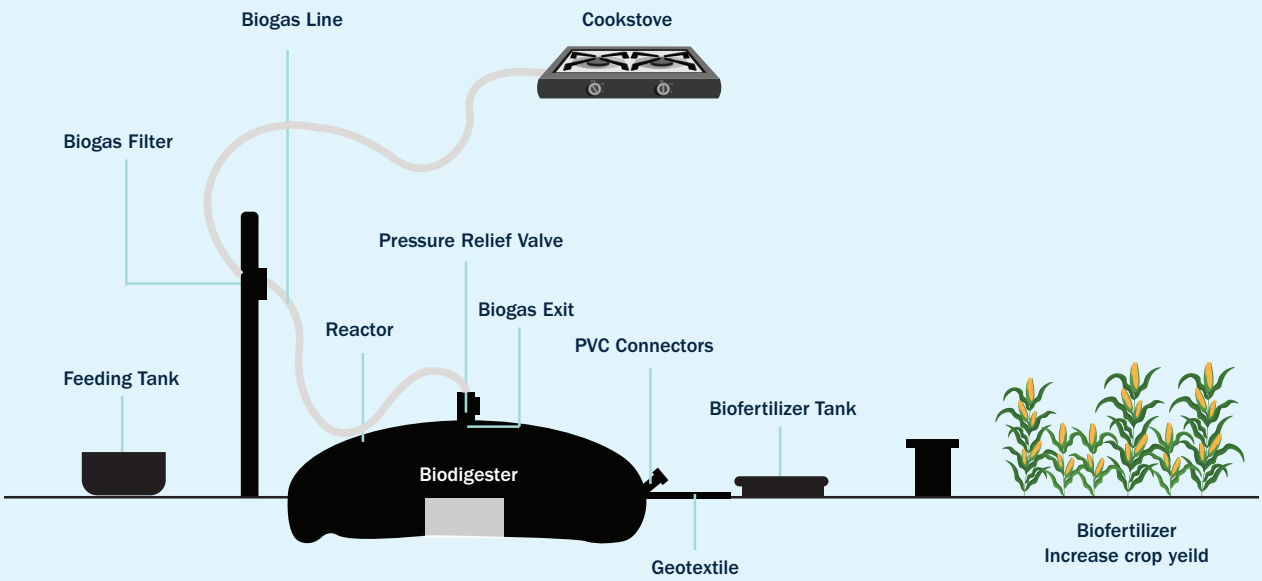


Figure 9: Schematic of a Balloon Biogas Plant with PVC Digester

Figure 10: Reactor[28]

Reactor

The reactor is an air-tight and waterproof container usually made of thermoplastics (plastics that respond to heat), for example, poly propylene-based or polyethylene-based or PVC coated polyester fibre-based material wherein raw materials constituting mixture of water and cattle dung/kitchen waste/agricultural waste react and are digested anaerobically to produce biogas.

Geotextile

The geotextile membrane is a high-density polyethylene anti-seepage membrane used to cover the biogas reactor.

Figure 11: Geotextile[29]

Figure 12: PVC Connectors[30]

PVC Connectors

PVC connectors, with regulatory gate valves, are a part of the piping system that helps to regulate the gas flow and connects the biogas plant with biogas appliances.

Feeding Tank

The feeding tank is a container where feedstock is mixed with the right proportion of water i.e., 1:1 by volume which means 1 kg of dung requires 1 litre of water for the mixture.

Figure 13: Feeding Tank[31]

Figure 14: Biofertiliser Tank[32]

Bio-fertiliser Tank

A bio-fertilizer tank stores excess slurry that can be used as a fertilizer in the farms.

Biogas Exit

Biogas exits the reactor through a gas pipeline with a PVC valve, connectors, and filters.

Figure 15: Biogas Exit[33]

Figure 16: Pressure Relief Valve[34]

Pressure Relief Valve

Pressure relief valves are safety devices that protect the biogas network from over pressure and/or under pressure. They are mostly mounted at places where biogas production occurs and near to gasholders.

Biogas Filter

Biogas filters are used to separate carbon dioxide (CO_2), water (H_2O), and hydrogen sulphide (H_2S) from the raw biogas to ensure more effective methane for cooking.

Figure 17: Biogas Filter[35]

Figure 18: Biogas Line[36]

Biogas Line

The biogas line carries the gas from the reactor to the cookstove.

Cookstove

Cookstoves for biogas application are similar to those of conventional appliances running on commercial gas-fuels or liquified petroleum gas (LPG).

Figure 19: Cookstove[37]

2.3 Installation

The technician will install the biogas plant in a location near the house of the user where sufficient ground space is available. The technician will lay down the pipelines necessary to transport the gas from the plant to the point of use, usually the kitchen.

The sizing of biogas pipe in the distribution line depends on the distance of the plant from the kitchen. With the pressure of approximately 8 cm water column, one cubic meter of biogas can be transported in one hour in a 12 mm pipe over about 20 meters.[38]

Table 3: Pipe Sizing and Biogas Plant Distance from the Kitchen (Source: MNRE)[39]

Diameter of Pipe (mm)	Distance Between Plant to Kitchen (m)
12	30
19	50
25	100

Preparing the Biogas Plant for Use:[40]

- Mix various biowaste sources such as cattle dung and kitchen waste with an equal quantity of water in the feeding tank. This forms the slurry.
- Feed the slurry into the reactor through the inlet chamber.
- When the reactor is partially filled with the slurry, stop the introduction of slurry into the plant and leave it unused for about 20 - 30 days. The initial 20 - 30 days (retention period) of the plant is required for birth & growth of anaerobic microbes. After the retention period, the plant can be operated daily.
- The gas that is produced in the first weeks after start-up is mainly carbon dioxide and it takes a while for the methane content to rise to a level that can sustain a flame. Let most of the gas inside the reactor escape; after a few days, the methane content of the gas will increase, providing quality biogas.
- During operation, anaerobic bacteria present in the slurry decompose or ferment the biomass in the presence of water.
- Since biogas is lighter than the decomposing slurry, it will rise and start collecting in the gas holder, prompting the gas holder to also start rising.
- The gas holder cannot rise beyond a certain level. As more gas collects, there is more pressure exerted on the slurry, which forces the slurry into the overflow chamber.
- Remove the slurry manually from the overflow tank, either daily or once the overflow tank is full.
- Open the gas valve to get a supply of biogas via pipeline to the cookstove.
- To obtain a continuous supply of biogas, feed the reactor continuously with prepared slurry.

2.4 Operations & Maintenance Guide

Typical daily activities to operate the biogas plant include preparing and adding a daily mixture of slurry, daily checks of the system, and managing the reactor effluent. Key steps for operating and maintaining biogas plants are listed in this section.[41]

Preparing and adding daily mixture

- The reactor should be fed at least once per day.
- The easiest way is to mix the slurry inside the inlet structure. Close the inlet pipe, e.g. with the cover flap provided in the mixing tank.
- Measure the correct amount of biowaste source such as dung and co-substrate (if applicable), and water. Co-substrate should be as fine as possible: for example, kitchen wastes should be cut in small pieces before adding it to the mix.
- Water should be an ambient temperature to avoid temperature shocks when adding the mix to the reactor. It may be best to prepare and fill a container of water every day, for use in the next day's mixture.
- The ingredients should be put in the feeding tank, allowed to soak for 15 to 30 minutes, and then mixed thoroughly by hand.
- Any dry lumps (e.g., from the animal dung) should be broken and soaked thoroughly. When the mixture is a uniform slurry, pull the plug from the inlet to let the mixture flow into the reactor.
- Withdraw the slurry manually once the bio-fertilizer tank is full and use it as manure for agriculture. Well digested slurry is practically odourless, easier to spread and does not attract weeds and insect flies. Digestion reduces the Carbon to Nitorgen ratio and increases the fertilizing effect of slurry. It contains nitrogen and other readily available plant nutrients and is more effective than other organic slurries including fresh cattle dung, compost, cattle urine, etc.[42]

Daily check-up

- Each day, the entire biogas system should be checked for irregularities (tears or cracks in bags or hoses, tightness of hose clamps).
- The water level inside the pressure relief system should be checked (hose should be submerged in 22 cm water or up to collar holes collar hole is the hole drilled on the reactor to fit the gas pipe).
- The amount of water in the pressure meter should be checked.
- To prevent scum formation in the reactor, mix the contents well before they enter the reactor.
- Replace the iron mesh in the biogas filter every month.
- Check the level of water in the condensation trap and empty the bottle, if necessary. Check the state of the roofing for any cracks or breakages.
- Clean the system regularly. Every three months, all the connections in the system should be checked for gas tightness. Call the technician if any leakages are detected in the system.
- Use a spray-bottle with soap and water to spray all connections (including reactor in- and outlet, and all gas connections up to the main valve) to ensure effective cleaning of connections and removal of any sand and debris.
- Clean the gas stove after every use to prevent blocking of burner holes from food.

Do's and Don'ts

Note 1: Ask the technician to regularly check on the ammonia content, volatile fatty salt, and heavy metal levels. The reactor can become toxic if these are not kept at optimum levels.

Note 2: Always keep the reactor safe from sharp objects.

Note 3: No smoking or open flames should be allowed near the biogas reactors and gas storage tanks, especially when checking for gas leaks.

2.5 Troubleshooting

The following are some of the most common problems to arise with biogas plants, and suggestions for how to address these problems:[43]

Problem 1: There is no or low gas production.

Possible Solutions

- **Check if the reactor has gone bad:** Flush out the reactor with a large amount of water and start it again.
- **Check if the bacteria inside is functioning properly:** The bacteria inside the reactor may have dropped or died due to high acidity, antibiotics, or poison. Add slurry from another reactor installed in the vicinity or call the technician to help.
- **Check if the feed is enough:** Gas production can be increased by adding a co-substrate. Discuss with a technician to identify the appropriate type.
- **Check if the feed is in excess:** Gas production can decrease due to over feeding (beyond prescribed limit) in the system. Discuss with a technician to identify the appropriate level.
- **Check for leakage from gas pipes and fittings:** First, close the main gas valve to disconnect the line. Second, carefully examine the joints. Finally, inspect and replace the broken PVC pipes, if any.
- **Check for foaming in the reactor:** In case of foaming, reduce or stop feeding the reactor. It is recommended to remove the solids from the reactor to allow the gases to escape and stabilize the foam.
- **Check for water level in the pressure relief valves:** If water level in the pressure relief valves is low, then gas may release from the valve. Refill it with water and wait for the gas formation.

Problem 2: Gas stove is not burning well.

Possible Solutions

- **Check for blocked primary ducts:** Clean the air ducts and burner holes.
- **Check for incorrect gas mixture:** Open the water drain to remove the accumulated water in the pipe.
- **Check for disconnected gas pipes:** Check for disconnection and connect it back.
- **Check for moisture in pipeline:** Lift gas pipeline to release water trapped in the pipeline and remove water collected inside the moisture traps.

Problem 3: Bio-slurry is overflowing.

Possible Solutions

- **Check for incorrect water/dung mixing ratio:** Always mix the manure and water in the prescribed ratio of 1:1.
- **Check for water leakage:** Ensure daily usage to allow movement.
- **Check if slurry is entering the gas pipeline:** Put a filter to allow only gas to pass through.

2.6 Relevant Resources

Flexi biogas plant installation in Hindi (video)

Flexi biogas plant maintenance in Hindi (video)

Flexi biogas plant connection in Hindi (video)

Benefits of biogas plants in English (video)

2 cubic meter biogas plant – installation and maintenance (video)

FAQ on biogas technology, MNRE & BDTC, Udaipur (document)

Complete installation (video)

Biogas plant components and benefits in Hindi (video)

Module 3:
Solar Water Pump

3.1 Introduction

A solar water pump is a pump that runs on electricity produced by solar PV modules, as opposed to grid electricity or diesel-powered water pumps. Consequently, a solar water pumping system is capable of functioning as a stand-alone system. Solar water pumps are cost effective to operate largely owing to the reduced need for other energy sources such as diesel. Solar pumps are used to raise water from tube wells, shallow wells, ponds, and canals for household consumption or for irrigation purposes. Solar water pumps are helpful in isolated locations, notably in remote villages and towns where grid energy is either not available or intermittently available, and alternate sources like diesel generators are expensive to operate.

A solar water pumping system has one or more solar PV modules, a motor pump set, a lightning arrester, a pump controller or a Universal Solar Pump Controller (USPC). A solar water pump works in the same way as any other pump set. When sunlight hits the solar PV modules, it creates direct current, which is used to power the motor that pumps the water out. If the motor needs alternating current for running, an inverter integrated in the pump controller changes the direct current produced by the solar PV module into alternating current. The main function of a pump controller is to manage the voltage and current generated by solar panels, ensuring optimal performance and efficiency of the pump.

The system also includes a lightning arrester which is a static discharge device installed next to the modules and is connected to the ground. It is meant to prevent the build-up of static charge and provide a path for very high current to flow to the ground if lightning strikes and protect the entire system from surge damage.

Solar Pumps can either be grid-connected or stand-alone. During the non-irrigating periods, a USPC can be used to run other electric equipment such as cold storage, flour mill or can be used for battery charging, etc.

Depending on whether the pump runs on an AC motor or a DC Motor and whether the pump is installed in a deep well (submersible) or a shallow well (surface), Table 4 below summarizes the system sizing and technical specifications. These water output figures are relevant on a clear sunny day under an average daily solar radiation of 7.15 kWh/m^2 on the surface of the module.[44]

Table 4: Specifications for SPV Pumping Systems (Source: MNRE)[45]

Motor Type	Pump Installation	PV Module (Wp)	Motor Pump-set capacity (HP)	Total Head (m)	Water Output (L per day)
DC	Surface (Shallow Well)	900	2	10	198,000
		2,700	3	20	148,500
		4800	5	30	182,400
		6,750	7.5	30	256,500
	Submersible (Deep Well)	1,800	2	30	68,400
		3,000	3	70	45,000
		4,800	5	100	50,400
		6,750	7.5	100	70,875
AC Induction-based	Surface (Shallow Well)	1,800	2	10	178,200
		2,700	3	20	132,300
		4,800	5	30	168,000
		6,750	7.5	30	236,250
	Submersible (Deep Well)	1,800	2	30	63,000
		3,000	3	70	42,000
		4,800	5	100	43,200
		6,750	7.5	100	60,750

Alternatively, the Ministry of New and Renewable Energy (MNRE) has developed an online Solar Irrigation Pump Sizing (SIPS) Tool which can determine the following:[46]

(a) Monthly Irrigation requirements based on the geography and cropping pattern.

(b) System head requirements based on the water depth, distance from source of irrigation to the field, pipe diameter, water source, and number of irrigation days in a particular month.

(c) Discharge in litres per day, motor rating (in HP) based on the choice of pump (AC/DC).

Below are the steps to determine the pump size online using the SIPS Tool:[47]

- Step 1: Search and enter the webpage https://pmkusum.mnre.gov.in/landing.html and click on to the Solar Irrigation Pump Sizing Tool.

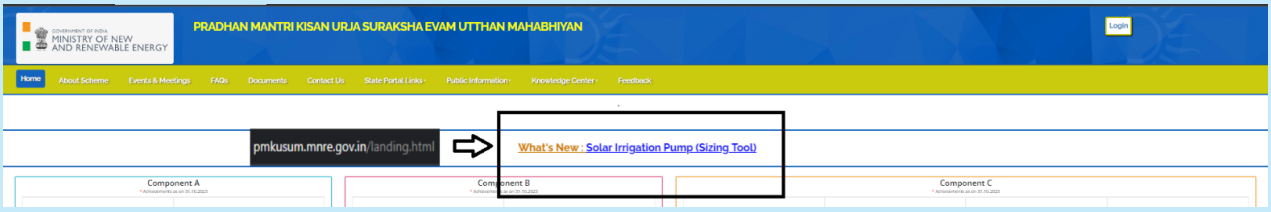


Figure 20. MNRE's PM KUSUM Portal

- Step 2: Point a location on the map where you want to determine the pump sizing. Alternatively, enter the coordinates of the location manually to visually check the annual data for temperature and rainfall.

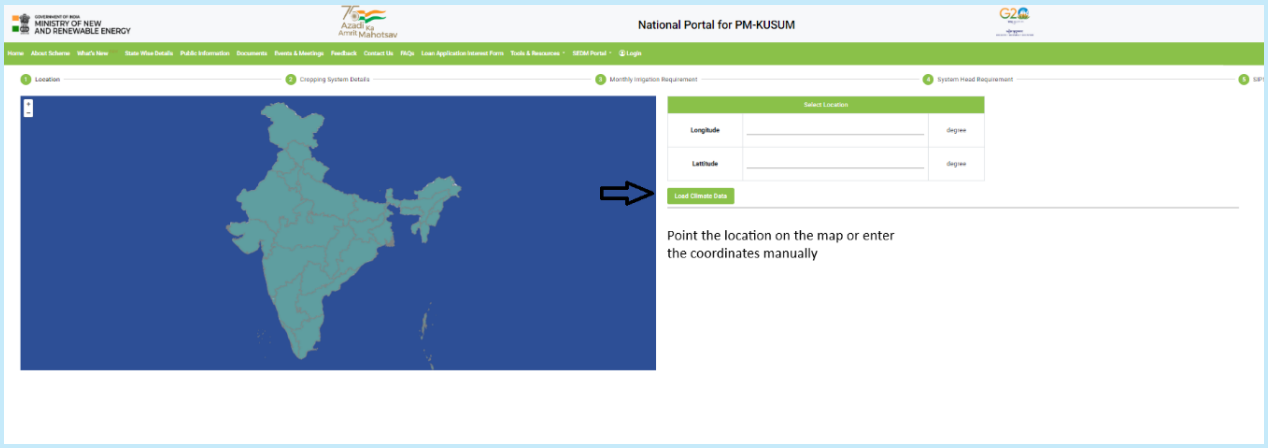


Figure 21. Geo-locator in the Pump Sizing Tool

Figure 22. Loaded Climate Data for the location

- Step 3: After checking the climate data, enter the cropping pattern that is to be practised by mentioning crop, area to be cropped, cropping period and the irrigation system in function (surface/flood, sprinklers, etc.) to determine the monthly irrigation requirement.

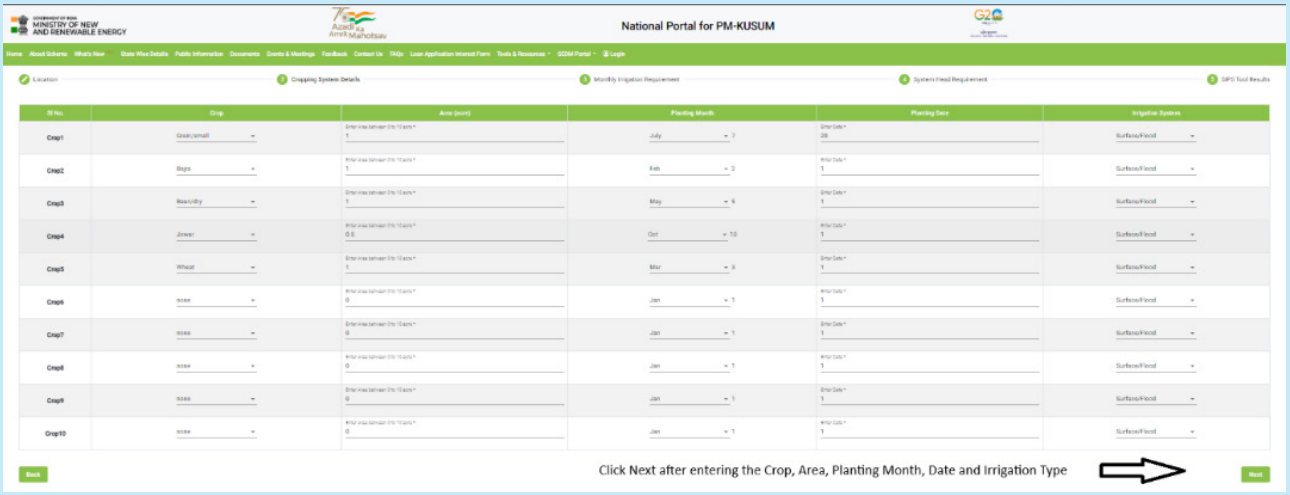


Figure 23. Inputs to Ascertain Total Head

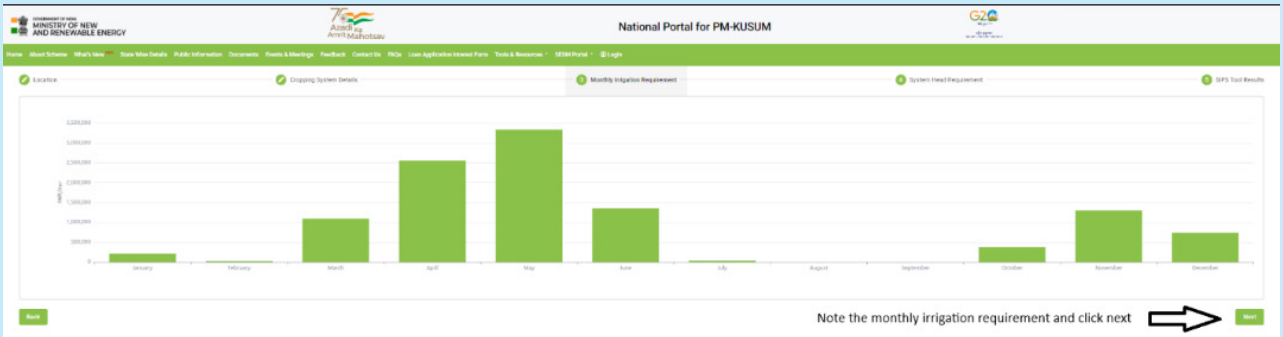


Figure 24. Monthly Irrigation Requirement

- Step 4: Determine the total system head requirement by entering details including water depth, source of water, number of irrigation days in a month, etc. Click next to find results from the SIPS Tool which summarizes pump options for the farmers to adopt by providing information including discharge, motor HP, category (submersible or surface), etc.

Figure 25. Total System Head measurement

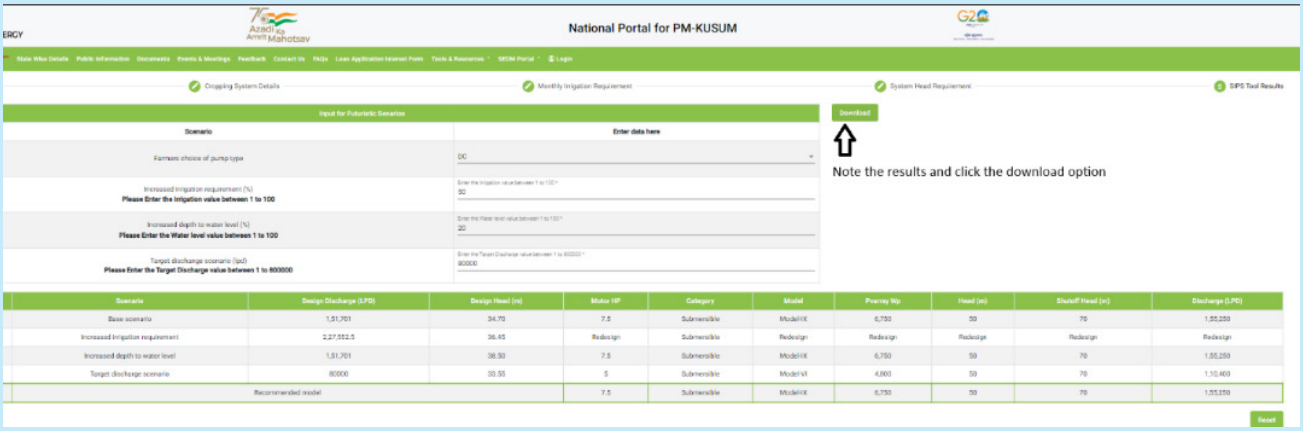


Figure 26. SIPS Tool Results on the Webpage

SIPS Tool Results

Input for Futuristic Senarios		
	Scenario	Enter data here
I	Farmers choice of pump type	DC
II	Increased irrigation requirement (%) **Please Enter the Irrigation value between 1 to 100**	50
III	Increased depth to water level (%) **Please Enter the Water level value between 1 to 100**	20
IV	Target dischange scenario (lpd) **Please Enter the Target Discharge value between 1 to 800000**	80000

	Scenario	Design Discharge (LPD)	Design Head (m)	Motor HP	Category	Model	Pvarray Wp	Head (m)	Shutoff Head (m)	Discharge (LPD)
Scenario - I	Base scenario	1,51,701	34.70	7.5	Submersible	Model-IX	6,750	50	70	1,55,250
Scenario - II	Increased irrigation requirement	2,27,552.5	36.45	Redesign	Submersible	Redesign	Redesign	Redesign	Redesign	Redesign
Scenario - III	Increased depth to water level	1,51,701	38.50	7.5	Submersible	Model-IX	6,750	50	70	1,55,250
Scenario - IV	Target discharge scenario	80000	33.55	5	Submersible	Model-VI	4,800	50	70	1,10,400
	Recommended model			7.5	Submersible	Model-IX	6,750	50	70	1,55,250

Figure 27. SIPS Tool Results (downloaded)

3.2 Key Components

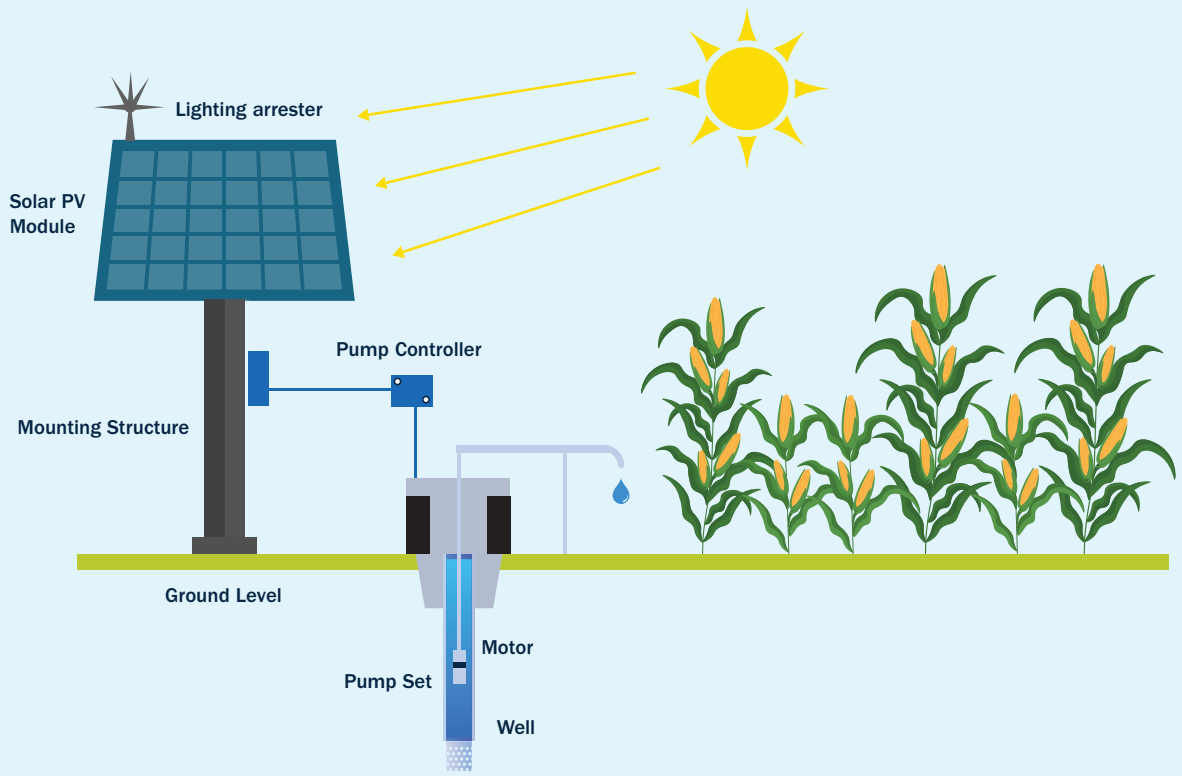


Figure 28: Schematic of a Solar Pump System

Figure 29: Solar PV Module[48]

Solar PV Module

The solar PV module absorbs light energy from the sun and uses it to generate an electric current.

Surface Motor-Pump set

The surface motor-pump set is suitable for drawing water from shallow wells.

Figure 30: Surface Motor-Pump set[49]

Figure 31: Submersible Motor-Pump set[50]

Submersible Motor-Pump set

The submersible motor-pump set is suitable for drawing water from deep wells.

Figure 32: Universal Solar Pump Controller[51]

Universal Solar Pump Controller (USPC) (Optional)

A USPC is a buffer device between the solar PV array and motor and pump. It monitors the flow and/or level variables and controls the pump accordingly to maintain the desired water flow levels. The pump controller also protect the pump from high/low voltage conditions. It can not only power a pump but can power any agrarian equipment or even household electric loads like a light, fan, TV, computer, or heater, etc.

Remote Monitoring System (RMS) (Optional)

A RMS is a monitoring device that gives vital inputs like power generation to the authorities and helps with the maintenance of the solar pump installation in remote areas.

Figure 33: Remote Monitoring System[52]

Figure 34: Mounting Structure[53]

Mounting Structure

Mounting structures are the supporting pillars for solar PV modules. These structures are used to set the solar PV modules at an angle that can collect maximum solar radiation.

Lightning Arrester

Lightening arresters are designed to protect the photovoltaic systems from direct lightning strikes and surge damages by redirecting excess voltage surges to the ground.

Figure 35: Lightning Arrester[54]

Figure 36: Pump Controller[55]

Pump Controller

A pump controller is a digital device that not only converts the DC from solar panels into AC but also ensure that water flow is maintained at a constant rate, and that solar power is used efficiently.

3.3 Installation/Usage

The technician will install the solar PV modules (in a shadow free area for efficient performance) and water pump based on the space availability and ground level scenario.

3.4 Operations & Maintenance Guide

Key steps for operating and maintaining solar water pumps are listed below:[56]

Insulation

- Make sure the control box and exposed wires are always insulated. Ensure that the pump controller is properly connected, and the system is tightly sealed.

Regular cleaning of solar PV modules

- Clean the modules to remove accumulated dust and debris. Cleaning should be done with a soft sponge and water. Cleaning should be done more frequently during the dry season or in dusty areas.

Trimming of trees

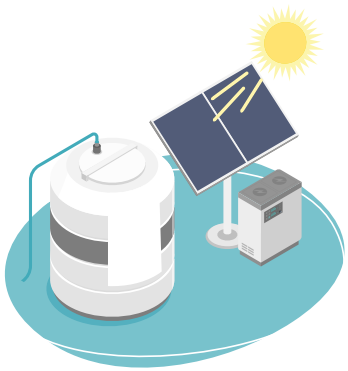
- Trees surrounding the solar PV modules should be regularly trimmed to ensure they do not block the sunlight.

Overflowing tank

- If the tank does not have a valve to cut off water supply when it is full, the system operator should immediately shut down the pump to prevent overflow.

Clearing the area around the borehole and solar PV modules

- The area where the solar PV modules and pumps are located should be litter-free and must be kept debris-free.



3.5 Troubleshooting

The following are some of the most common problems that may arise with solar water pumps, and suggestions on how to address these problems:[57]

Problem 1: Pump does not start or function at all.

Possible Solutions

- **Check if the pump is plugged in:** If not, connect pump to the solar PV system.
- **Check if the pump is receiving power:** Taking adequate precaution, check the wires to make sure they are connected properly. Ensure that the wires are not burned or melted. Replace if required.
- **Check the voltage of the system:** Voltage should be as prescribed by the technician. The voltage number is usually listed on the pressure switch control box or on the name plate of the submersible pump.
- **Check the pump and motor:** If none of the above yields results, get the pump/motor checked and repaired by a certified technician.
- **Check if solar PV modules are generating electricity:** Inspect the inverter; check if the inverter lights are working in accordance with the technician's description. Remove dust or dirt accumulation. Ensure wires are not loose as prescribed by the technician during installation.
- **Check if the wiring is loose:** Loose wires can lead to unexpected electrical problems. Remember that the wiring in the solar PV system connects the modules to each other, to the home solar batteries, and to the inverters. As a result, the wiring connection could be broken at one or several places. Talk to a technician to fix any wiring problems; they can use meters and other tools can identify the problem as well as repair damaged parts without affecting other parts of the solar PV system.
- **Check if the system is overheating**[58] Check for heat fade, that is when the sun's heat causes the solar PV modules to overheat. This can cause the solar PV modules to have a lower power output. If the heat fade is severe, it might be due to damaged PV modules or poor connections. Check for improper or loose wire connections. If the wire needs to be replaced, then use the thickest gauge wire that the system can handle. Call the technician in case this was not demonstrated during system installation phase. Do not attempt to tamper with the system without proper training and safety measures in place.

Problem 2: Electricity generation from solar PV is lower than expected.

Possible Solutions

- **Check if the solar panels are installed at correct angle:** Ensure that the solar PV module is correctly mounted in the south direction at a suitable angle.
- **Check if the system is dirty:** Performance issues are mostly caused by the accumulation of dirt, dust, pollen, leaves, and other debris. Dirt reduces module efficiency. Cleaning is an easy fix and should be done on a regular basis. If the dirt has hardened over certain sections of the solar PV module, use a soft broom to remove it.
- **Check if any module is damaged:** Modules can sustain small cracks and continue to function normally. However, in most cases, the cracks tend to grow larger over time, causing the performance to drop. When this occurs, the module should be replaced by the authorised service provider.

Problem 3: Water is running continuously.

Possible Solutions

- **Check for break in line or a check valve:** This break can happen between the pump and the field/house where the water is being supplied.
- **Shut off the water in the field/house and look at the water pressure gauge:** If it remains constant, there is no problem with the check valves and hence no leakage.
- **Check for valve leaks:** If the pressure drops, then there is either a leak in the line to the house or an issue with the valve. If it is an issue with the valve, contact a technician plumber to help fix the problem.
- **Check the pressure switch:** Try to lower the minimum pressure. In every pressure switch, there is a minimum threshold pressure below which the switch remains inactive. By lowering the threshold, the direction of water can be controlled. Make sure to turn off the power before adjusting the pressure switch.

Do's and Don'ts

Note 1: While troubleshooting, it is recommended to start at the surface level. First, check the solar PV modules and connections before moving to pump and controller.

Note 2: Call the technician whenever there is an issue with the controller or pump wiring.

3.6 Relevant Resources

Solar pump installation in Hindi (video)

Video on solar pumps brief description in Hindi (video)

Solar water pumps benefits

Solar irrigation pump sizing tool developed by MNRE

Operating a 5HP USPC by TAG solar system (Kisan Solar) (video)

Module 4:
Solar Precision Irrigation System

4.1 Introduction

Precision irrigation is a highly effective method of delivering water and nutrients to crops. This technique provides water and nutrients directly to the root zone of the plant in proper quantities and at the right time. It ensures that each plant receives the right nutrients in a timely manner, which helps plants develop more efficiently and successfully, alongside optimizing water usage. Precision irrigation technique can result in waters savings of about 40-60% compared to conventional surface irrigation, depending on soil and climate conditions.[59]

This technique mitigates the pressing issue of water scarcity and resource inefficiency found in traditional irrigation methods like flood or furrow irrigation.[60] In addition, it increases nutrient uptake for crops, minimizes water stress which can result in improved crop yield, quality, and increased profitability for farmers. Furthermore, it limits water availability to weeds reducing their growth and proliferation.

In a solar precision irrigation system, water is ransported across the field via pipes known as dripper lines, which include smaller units known as drippers. Each dripper releases water, resulting in the consistent administration of water to each plant's root zone throughout an entire field. This method requires less energy for water distribution as compared to conventional methods, ereby reducing the energy consumption and operational costs for farmers.

Water is supplied from the source to the laterals through a network of pipes consisting of mainline and sub-mainline. Water with pressure is supplied to main, main to sub-main and sub-main to laterals (pipes used for conveying water from sub-main lines to drip lines) using a pump as shown in Figure 38.

4.2 Key Components

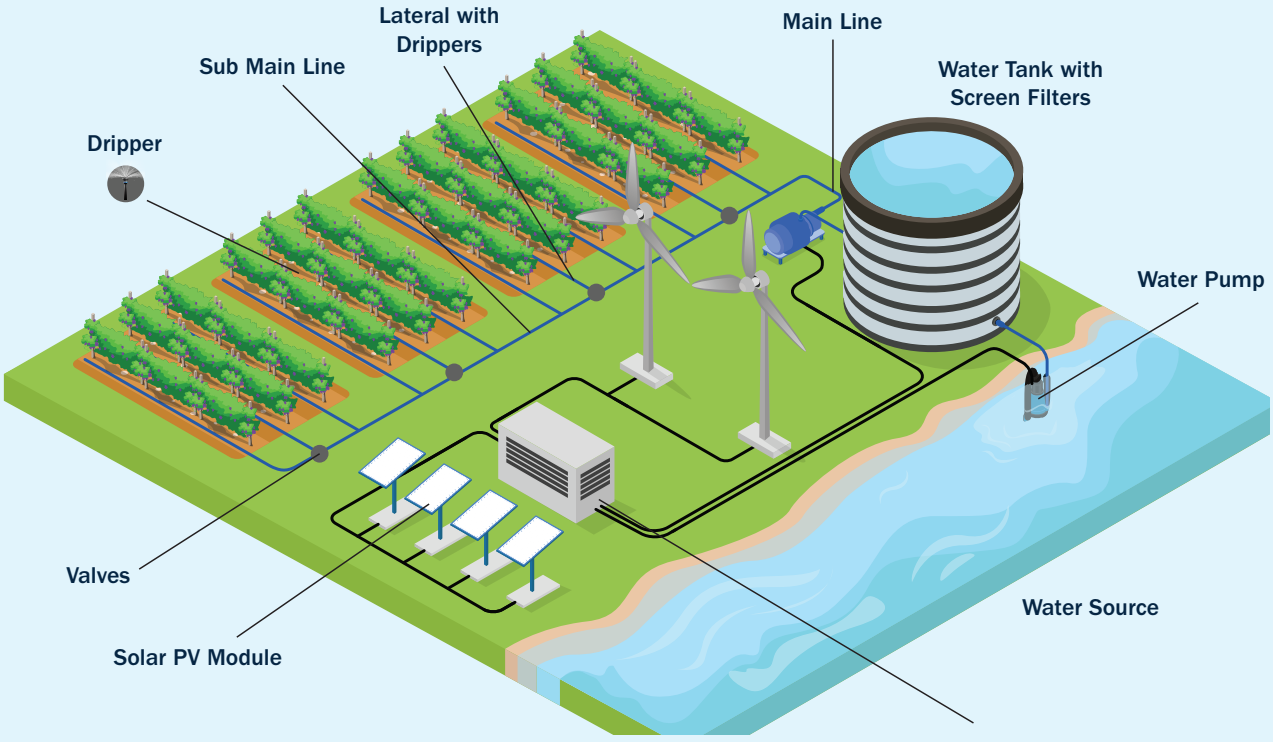


Figure 37: Schematic of a Solar Precision Irrigation System

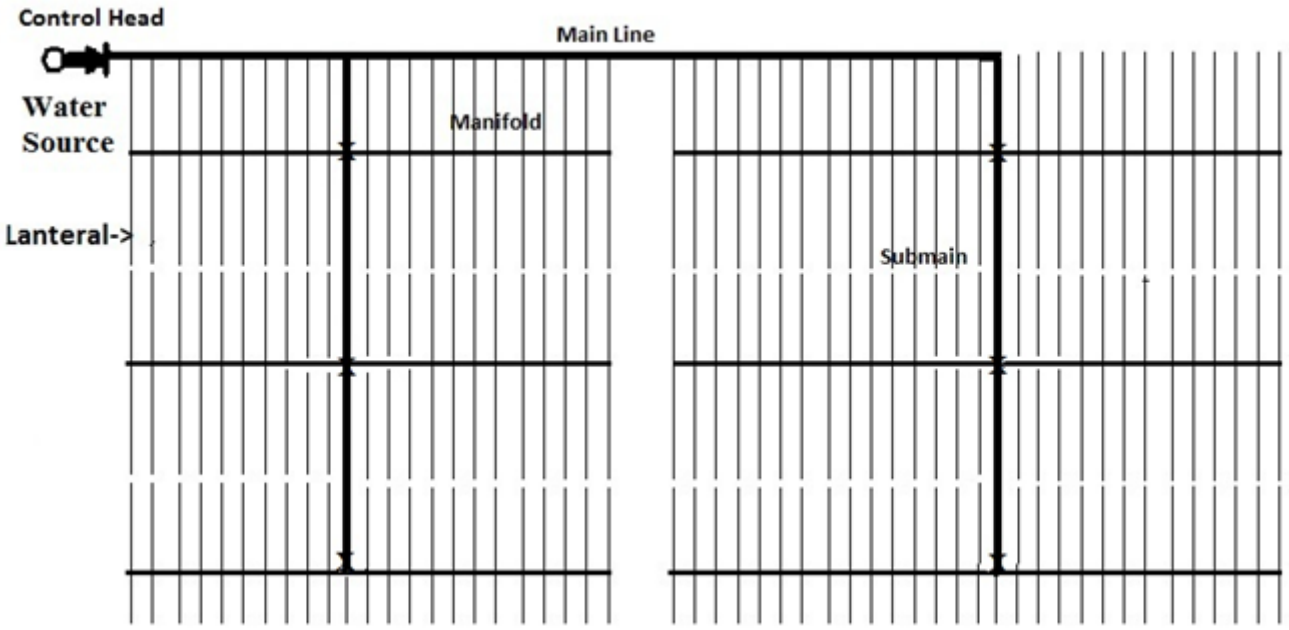


Figure 38: Typical Layout of Drip Irrigation System (Source: IASRI, ICAR)[61]

Figure 39: Solar PV Module[62]

Solar PV Module

The solar PV module absorbs light energy from the sun and uses it to generate an electric current.

Pump

The pump draws water from the open well, bore well, stream, pond, canal, etc. It allows water to be pumped from a bigger water reservoir to a smaller raised tank.

Figure 40: Pump[63]

Figure 41: Subsurface Tank[64]

Subsurface Tank

The subsurface tank is a small and raised water storage tank, which contains sufficient water to feed the system with enough water for a day.

Screen Filter

It is a metal or fibre-based filter that removes particles from flowing water (pumped from borewell) through its mesh screens. The screen filter prevents the clogging of small holes in drip tubes.

Figure 42: Screen filter[65]

Figure 43: Pressure Gauge[66]

Pressure Gauge

The pressure gauge maintains the normal operating pressure to ensure uniformity of irrigation.

Valves

Valves control the water pressure.

Figure 44: Valves[67]

Figure 45: Main Line[68]

Main Line

A Polyvinyl Chloride (PVC) main line is used to carry water from source to sub-main line. The filter is attached to this line.

Sub-main Line

A PVC sub-main line supplies water for further irrigation. The diameter of the sub-main line should be smaller than the main line.

Figure 46: Sub-main Line[69]

Figure 47: Dripper[70]

Dripper

The dripper allows water to reach the plant roots.

Poly Joiners

The poly joiner is a pipe fitting which is used to connect two ends of polytube or plain lateral.

Figure 48: Poly Joiners[71]

Figure 49: Power Management Box[72]

Power Management Box (PMB)

Power is delivered from the solar PV module to the PMB where pressurized air/ water is produced and delivered to the pump unit. Batteries are housed inside the PMB. In case PMB is not supplied, then a charge controller and battery will be provided.

Battery

(Optional and is applicable for systems without a Power Management Box)

The battery is added to the solar PV system to store excess electricity generated by the solar PV modules. This stored energy can be used to electrify appliances during non-generation periods such as nights and cloudy days.

Figure 50: Battery[73]

Figure 51: Charge Controller[74]

Charge Controller

(Optional and is applicable for systems without a Power Management Box)

The solar charge control unit is an electronic device that controls the power going from the solar PV module to the battery bank. It ensures that batteries are not overcharged during the day, and that the power does not run back to the solar PV modules overnight thus draining the batteries. Its primary job is controlling the power flow, but some charge controllers are available with additional capabilities, like lighting and load control.

Lateral Pipe

Lateral pipes are used for conveying water from sub-main lines.

Figure 52: Lateral pipe [75]

4.3 Installation/Usage

The technician will follow the steps mentioned below to install a solar precision irrigation system with your support:[76]

- Identify the farm area and relevant crops where the drip irrigation will be set up.
- Analyse the soil characteristics and the amount of water needed for the crops.
- Design the system in an efficient manner that uses the least number of pipes and tubes. Tentative water requirement for crops (litres/plant/day) can be used as a guideline to design the system as shown in Table 5 below.

Table 5. Essential Parameters for Designing a Drip Irrigation System (Source: IASRI, ICAR)[77]

Essential Parameters	Orchard Crops (fruits, nuts)	Vegetables and Other Closely Spaced Crops
Stream size (discharge)	1 Litre per second per hectare for 4 hours per day	3 Litre per hectare for 4 hours per day
Storage Tank (Subsurface Tank) capacity	15 m3 per hectare	45 m3 per hectare
Power requirement	1 HP per hectare	3 HP per hectare

- Set up the water source using water tanks and select the sizing of the drippers that is best suited for the type of soil in the field and various crops to be planned in different seasons. Determine the number of drippers to be installed.
- Dripper placement and spacing also becomes critical to adequately supply water to the roots. If drippers are poorly placed, too far or too few, root development may be restricted to the soil area which is wetted. Dripper placement depends on the plant size, type of vegetation and the type of soil. Generally, drippers are placed 12 inches apart in sand, 18 inches apart in loam and 24 inches apart in clay.[78] Connect water tank to the water hose and pump and fit all the drip lines. Before the installation of drippers, flush the entire system to prevent the drippers from clogging due to dirt.
- Measure and calculate the pump size based on the field as well as the length of the pipes need to be laid in the field and appropriate PV system to power the pump. by taking guidance from the Table 6 below.

Table 6. Technical Specifications for Solar PV Precision Irrigation System (Source: Spowdi)[79]

Solar PV Module	Motor Capacity (HP)	Head (in meter)	Water Output (in Litres per minute)	Water Output (in Litres per day)
150 Wp	0.1	10	10	6,300
150 Wp	0.1	5	25	15,900
150 Wp	0.1	1	35	21,000

- Connect the solar components in the correct order:
  - Ensure that the solar PV module is correctly mounted in the south direction at suitable angle based on geographic location of the site. A link to the calculator to find the most suitable tilt angle, is provided in Section 4.6.
  - Complete all the necessary wiring and connections to power the pump using solar power.
  - Connect the positive and negative wires of solar panel to the back of PMB. In the absence of a PMB, the pump is supported with charge controller and a battery as separate components linked with the solar PV modules, then follow the additional steps mentioned below:
    a. Hook up the charge controller to the battery.
    b. Connect the pump to the battery.
    c. Hook up the solar PV module to the charge controller with appropriate connector cables.
    d. Once all connections are complete, uncover the module and let the battery charge.
    e. The charge controller will inform when the charging is complete and optimally regulates the battery charge.
    f. Charging the battery all day prior to running the pump is preferred.

4.4 Operations & Maintenance Guide

Key steps for operating and maintaining solar precision irrigation system are listed below:[80]

- Check the lateral functioning of pipes. Check if any area is wetted due to leakage of pipes, valves, fittings, etc.
- Check the placement of drippers. In case a dripper is displaced, return the dripper to its proper location.
- Ensure all drippers are working properly without any leakage.
- Flush the sub-main and laterals by opening the flush valve for 5 mins. System flushing, in general, needs to be carried out at regular intervals.
- Treat the system with chlorine/acid once per month or as per instructions provided by the equipment supplier.
- Regularly backwash the screen filter:
  - Backwash the screen filter to remove the silt and other accumulated dirt. Backwash is a process in which the direction of the flow of water is reversed so that the water flows upwards through the sand bed.
  - Backwash the screen filter every day before starting the system and possibly before stopping irrigation.
  - For daily backwash, follow these steps: Brush the fibre/metal filter and clean it with water. Allow it to dry before placing it back.
- Ensure the screen filter is clean and ready for use:
  - Clean the screen filter every day.
  - Open the drain valve to remove impurities before cleaning.
  - Use a thin water jet/nylon brush to clean the filter element.
  - Do not use stones to rub the screen surface.
  - Check for any mechanical damage.
  - Never use the system without the filament (a fibre like material and a sub-component of the screen filter) inside the filter.

Do's and Don'ts

Note 1: If water is not flowing to the lateral end, it may be due to one of the following: cuts, holes, or bends in the pipes. Use Poly-joiners to close the cuts and holes and try to manually remove the bends on the lateral pipes.

Note 2: Look for algae or ferrous material formation in the water that may be naturally present in sub-surface or ground water. Use chemical treatment or clean the laterals with water.

4.5 Troubleshooting

The following are some of the most common problems that may arise in the solar precision irrigation system and corresponding suggestions that may help address these problems:[81]

Problem 1: Clogged drippers.

Possible Solutions

- **Check if filters have accumulated dust:** If the drippers are clogged, inject water with pressure to immediately remove the accumulated dust. To avoid such issues, maintain a routine for cleaning the screen filters and/or replacing them at regular intervals.
- **Check for scaling in the pipelines:** Inject irrigation water with sulfuric acid and chlorine which can treat scaling in the pipelines and reduce the algal growth in the reservoir.[82]

Problem 2: Leaks from broken drippers, valves, pipes; wear and tear of the components.

Possible Solutions

- **Check for required repairs and regular wear & tear:** Have a mechanism in place for detecting damages and regular wear & tear such as regular system inspections. At the beginning of the irrigation cycle, it is customary to drive around the perimeter and every other row of the irrigation system and to fix any issues promptly. Check and clean air vents at the beginning of each season. Farmers must carry the necessary components and tools with them in the field to conduct fast repairs.
- **Check for damaged equipment:** Inspect the pump station's pressure gauges during start-up and before each watering event. Replace damaged equipment and pipelines.
- **Check if drippers require replacement:** This will be necessary if the performance of drippers is compromised by leaks, cracks, or physical damage.

Problem 3: Electricity generation from solar PV is lower than expected.

Possible Solutions

- **Check if the solar panels are installed at correct angle:** Ensure that the solar PV module is correctly mounted in the South direction at an angle of 15 degrees.
- **Check if the system is dirty:** Performance issues are mostly caused by the accumulation of dirt – dust, pollen, leaves, and other debris. Dirt reduces module efficiency. Cleaning is an easy fix and should be done on a regular basis. If the dirt has hardened over certain sections of the solar PV module, use a soft broom to remove it.
- **Check if any module is damaged:** Modules can sustain small cracks and continue to function normally. However, in most cases, the cracks tend to grow larger over time, causing the performance to drop. When this occurs, the module should be replaced by the authorised service provider.

Problem 4: Problem with pump pressure

Possible Solutions

- **Check whether the solar PV system is generating enough electricity** to draw water from the main water source. If not, then refer to Problem 3.
- **Check for routine pressure measurements.** Adjust the pressure regulating valves in the field, so that all valves have the same incoming pressure. Make sure to turn off the power before adjusting the pressure switch.

4.6 Relevant Resources

Introduction to the drip irrigation system in English (video)

Components and installation of drip irrigation system in English (video)

Introduction, installation, and usage of the system in English (video)

Installation of drip irrigation Driptech India in English (video)

Handbook on drip irrigation (Document)

Guidelines for planning and design of drip irrigation system (Document)

Introduction to micro irrigation system (Document)

Operation and maintenance of micro irrigation system (Document)

Calculator for finding tilt angle for solar panel according to geographical location

Module 5:
Solar Fencing

5.1 Introduction

A solar fence works like an electric fence; it deters animals encountering the fence with a short but safe shock. Usually, even if only one animal receives a shock, the rest of the herd avoids contact with the solar fence. Crops, including large farmsteads, can be saved from damage caused by animal trespassing using solar fencing as it creates a useful barrier to keep wild animals out.[83]

A solar PV module generates DC current and stores it in the battery. A pulsed electric current is sent along the fence wire, about one pulse per second, from an earthed energizer. When the animal touches the fence, it completes the circuit between the fence and the ground, and the animal receives a short but safe shock. The shock deters that animal, and as well as other animals in the herd from trespassing in the future.

The height of the solar fence and the number of lines used is dependent on the specific animals intended to be repelled or deterred. Table 7 below lists the perimeter for fencing required for a specific area.

Table 7: Perimeter for Fencing v/s Protected Areas (Source: NABARD)[84]

S. No.	Protected area or farm (acre)	Perimeter for fencing (fence wire length in meters for one line of fencing)
1	1	300
2	5	700
3	10	1000
4	20	1400

5.2 Key Components

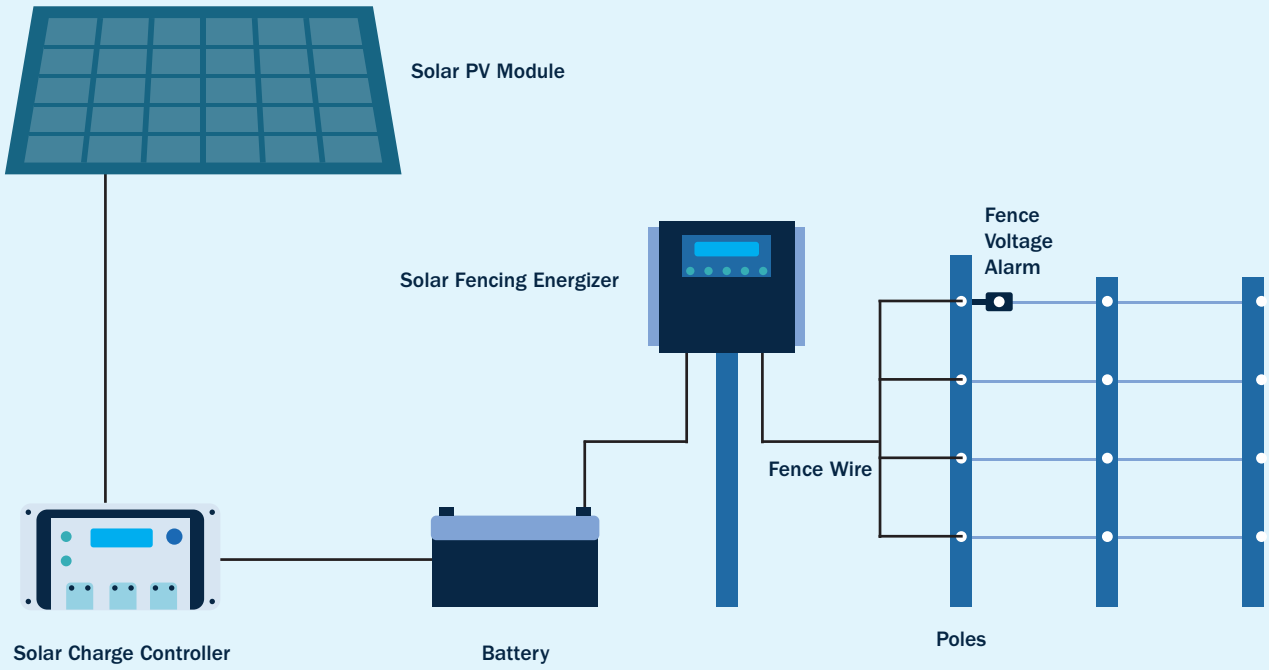


Figure 53: Schematic of Solar Fencing

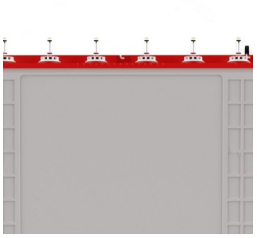


Figure 54:Battery[85]

Battery

The battery is added to the solar PV system to store excess electricity generated by the solar PV modules. This stored energy can be used to electrify the fencing during non-generation periods such as at night or on cloudy days. Considering that if the battery is small in size, it is usually attached to the solar fencing system.

Solar Charge Controller

The solar charge control unit is an electronic device that controls the power going from the solar PV module to the battery bank. It ensures that batteries are not overcharged during the day, and that the power does not flow back to the solar PV modules overnight, thus draining the batteries. Its primary function is to control the power flow, but some charge controllers are available with additional capabilities like lighting and load control.

Figure 55: Solar Charge Controller[86]

Figure 56: Solar Fencing Energizer[87]

Solar Fencing Energizer

The solar fencing energizer is the powerhouse of the electric fence and converts electricity from the battery into regular high voltage pulses that travel along the fence.

Fence Voltage Alarm (Optional)

The fence voltage alarm detects any kind of tampering/interference on the fence or system.

Figure 57: Fence Voltage Alarm[88]

Figure 58: Solar Modules[89]

Solar PV Modules

Solar PV modules absorb the light energy from the sun and use it to generate electric current.

Fence Wires and Poles

Fence wires and poles are placed around the farm perimeter to prevent trespassing of animals.

Figure 59: Fence Wires and Poles[90]

5.3 Installation/Usage

The technician will install the solar fencing and make necessary connections which include the following key steps:[91]

- Determine where you want to install the solar panel: Make sure that the area which you choose gets plenty of sunlight and place the solar panels in this area. Also ensure that animals are not likely to wander off in that area.
- Install the pole: Make sure that the material of pole is resistant to rust, such as aluminium or stainless steel. Dig a hole for each pole which should be at least two feet deep. Place the pole and fill it with concrete. The concrete will help to keep the poles in place and prevent them from being knocked over by animals.

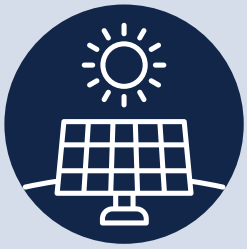
Attach the solar panel is connected to the solar charge controller which in turn is connected to the battery. Battery is then connected to the solar fencing energiser which is also connected to the fence wire. Make sure that the solar charge controller, battery, and solar fencing energizer are protected from rain and housed inside a secured area.

- Connect the fence to the battery.
- Test the fence to make sure it's working properly:
    1. Make sure the fence is turned on and the batteries are fully charged.
    2. Next, put on a pair of gloves and touch the fence wire in several places to make sure the current is flowing properly.
    3. Finally, watch for any signs of fence not working properly, such as gaps in the wire or loose connections.

5.4 Operations & Maintenance Guide

The solar electric fence system requires very little maintenance. The following tips are helpful in ensuring its proper maintenance:[92]

- Ensure that the solar electric fence is a complete electric fence system with all the correct accessories.
- Clean the top surface of the solar PV module regularly to remove any accumulated dust.
- Ensure that the solar PV module is correctly mounted in the south direction at a suitable angle based on geographic location of the site to ensure maximum output.
- Before heavy storms and lightning, disconnect the energizer from the fence to prevent it from being severely damaged.
- Regularly check for and remove any vegetation growth on the fence line.



Earthing for Solar Fencing

- Earthing is very important for good performance. Earthing creates an easy passage for excess charge (that may flow due to any fault/lightning) to an electrode buried underground, thereby preventing equipment damage and human injury.
- For the solar fencing system, one may use "Super Earth Kits" comprising of stainless-steel rods (equivalent to three conventional earth stakes) along with salt and bentonite clay. These kits are effective in difficult or poor soils (like sandy, pumice, stoney, ash) as salt attracts moisture and absorbent clay retains this moisture, which increases the conductivity of the surrounding soil.[93]
- Do not install the Super Earth Kit near a home's main earthing system.[94] Grounding systems should maintain a distance equal to (or greater than) the vertical length of the electrode, so that the fault current in one electrode does not jump into the other electrode and cause damage to the electrical system to which it is connected.

5.5 Troubleshooting

The following are some of the most common problems that may arise with solar fencing, and suggestions on how to address these problems:[95]

Problem 1: Solar Fence is not working

Possible Solutions

- **Test the energizer first:** Energizer is the key component in any electric fence which converts battery power output to high voltage pulse:
  - Turn off the energizer.
  - Disconnect the wires going to the fence and ground rod system (if installed).
  - Turn the energizer back ON.
  - Measure the voltage using a voltage tester.
- **Determine what is causing the problem:** the battery or the energizer – check if the battery is drained. If not, then check whether energizer has proper output through a voltage tester.
- **Problem with the fence:** If the fence is at fault, turn off the energizer, re-attach the wires to the energizer and turn it ON and look for situations which are reducing the voltage.

Problem 2: Electricity generation from solar PV is lower than expected.

Possible Solutions

- **Check if the solar panels are installed at the correct angle:** Ensure that the solar PV module is correctly mounted in the south direction at an angle of at a suitable angle based on geographic location of the site. A link to the calculator to find the most suitable tilt angle is provided in section 5.6.
- **Check if the system is dirty:** Performance issues are mostly caused by the accumulation of dirt, dust, pollen, leaves, and other debris. Dirt reduces module efficiency. Cleaning is an easy fix and should be done on a regular basis. If the dirt has hardened over certain sections of the solar PV module, use a soft broom to remove it.
- **Check if any module is damaged:** Modules can sustain small cracks and continue to function normally. However, in most cases, the cracks tend to grow larger over time, causing the performance to drop. When this occurs, the module should be replaced by the authorised service provider.

Problem 3: Power source is not working.

Possible Solutions

- Make sure the fence charge controller is on.
- Make sure the battery is plugged in, the connections are proper, and the battery is charged.

Problem 4: Voltage on the fence suddenly dropped to zero.

Possible Solution

- Ensure that the fence wires are not touching each other and the ground wire.

Problem 5: Fence voltage dropping over time.

Possible Solution

- Remove long grass, spider webs, collected water or ice that maybe have developed or collected over time along the fence.

5.6 Relevant Resources

NABARD's document on solar fencing - introduction, key components, usage etc

Troubleshooting for electric fence

Solar energizers basic troubleshooting (video)

Calculator for finding tilt angle for solar panel according to geographical location

Module 6:
Solar Fodder System

6.1 Introduction

A solar hydroponic fodder system uses water and solar power to grow fodder for livestock without soil.[96] Instead of soil, the plants, under controlled temperature and moisture, absorb their nutrients from water that is supplemented with necessary nutrients, including nitrogen, potassium, calcium, phosphorus, magnesium and sulphur.[97] With solar power, the plants are irrigated automatically, and less maintenance is needed. In these systems, plants grow extremely quickly. As a result, highly nutritious fodder can be harvested once every eight days with proper maintenance and upkeep.

Solar hydroponic fodder systems reduce the amount of land needed to grow fodder for livestock as this enables vertical farming and is modular in nature. Through these systems, farmers get access to nutritious fodder regularly, eliminating the need to purchase expensive fodder from the market. Solar hydroponic fodder systems produce fodder year-round, regardless of the season. They use up to 60% less water than normal agriculture.[98] With proper care, they operate almost entirely automatically, apart from regular harvesting and planting. They can be a valuable and cost saving asset for any rural household engaged in animal husbandry.

6.2 Key Components

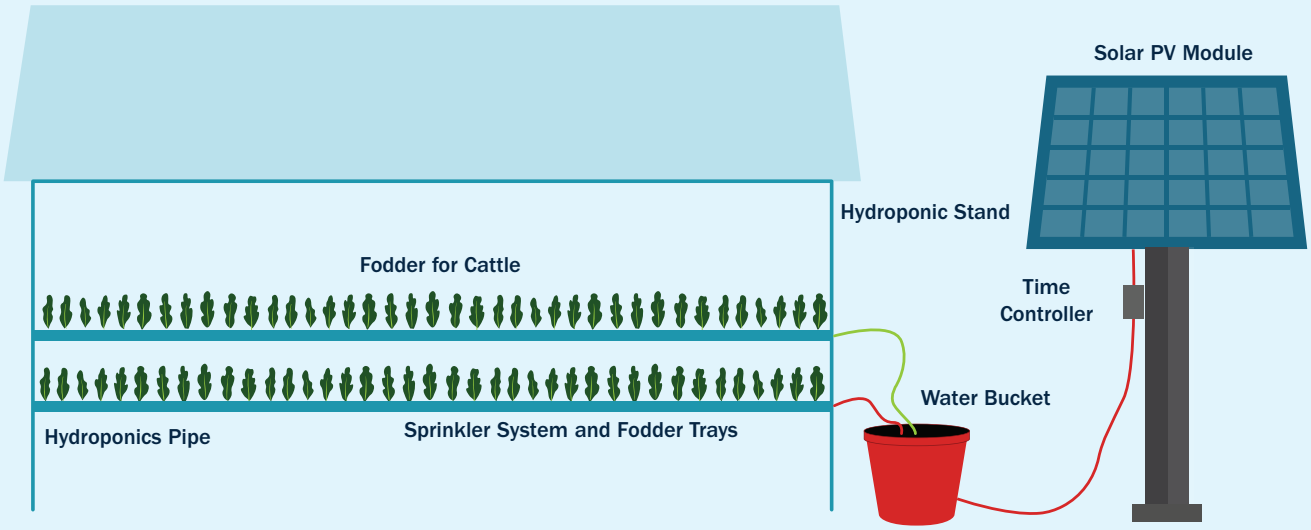


Figure 60: Schematic of a Solar Fodder System

Figure 61: Solar PV Module[99]

Solar PV Module

The Solar PV module absorbs light energy from the sun and uses it to generate an electric current to power the hydroponic system.

Computer containing Hardware Solution

(such as, Arduino or Raspberry Pi)

The computer ensures that the plant has an appropriate temperature, water sprinkling, and air flow. Arduino or Raspberry Pi are hardware solutions available for controlling temperature, moisture, and water in a solar hydroponic system.

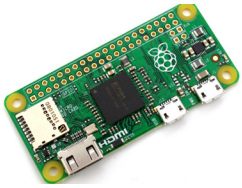


Figure 62: Computer, e.g., Arduino or Raspberry Pi[100]

Figure 63: Sprinkler System[101]

Sprinkler System

The sprinkler system provides adequate water to the plants.

Water Bucket

The water bucket stores water to sprinkle over the plants when required.

Figure 64: Water Bucket[102]

Figure 65: Hydroponic Stand[103]

Hydroponic Stand

The hydroponic stand is the overall structure of the system; it is available in different sizes depending on the requirement of the operator.

Fodder Trays

Fodder trays are used to build one or more levels/floors in the hydroponic system.

Figure 66: Fodder Trays[104]

Figure 67: Time Controller[105]

Time Controller

The time controller creates an ideal lighting schedule that keeps the lights on and turns them off at the right times.

Sand Filter

Sand filter prevents the clogging of small holes in drip tubes.

Figure 68: Sand Filter[106]

6.3 Installation/Usage

Key steps for using a solar fodder system are below:[107]

- Clean, wash, and dry the seeds.
- Soak the seeds for 24 hours.
- Germinate seeds in gunny sacks, sprinkling them with water every 2-3 hours.
- Load germinated seeds evenly in trays. Place trays in the hydroponic stand.
- Check trays every day to ensure that the if the seeds are watered.
- Harvest the fodder once ready – usually after 9-10 days, as specified by the technology supplier and clean trays before reuse.

6.4 Operations & Maintenance Guide

Most solar hydroponic systems for growing fodder are designed for use in villages and are easy to maintain. The most important cleaning tools are disinfectant solution, a jet cleaner pump, detergent solution, and a hard brush. A fungicide may be useful, if needed.

Key steps for operating and maintaining solar fodder systems are listed below:[108]

Tray cleaning

The trays must be cleaned regularly every time the all the fodder grown in a tray is removed.

- Start with cleaning solution or detergent and then rinse the tray with fresh water.
- Wipe the rinsed tray with clean cloth.

Figure 69: Cleaning Fodder Trays with Cleaning Solution (Source: Rashtriya Krishi Vikas Yojana)[109]

Chamber cleaning

The chamber for washing and soaking seeds, the aluminium stool, and the gunny bag must all be cleaned once before every soaking and germination cycle.

- Use the cleaning solution or detergent to clean the rinsed equipment.
- Rinse everything with freshwater.

Hydroponic structure cleaning

The hydroponic structure must be sterilized twice a month, to ensure that fungus and mold do not grow.

- Before sterilization, turn off the power supply.
- Take out all the trays.
- Use detergent and a hard brush to clean the inside of the hydroponic structure. Reach all surfaces of the structure including pipes and covers, to remove any seeds, dirt, algae, or fungal spores that could have grown inside the chamber due to humidity.
- With a jet cleaner pump (preferably, with a minimum pressure of 120-130 bar), if available, hose down the inside of the structure. Or else clean with a cleaning solution and a brush.
- Use a disinfectant to wipe down the rinsed surfaces.
- Return the trays to the structure and turn on the power.
- After sterilization, if you continue to notice fungal growth, fumigate the structure with 40% formalin or potassium permanganate.

Sand Filter Cleaning

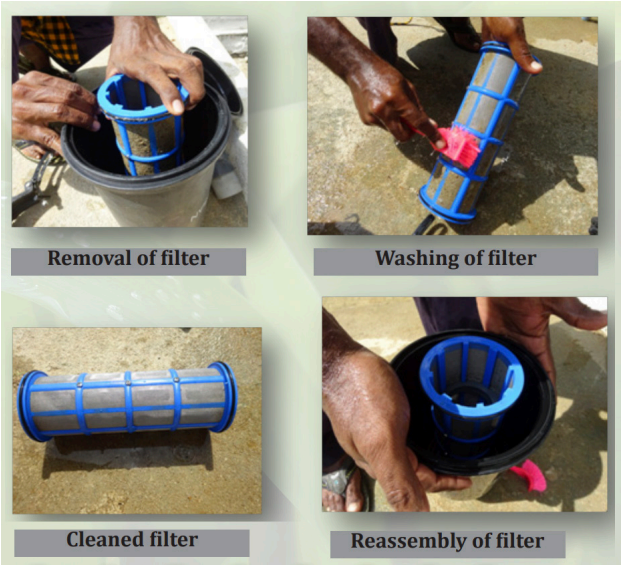


Figure 70: Sand Filter Cleaning Process (Source: Rashtriya Krishi Vikas Yojana) [110]

Daily maintenance practices relevant for large-scale hydroponic units are below:

- Place a foot bath at the unit entrance and fill it with disinfectant.
- Change the disinfectant in the foot bath every day.
- Have people follow separate paths for entering and exiting.
- Protect the unit and seed storage room from stray animals and rodents.
- Make sure everything is clean.
- Visitors should not enter the unit frequently.
- Disinfect the water tank every day with a disinfectant.
- Change the water in the water tank completely every 3 days. Let the water drain and wait for the tank to dry before filling it again.
- Clean the filter frequently (at least once a day).

Do's and Don'ts

Note 1: If sprouted seeds have fungal growth, do not sprout seeds in airtight chambers. Sprouts and mold grow in warm, humid environments.

6.5 Troubleshooting

The following are some of the most common problems to arise with solar fodder system, and suggestions for how to address these problems:

Problem 1: Poor germination

Possible Solutions

- Double check the seed quality.
- Buy fresh seeds as these seeds are preferred for hydroponics for better germination. Also, choose seeds with less waste and with unbroken tips.
- If possible, check the seed moisture content; it should have less than 12% moisture.[111]
- Double check the quality of the water.
- Make sure trays are not overloaded with seeds.
- Check for regular electricity supply from the solar PV modules.

Problem 2: Fungal attack

Possible Solutions

- If possible, check the seeds for their fungal (aflatoxin) levels. Note that there are about 100 billion mould spores per ton of grain.[112]
- Check if the machine has fungal growth.
- Check if rainwater has leaked into the machine.
- Check the water tank for presence of any dirt, sediments, or fungi.
- Ensure the water tank and sprinklers are regularly cleaned.
- Ensure the structure is cleaned twice a month.
- Ensure all visitors and workers are disinfecting before entry.
- Ensure there is no water logging or water draining.
- Check for clogs in the sprinklers.

Problem 3: Bleaching of leaves

Possible Solutions

- Check for chlorine/chlorine levels in the water being sprinkled on the seeds.
- Use less chlorine to sanitize the water.

Problem 4: Drying of leaves

Possible Solution

- If you notice the leaves drying out, see if the cooling system or temperature is fluctuating.

Problem 5: Uneven pouring of water on plants

Possible Solution

- If water is not pouring evenly, look for clogging in the pipes and sprinklers.

Problem 6: Water stagnating inside filter

Possible Solution

- Ensure the filters are not clogged and are cleaned regularly.

Problem 7: Storage tank has bad water quality

Possible Solutions

- Regularly check and clean the water filters.

6.6 Relevant Resources

Solar power based hydroponics monitoring system

Common problems with hydroponics

Harvesting green fodder in extreme climate conditions (video)

Hydroponic Green Fodder Production – TANUVAS, NADP (document)

Module 7:
Solar Trap Light

7.1 Introduction

Solar trap lights are one of the safest solutions to protect crops from pests (especially flying nocturnal insects that are active during the night).[113] Solar trap lights provide a good alternative to pesticides that damage human and environmental health. They use a solar module to generate power for an ultraviolet light-emitting diode (LED) light, which turns on when the sensor detects that the sun has set. Pests flying at night get attracted to this light and then get trapped inside a collection tray which is filled with water.

Solar trap lights can control pests that are extremely damaging to crops, including rice, millets, vegetables, etc. As a result, solar trap lights save farmers money that would otherwise be spent on buying pesticides. They also stop harmful pesticides from entering the soil and protect the overall crop health. Moreover, because they use automatic sensors and solar power, the lights require almost no regular maintenance and largely work on their own.

7.2 Key Components

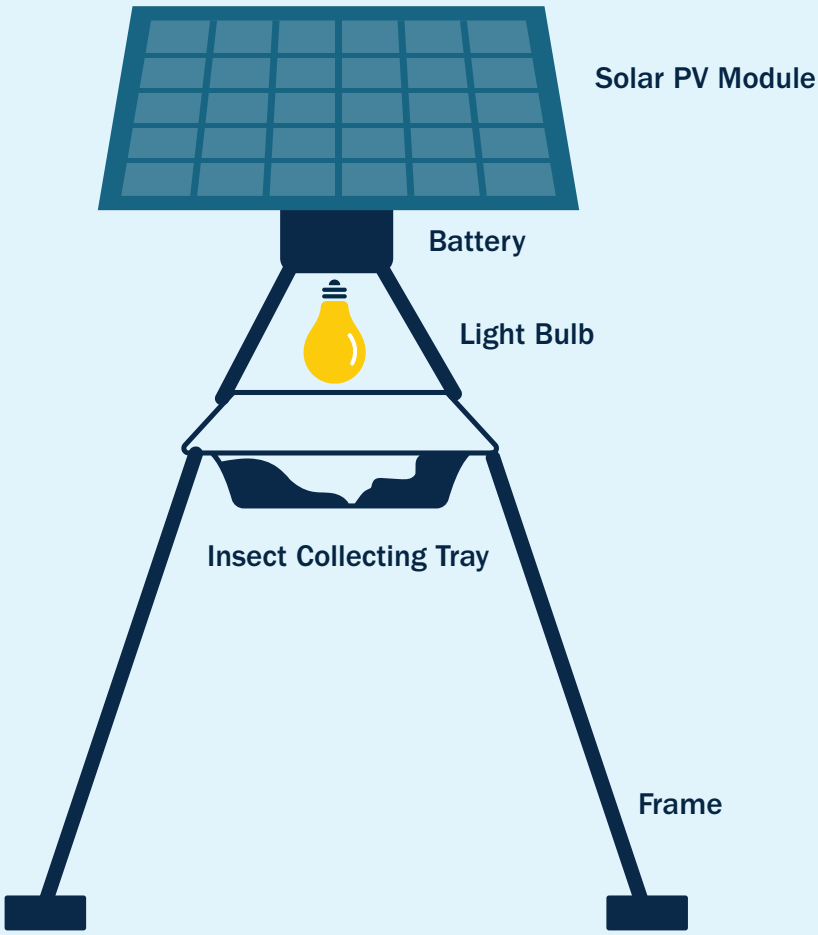
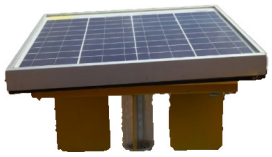


Figure 71: Schematic of a Solar Trap Light



Solar PV Module

Solar PV modules absorb light energy from the sun and use it to generate electric current.

Figure 72: Solar PV Modules[114]

Battery

The battery is used to store excess electricity generated by the solar PV modules. This stored energy can be used to electrify the LED bulb during non-generation periods such as nights or on cloudy days.

Figure 73: Battery[115]

LED Array or Light Bulb

The LED array is a series of ultraviolet lights that attracts insects towards it at night.

Figure 74: LED Array or Light Bulb[116]

Insect Collecting Tray

The insect collecting tray is usually filled water where all the trapped insects are collected.

Figure 75: Insect Collecting Tray [117]

Frame

The frame is adjustable in height and keeps the entire apparatus at a height sufficient to attract the pests most damaging to the crops.

Figure 76: Frame[118]

7.3 Installation/Usage

Installation of solar trap lights is very simple. The solar trap light does not need any electricity connection and can operate entirely on its own. To install a solar trap light, follow the instructions provided by the manufacturer.[119]

- Set the height of the trap light frame according to the type of crop the solar trap light will be supporting. It is recommended that the height of trap light be at least 60 cm above the crop.[120]
- Choose a location and position for the solar trap light such that it gets maximum sunlight during the day. Ensure that the solar trap light, especially the solar PV module, is not under any shade.[121]

Ensure that the angle of the solar PV module allows it to absorb the maximum amount of sunlight. For this, the solar PV module must face towards the south. Depending on the sun's path, it can be tilted by a few degrees to absorb maximum sunlight throughout the day. Note that during normal conditions, the solar PV module should be able to receive sunlight and charge for at least eight hours a day. Since the solar trap light depend on sunlight to power the LED light, their efficiency may vary during seasonal fluctuations such as monsoon or winter fog.

Figure 77: Solar Trap Lights Installed in a Field (Source: NRDC India and SEWA)

7.4 Operations & Maintenance Guide

Key steps for operating and maintaining solar trap lights are listed below.[122]

Operations

- Press the ON switch to turn on the solar PV module to start charging the battery. Now, the light should turn on automatically at night.
- Connect the solar PV module pin to the control box during the day. An LED indicator, if available, should light up if the unit is charging.
- Fill the collection tray up to the halfway mark with water. Add a little bit of soap powder or kerosene to the water to effectively trap the insects that land in the tray.
- Every day or two, depending on the number of insects, change the water in the collection tray.

Maintenance

When not in use, such as during the monsoon or winter season, the solar trap light should be stored carefully so that the technology stays operational. Ensure the switch is in the OFF position. Store the solar PV module carefully so its surface is not damaged.

If the solar trap light has been stored for more than a month, the battery might have discharged. The battery would need to be recharged before the solar trap light is ready for operation.

7.5 Troubleshooting

Problem 1: Light is malfunctioning.

Possible Solutions

- **Check if light is on:** Ensure the switch is in the ON position.
- **Check if solar PV module is working effectively:** Make sure the solar PV module's surface is clean so the battery can charge.
- **Check if battery is working:** Check that the LED in the battery for the solar PV module turns ON during the day to indicate that the battery is charging.
- **Check LED bulb for damage:** Call the technician or buy a new one.

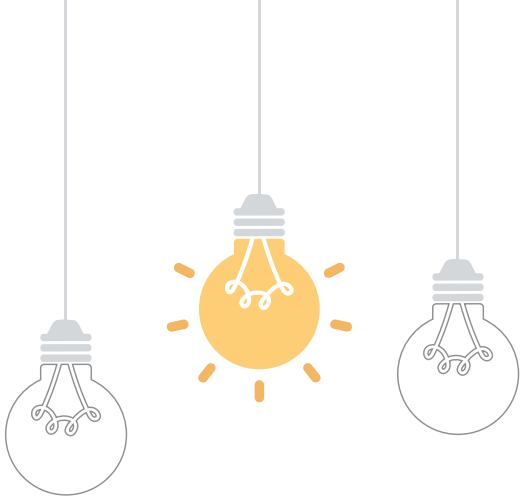
7.6 Relevant Resources

How to install solar insect trap in Hindi (video)

Design a solar light trap for control of field crop insects

Module 8:
Light-emitting diode Bulb

8.1 Introduction



Light-emitting diode (LED) bulbs are one of the most popular ways of saving energy for lighting. Compared to incandescent bulbs, LED lighting uses up to 90% less energy, resulting in substantial energy savings over a long period of time.[123] This also translates into direct consumer savings through lower electricity bills for users. In addition, LED bulbs can last up to more than 50,000 hours (5-10 years) which is almost 30 times longer than incandescent bulbs, thereby saving households the additional costs of purchasing new light bulbs every few weeks or months.[124]

8.2 Key Components

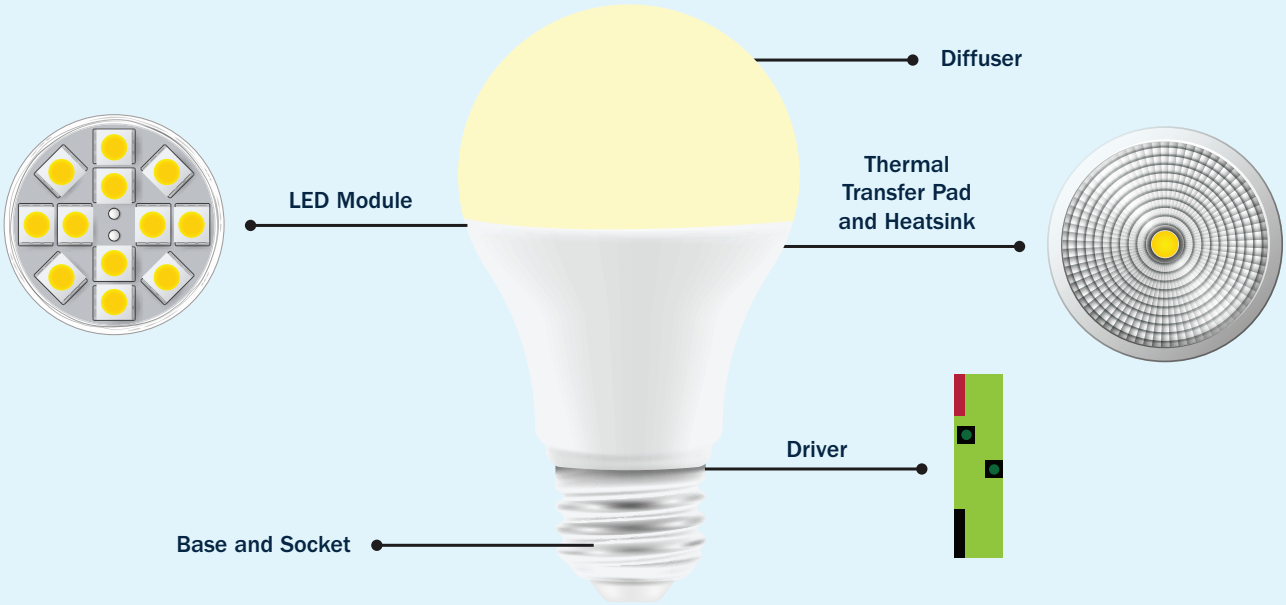


Figure 78: Schematic of a LED Light Bulb

Figure 79: Diffuser or Lens[125]

Diffuser or Lens

The diffuser or lens works to evenly spread the light generated and uniformly illuminate the area.

LED Module

The LED Module is what makes the light. It can either be made of single chips or multiple chips, depending on the kind of illumination.

Figure 80: LED Module[126]

Figure 81: Thermal Transfer Pad and Heat Sink[127]

Thermal Transfer Pad and Heat Sink

The thermal transfer pad and heat sink takes heat from the LED Module and moves it away into the open air to keep it at a functional temperature.

Driver

Driver is referred to as the “brain” of the bulb. This component takes energy from the electrical socket and sends instructions to LED module on what functions to perform like turning on and off. They also protect LED bulbs from voltage and current fluctuations.

Figure 82: Driver [128]

Figure 83: Base and Socket[129]

Base and Socket

The Base and Socket allow an LED Light Bulb to be installed in place of a non-energy efficient light bulb (for example, an incandescent bulb).

8.3 Installation/Usage

LED bulbs can be used in the same way as other kinds of light bulbs. The users can themselves install the LED bulb after ensuring that the socket is compatible with the bulb as per the instructions provided by the manufacturer. The light switch can be used to turn the LED bulb on or off.

8.4 Operations & Maintenance Guide

LED bulbs can last for a very long time with proper installation and maintenance, as mentioned below:[130]

Installation

- It is important to use the bulb with suitable ratings to meet the lighting needs. Table 8 provides the comparative information about the energy consumed by different type of bulbs providing the same light output.

Table 8: Energy Consumed by Different Type of Light Bulbs (Source: Viribright)[131]

S. No.	Lumens (Brightness)	Incandescent Bulb (watts)	CFL Bulb (watts)	LED Bulb (watts)
1	400-500	40W	8-12W	6-7W
2	650-850	60W	13-18W	7-10W
3	1000-1400	75W	18-22W	12-13W
4	1450-1700+	100W	23-30W	14-20W
5	2700+	150W	30-55W	25-28W

- Ensure the electricity supply provides a consistent current.
- Place your bulb in a place with low temperature and humidity.
- Place your bulb away from other bulbs to avoid overheating. Ensure there is proper ventilation around the bulb.
- Position your bulb in either an upwards or downwards position so that heat escapes readily. Do not cover the top of the bulb to avoid blocking the release of heat.
- Check the fixture or socket wattage rating before installing the LED bulb. It should not be lower than the LED bulb wattage.

Maintenance

- Check LED bulbs regularly for cracks or other kinds of wear and tear. Ensure there are no loose or exposed wires.
- Clean your LED bulb at regular intervals. Make sure the bulb is free of dirt and debris, both inside and outside the casing. A dirty LED bulb will have a shorter lifetime.
- Avoid turning LED bulbs on and off frequently to prevent a rush of current to the bulb.

8.5 Troubleshooting

The following are some of the most common problems to arise with LED bulbs, and suggestions for how to address these problems:

Problem 1: LED bulb is flickering, buzzing, or dim.

Possible Solutions

- **LED bulb is flickering:** Check the wattage. Ensure the socket is in good condition.
- **Bulb is making buzzing sound:** Make sure the LED bulb is receiving the correct voltage.
- **Dim light:** It is possible that the bulb may be approaching the end of its life. Get it checked by a technician to see if the bulb is repairable before discarding it.

Problem 2: LED bulb has stopped working.

Possible Solutions

- Ensure the socket is compatible with the LED bulb.
- Check the bulb for any short circuits.
- Make sure the bulb is receiving sufficient ventilation.

8.6 Relevant Resources

Repairing LED bulbs and addressing blinking problem (No audio script) *(video)*

Repair an LED bulb (No audio script) (video)

Module 9:
Brushless Direct Current Motor (BLDC) Fan

9.1 Introduction

Fans are essential to keep indoor temperatures manageable, and energy-efficient fans are an excellent way of reducing electricity usage and costs. Brushless Direct Current Motor (BLDC) fans are power-saving and energy-efficient fans. Their mechanism ensures that the electricity usage is low while meeting a room's cooling needs effectively. BLDC fans use less than half the energy compared to a normal fan, and it leads to lower electricity expenditure.[132]

9.2 Key components

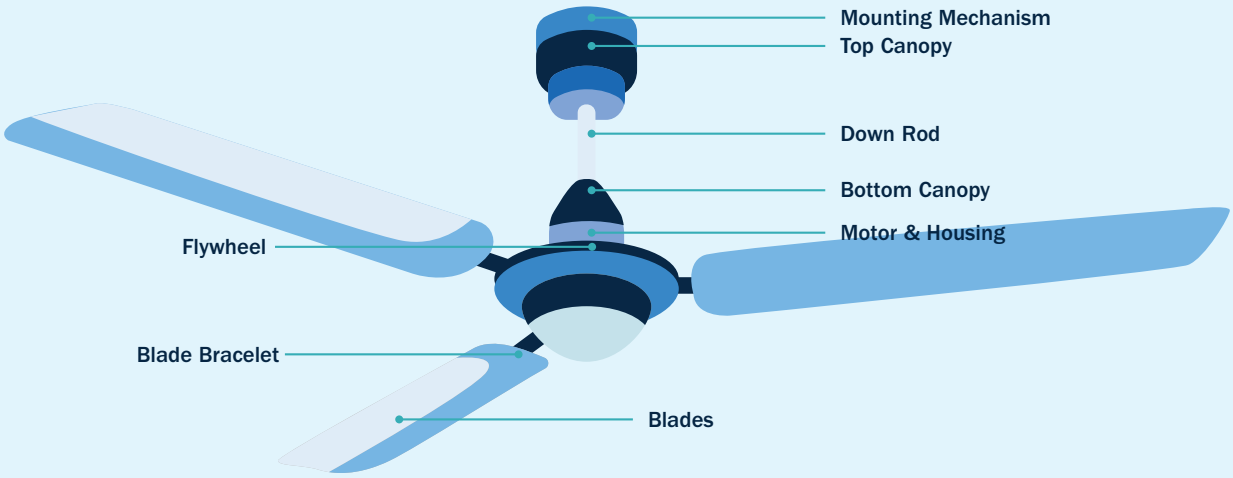


Figure 84: Schematic of a Ceiling Fan

Figure 85: Mounting bracket[133]

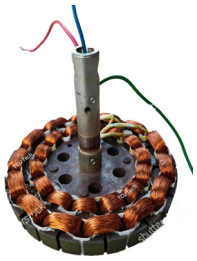
Mounting bracket, top and bottom canopy

The mounting bracket attaches the fan to the ceiling or its stand. The top and bottom canopy act as a cover that is attached to the mounting bracket and covers the wiring between the ceiling and fan.

Down rod

The down rod helps suspend the fan. One end connects to the mounting mechanism and the other connects to the motor and absorbs the vibrations from the fan's movement.

Figure 86: Down rod[134]



Motor and housing

The motor converts electricity into the movement of the fan's blades. A housing protects it from dust and debris.

Figure 87:Motor and housing[135]

Flywheel

The flywheel connects the fan blade bracket and the motor. The quality of flywheel is important as it ensures that the fan blades remain attached securely.

Figure 88: Flywheel[136]

Blade bracket and blades

The blade brackets and blades are attached to the fan by the flywheel, and it circulates the air.

Figure 89: Blade bracket and blades[137]

9.3 Installation/Usage

The technician or the users themselves can install the ceiling fan according to the instructions as per the user manual provided by the manufacturer. Use the fan as per the instructions from the manufacturer. Turn it on and off with the designated switch.

9.4 Operations & Maintenance Guide

- To maintain your fan, ensure you clean it regularly. Keep it free of dust and debris. While cleaning, use only a soft lint-free cloth or brush to avoid scratching the smooth paint finish. A moist cloth can be used to remove stains if any, but direct use of water must be avoided. Abrasive cleaning agents also need to be avoided to prevent any damage.
- In addition, periodically check the screws to make sure the blades and bracket are not loose. Tighten any screws as necessary.

For any other issues, call an electrician.

9.5 Troubleshooting

The following are some of the most common problems that may arise with BLDC fans, and suggestions on how to address these problems:[138]

Problem 1: Fan is not working.

Possible Solutions

- Check for blown fuses and change faulty fuse if needed.
- Check the wire connection and restore the connection, if broken.
- Check if the wall switch is working properly. If none of the above, call an electrician to handle frayed wires or to check the circuit-breaker for a tripped breaker, and reset the circuit breaker, if needed.

Problem 2: Fan is wobbling.

Possible Solutions

- Check if the ceiling surface is uneven. Make sure that the fan is hung on an even ceiling.
- Check if the down rod is mounted and secured properly.
- Look for loose screw and bolts and tighten them accordingly.
- Check if the blades are fixed in the reverse direction and accordingly set it right.
- Check for damaged and bent blades. Straighten yourself or replace if possible.
- Ensure ceiling fan is hung on outlet box rated for ceiling fans.

Problem 3: Fan is making a humming, squeaking, or buzzing sound.

Possible Solutions

- If the fan is new, wait 24 hours and check again.
- Make sure the blades are properly attached to the body.
- Make sure that the screws and nuts are securely fastened along with washer provided.
- Make sure that the canopy and the wire that connects the fan are not touching the body of the motor.
- Make sure that the canopy is not touching the ceiling.
- Check for obstructions in blade movement.
- If none the above, call an electrician or the service centre of the manufacturer for support.

9.6 Relevant Resources

Repairing BLDC fans *(video in Hindi)*

Installation of BLDC fan in English *(video)*

How to repair BLDC fan with local circuit board *(video in Hindi)*

How to repair BLDC fan circuits *(video in Hind)*

Website on common fan issues and solutions

Module 10:
Improved Pellet Cookstove

10.1 Introduction

An improved pellet cookstove burns pellets made from locally found raw material, such as babul tree, garden waste, corn cobs, etc. An improved cookstove provides a cleaner cooking alternative to traditional biomass cooking. In addition, they save user's money and time spent on procuring other fuels for cooking such as firewood, LPG, etc.

Pellet is a heating fuel made from recyclable biomass residues – generally sawmill residues and agricultural waste. They are small pieces and are environment-friendly and can be used in residential heating and cooking applications.[139] The pellets burn efficiently and are mostly smoke free. A tray at the bottom of the chamber collects ash after combustion. The ignition of pellets is quick and easy and helps in speeding up the cooking process. The combustion chamber is made of ceramic material for prolonged life. A forced draft fan with a fan controlling unit is employed to regulate the speed of the fan circulating the air for complete combustion.[140]

The process of manufacturing fuel pellets involves placing ground biomass under high pressure and forcing it through a round opening. They are generally a superior fuel when compared to their raw feedstock. Not only are these pellets more energy dense, but they are also easier to handle and can be used in automated feed systems. Pellet-based cookstoves offer smokeless operation and can be manufactured locally based on the available biomass residue.[141] Food is cooked by gasification of solid fuel pellets (initial ignition with the help of diesel/kerosene) and supply of forced draft air for complete combustion. Upon initial ignition, air flows from the bottom and causes combustion of fuel. Solid state fuel is directly converted into combustible gas which in the presence of air allowing complete combustion of fuel.[142]

Biomass-based pellets are manufactured from raw materials which include rice straw/husk, cotton husk, saw dust, coconut shell, corn cobs or any dry biomass.[143] One kg of pellet roughly requires 1.5 kg of raw materials to be processed. For a family size of four, an improved cookstove would require approximately 1.2 kg of pellets for cooking two meals a day and would support a cooking time of about two hours.[144]

10.2 Key Components

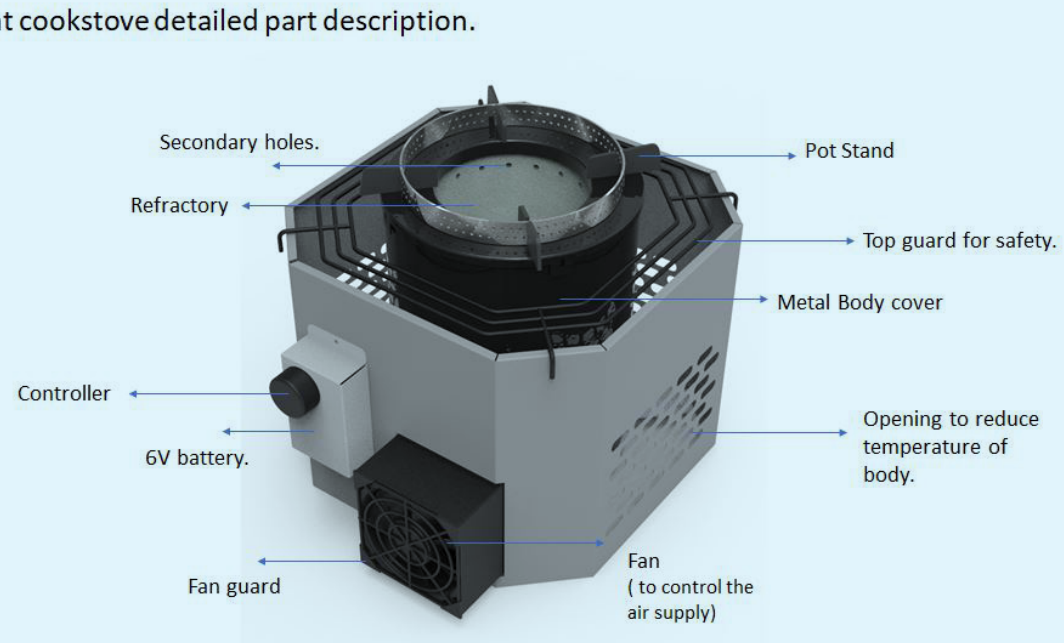


Figure 90: Schematic of Improved Cookstove (Source: Ecosense)[145]

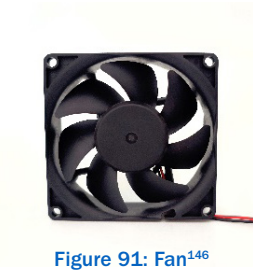


Figure 91: Fan[146]

Fan

The fan controls the inlet air supply required for combustion.

Fan Guard

The fan guards are used to provide a physical barrier around the spinning fan blades to prevent accidental contact with fingers or other objects. The fan guard is typically constructed using metal wire or plastic.

Figure 92: Fan Guard[147]

Figure 93: 6V Battery[148]

Battery

A 6V battery powers the electrical sub system of the cookstove including the fan. The battery has a backup that lasts up to 10 days and usually doesn't need any maintenance.

Controller

The controller regulates the flame intensity of the cookstove.

Figure 94: Controller[149]

Figure 95: Pot Stand[150]

Pot Stand

The pot stand is a metallic frame used to hold the vessel for cooking.

Secondary Holes

The secondary holes create the passage for supplementary air to help complete combustion of pellets.

Figure 96: Secondary Holes[151]

Figure 97: Refractory[152]

Refractory

It is a ceramic material that constitutes the entire combustion chamber

10.3 Installation/Usage

To install and use improved pellet cookstoves, follow these key steps:[153]

- To use your improved cookstove, pour pellets into the stove up to the level just below the secondary holes.
- Then, drizzle diesel or another liquid fuel to soak the pellets. Do not pour the fuel all in one place; instead, pour it in a circular motion to evenly cover the pellets.
- Use a matchstick to light the pellets and ensure that a few catch the flame.
- Now, switch on the fan with the controller. Ensure the controller starts in the low position at first. Wait for a few minutes until the flame stabilizes. Then you can start cooking.
- While cooking, use the controller knob to adjust the flame strength.

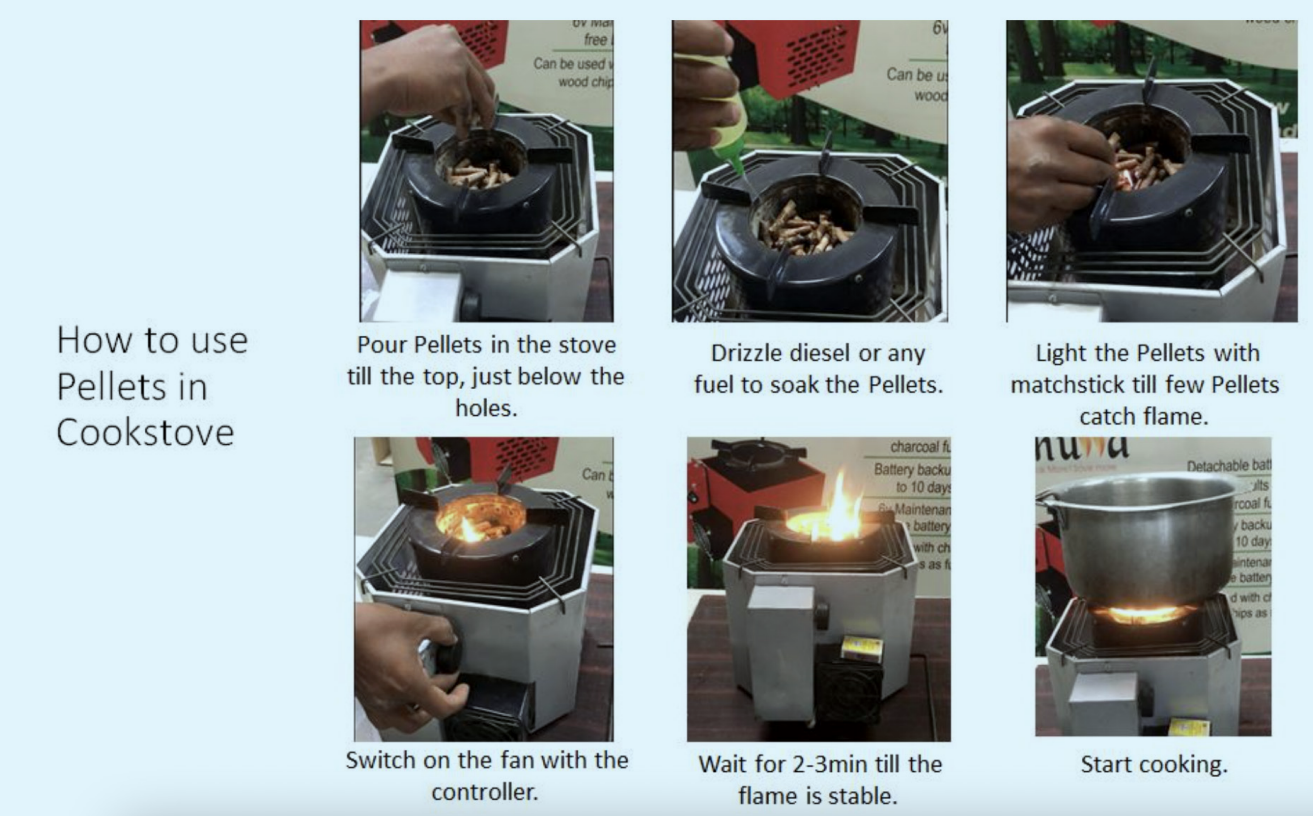


Figure 98: Process to Use Pellets in Cookstove (Source: Ecosense Appliances)[154]

10.4 Operations & Maintenance Guide

Once operational, an improved pellet cookstove has a regular, consistent flame (when the fan is on) which can be regulated with the controller.

Proper care after cooking will help ensure the improved cookstove lasts for a long time. After cooking, turn off the controller. After the stove cools down, remove the ash and charcoal (if used) and dump it in a safe place. Do not pour water inside the stove to extinguish the fire. After turning off the stove, wait for the stove to cool down and then use a damp cloth to clean the stove, if required.

10.5 Troubleshooting

The following are some of the most common problems to arise with improved pellet cookstoves, and suggestions for how to address these problems:[155]

Problem 1: Pellets are not burning properly while starting the stove

Possible Solutions

- Check the fan to make sure it is not dirty.
- Ensure no hoses are clogged and stove is clean.
- Look for any clogs caused by unburnt pellets.

Problem 2: Stove shuts down randomly

Possible Solutions

If the stove is clogged with dust, it may operate at high heat settings but will fail at lower ones. Clean the stove properly to address this concern.

- Ensure to clean the stove and remove any unburned pellets before the next use.
- Ensure that when you feed in new pellets, there are enough pieces of burning pellets which can act as an ignitor to reignite the fuel.
- Ensure pellets are of appropriate size compatible with the cookstove.
- Ensure secondary holes are clean and open.
- Make sure that the stove is airtight to control the amount of air that enters and exits the stove. Any leaks would cause the heat to dissipate and warm the ambient air.
- Ensure that the stove ventilation is working properly.

Problem 3: Stove does not shut off

Possible Solutions

- Check if the controller and battery are functioning properly or get it checked by an electrician, if necessary.

10.6 Relevant Resources

Ecosense appliances product description

Eco-65 pellet stove manual

Working of a pellet cookstove (video)

Pellet cookstove basic operations – Mini Moto stove (video)

Module 11:
Cool Roof

11.1 Introduction

Cool roofs are a simple and effective way of keeping houses cool, reducing energy usage, and making life more comfortable. Cool roofs have shown both health benefits and environmental benefits, as they increase thermal comfort and reduce dependence on electrified cooling appliances.[156] Cool roofs are an affordable climate change adaptation solution, especially for poor and vulnerable communities that have limited access to cooling appliances, as well as limited financial resources.

Cool roofs use materials with high reflectivity (materials that reflect rather than absorb incoming solar energy) and high emissivity (materials that effectively emit infrared rays/heat energy). As a result, the roofs retain less heat and reflect more sunlight. Cool roofs can keep indoor temperatures 1.5 to 5°C lower than conventional roofs, depending on the roof material as well as the cool roof technology used.[157]

While cool roofs can be made from a variety of materials, the most common solution is to apply white reflective paint to the surface of a roof. Other techniques include the installation of reflective light-coloured tiles on a flat roof, broken mosaic terracing by embedding broken glazed mosaic in wet mortar, traditional Indian method that involves cementing earthen pots upside-down onto roofs and green roofing by cultivating vegetation on rooftops. However, this module focuses solely on solar reflective paint technology.[158]

Cool roofs can create comfort and help protect inhabitants from heat stress.

In addition, cool roofs make roofs last longer and increase the overall lifespan of roofs and houses. By stopping roofs from heating up excessively, they prevent roofs from cracking due to heat expansion and shrinking.[159] Particularly in hot regions, cool roofs are an easy, cheap, sustainable strategy for clean energy and comfort.

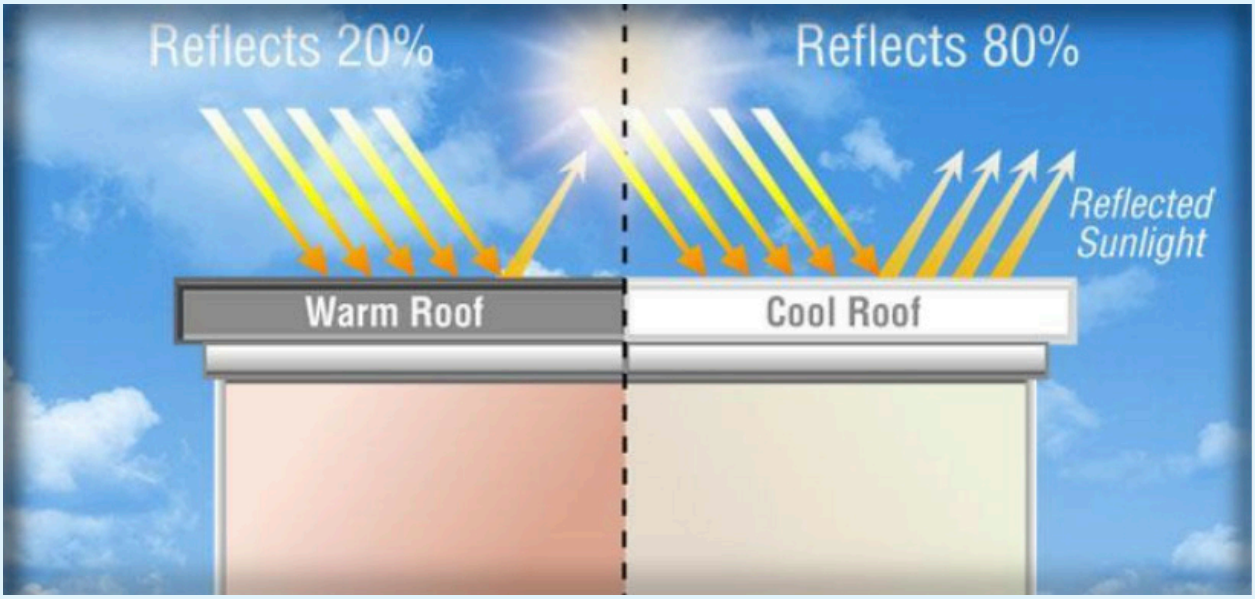


Figure 99: Schematic of Cool Roofs (Source: Exteriro Pro Roofing)[160]

11.2 Installation/Usage

- Though there are multiple technology solutions available for cool roofs, this section focuses on the strategy of using high reflectivity and high emissivity paint applied on the roof so that it retains less heat and reflects more sunlight. Before the application of the paint, it is important to clean the roof properly. Usually, two coats of this paint are applied on the roof and leaving the coating to dry in between two coats is also very important for good bonding. Table 9 indicates the amount of reflective paint required.

Table 9. Quantity of Paint Required for Different Roof Areas (Source: Lumincoat)[161]

S. No.	Roof Area (Sq. Ft)	Paint Required (kg)
1	500	25
2	750	37.5
3	1000	50
4	2500	125

11.3 Operations & Maintenance Guide

Common problems with cool roofs are cracks and plant growth that can damage the roof surface, and dirt accumulation that can reduce the effectiveness of cool roofs in reducing the ambient temperature.

Although cool roofs do not require special care, regular maintenance can help them last longer. A reapplication of paint is only required in every 7-10 years as it should be effective till then.[162]

Cool protective coatings can be reapplied every 7-10 years.

Key steps to maintaining cool roofs include:

- Inspecting cool roofs, especially at the beginning and end of each season, can help ensure their durability. Check for any cracks, plant growth, or anything else that might damage the roof structure.
- Pay attention to low-sloping areas where dirt can accumulate. Dirt accumulation can damage the endurance of cool roofs, so it is important to clean out dirt as frequently as possible.
- Clean regularly with a soft broom to avoid damaging the solar reflective paint coating.
- Avoid keeping scrap or heavy material on the roof. This could also damage the roof surface and reduce its effectiveness.
- Repair small damages in a timely manner as small issues can accumulate and reduce cooling effectiveness, over time.

Do's and Don'ts

Note 1: Ponding problems (when rainwater collects and stagnates on a roof) can happen when a roof has insufficient slope.

11.4 Troubleshooting

The following are some of the most common problems that may arise with cool roofs, and suggestions on how these problems can be addressed:

Problem 1: Condensation

In relatively cool climates where warm, humid air (generated through building occupancy and/or during construction) is present inside a building, it can sometimes lead to condensation of moisture on a cool roof.

Possible Solutions

- During occupancy, using fans and ventilation inside the building to circulate and mix cold air with warm air can also help prevent moist air from collecting[163].

Problem 2: Cool Roof is ineffective[164]

Possible Solution

Keep the cool roof surface clean and reflective. Remove the dirt and dust that accumulates over time, since dirty roofs may not be able to reflect the heat rays effectively.

11.5 Relevant Resources

PDF on House Owner's Guide to Alternate Roof Cooling Solution

What are Cool Roofs

Cool Roofs in Heat Action Plans

Concept of Cool Roofs (video)

Guidelines for Selecting Cool Roofs

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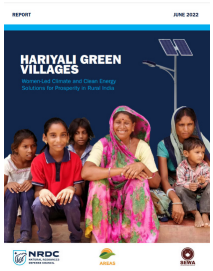
Highlighted Reports



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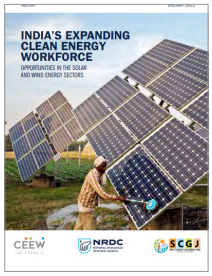

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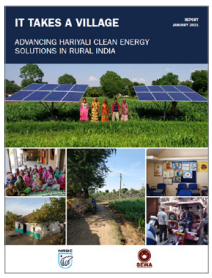

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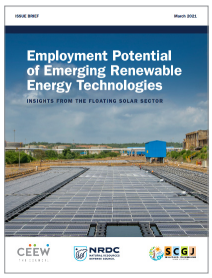

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