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Best practices in Solar Water Pumping

AURORE
Auroville Renewable Energy

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1. Introduction to solar power

From time immemorial, the sun has been the prime source of energy for all life on earth. The solar energy was being used directly for purposes like drying clothes, curing agricultural produce, preserving food articles, etc. Even today, the energy we derive from fuel-wood, petroleum, paraffin, hydroelectricity and even our food originates indirectly from the sun.

Solar energy is virtually inexhaustible. The total energy we receive from the sun far exceeds our energy demands. It is probably the most reliable form of energy available everywhere and to everyone, unlike other sources. With dwindling supplies of petroleum, gas and coal, tapping solar energy is a logical and necessary course of action.

1.1 Solar Power

Put most simply, Solar Power is a way of converting sunlight into a useful energy source. There are two ways of using solar energy; as heat and as electricity. Devices like solar water heaters, driers and solar cookers use the heat to produce hot water, to dry grains or to cook food respectively. This way of using solar energy is called solar thermal. On the other hand, solar panels use the light to produce electricity, which can then be used for a multitude of purposes.

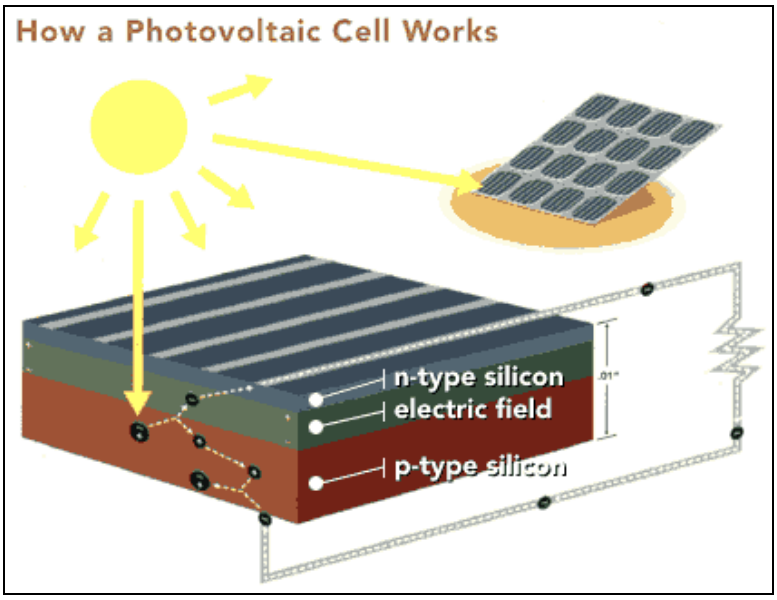
Here are the main advantages of solar energy.

- One of the cleanest forms of energy.
- Harmonious with nature.
- Easy to install, operate and maintain.
- Long life. Solar panels can last up to 20 years or more.
- Modular design, hence easy to expand.
- Ideal for remote areas, where electricity is not reliable and diesel is difficult to obtain.
- Safe to handle. Once installed properly, most devices can be used by laymen without risk.
- Freedom from grid, which is often unreliable especially in remote areas.
- Can be used as stand alone or grid connected systems as well as with other energy sources as hybrid systems.

1.2 Photovoltaic cells (PV)

Photovoltaic cells are devices which ‘collect’ the light and convert it into electricity. The cells are wired in series, sealed between sheets of glass or plastic, and supported inside a metal frame. These frames are called solar modules or panels. They are used to power a variety of applications ranging from calculators and wrist-watches to complete home systems and large power plants.

PV cells are made of thin silicon wafers; a semi-conducting material similar to that used in computer chips. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the “photovoltaic effect”.



1.2.1 Types

Two primary types of PV technologies available commercially are crystalline silicon and thin film.

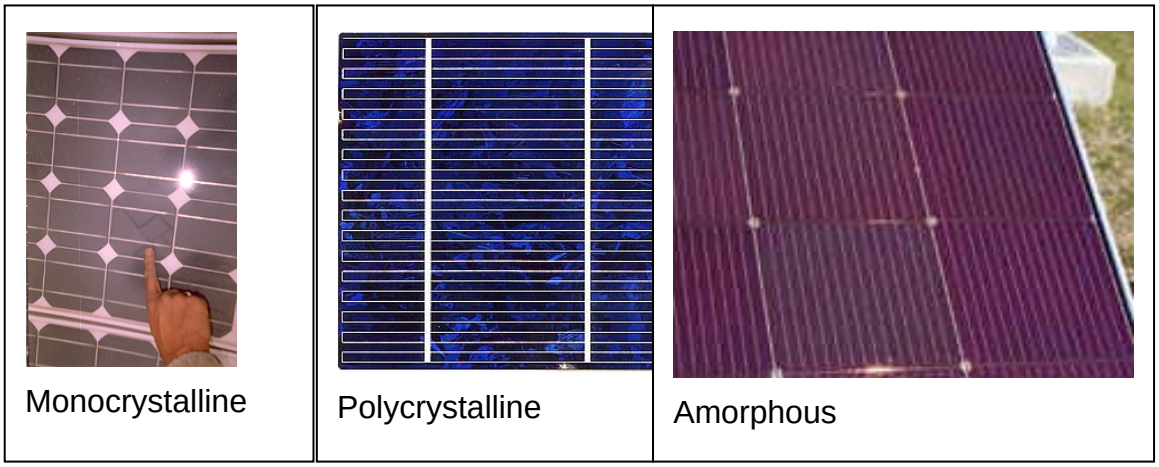


Diagram showing the three types of photovoltaic cells

Crystalline

Crystalline technologies are currently predominant in the market. There are two types of crystalline technologies, monocrystalline and polycrystalline. Monocrystalline cells are cut from large single crystals or from cylindrical blocks (ingots) of crystalline silicon. They are more efficient (12-16%) but more costly. The polycrystalline cells, as the name suggests, are produced from square blocks (cast ingots) of polycrystalline silicon. They have slightly lower efficiency (11-13%), but are less costly.

Thin film

In thin film PV technologies, the PV material is deposited on glass or thin metal that mechanically supports the cell or module. Thin film based modules are produced in sheets that are sized for specified electrical outputs. They are much less efficient (5-8%) and therefore take larger area. However, they are much cheaper than crystalline modules. These modules degrade over time, and sometimes may lose about 20% of their production capacity.

Note: It must be noted that lower efficiency of thin film technology does not mean lower performance. It only means that it needs a larger area for producing the same amount of electricity as compared to crystalline technologies.

1.2.2 Electrical output

PV modules are manufactured with varying electrical outputs ranging from a few watts to more than 150 watts of direct current (DC) electricity. The most popular panel sizes in India are 35 Wp and 75 Wp. The modules can be connected into PV arrays for powering a wide variety of electrical equipment. However, the actual amount of energy produced by a solar module depends upon many factors, like quality of the module, maintenance, season, cloud cover, dust, etc.

1.2.3 Common terms

- Solar Insolation: the amount of sunlight falling on the surface of the earth on a specified area in a given period of time. It is measured in kilowatt hours per square metre per day (KWh/m^2/day).
- Watt: the unit of measuring the power i.e. the rate at which energy is supplied.
- Watt peak (Wp): measures the capacity of the panel. It is the maximum amount of power the solar panel can produce under standard test conditions. It is called the rated power of the solar panel.
- Peak sunshine hours: the equivalent number of hours each day when the intensity of sunshine over one square meter is enough theoretically to produce 1000 watts of energy. For India, the average is 5.5 hrs.

1.2.4 PV cell performance

The performance of a PV cell is measured in terms of its efficiency at turning sunlight into electricity. Only sunlight of certain energies will work efficiently to create electricity, and most of it is reflected or absorbed by the material that makes up the cell. Because of this, a typical commercial PV cell has an efficiency of 10-16%. This means that about one-eighth of the sunlight striking the cell generates electricity.

Solar panels work on light, not heat. So, as long as there is some light, even if it's cloudy, the cells continue producing a certain amount of electricity. The amount of electricity produced however varies significantly and is lower during rainy days.

1.3 PV applications

Solar panels are used in a variety of applications. The applications vary from small simple lanterns to large elaborate power plants.

- Rural and urban households for domestic purposes like lighting.
- Communities, small industries and institutions like schools, for lighting as well as for powering television sets, computers, etc.
- Water pumping systems.
- Telecommunications, as these systems are often installed in isolated places with no other access to power.
- Health centre vaccine refrigeration in rural areas. Such solar refrigerators are also utilised to store blood plasma. WHO supports programmes that install solar power for medical purposes.

- Power plants for larger areas.

		
Matrimandir Power Plant 36 KWp	Roof Installation Verite Community	Solar Pumping installation in Punjab

Different types of solar installations

Out of all these applications, however, this manual concentrates exclusively on solar pumping, which is explained in detail in further chapters.

2. Aurore, the organisation

Aurore has been working in the field of renewable energy for more than 15 years. It specialises in solar photovoltaic (PV) system integration and installation. The systems installed include solar power packs, solar pumping systems, home lighting systems, solar power plants and solar water heaters in various states like Andaman and Nicobar, Tamil Nadu, Pondicherry, Karnataka, Kerala, Orissa, Jammu & Kashmir, Punjab and Gujarat. Aurore has an arrangement with leading PV panel manufacturers to integrate systems and distribute solar PV pumps, solar home power packs and solar power plants.

2.1 Four-fold strategy

Aurore Projects and Services is a renewable energy service providing agency. It aims at progressively introducing renewable energy systems in India by interacting with product manufacturers, lease companies, subsidy givers and end-users. The following four-fold strategy is used to realise these goals.

- Develop into an Energy Service Provider (ESCO) to provide reliable energy supply for rural as well as urban end users. Facilitate setting up similar ESCOs in India.
- Act as a system integrator and installer, providing high quality renewable energy systems to rural and urban populations in developing countries.
- Provide innovative financial solutions to mitigate high-entry cost barrier of renewable technologies.
- Operate as a maintenance & service company, providing proper and prompt maintenance service as well as advice to end-users.

2.2 High quality standards

Aurore and CSR have combined more than 15 years of experience in the field of renewable energy. Aurore specialises in solar PV system integration and installation, and endeavours to supply these systems and services to high quality standards, realising that only this will guarantee sustainable, reliable and long-lasting operation of such systems.

In addition to this, training of the end-user and long-term service and maintenance provision are both seen as an essential part of the successful implementation of renewable energy systems.

More recently, realising the importance of long-term sustainable operation of solar PV systems, Aurore has been actively exploring ways to become an energy service provider rather than just a system integration and installation company.

2.3 Services

Aurore offers the following services to its institutional and private clients:

- Setting up of Energy Service Providers (ESCOs)
- Programme and project management
- Financial facilitation
- System integration, installation and commissioning
- Post installation maintenance services
- Project identification & feasibility studies
- Managerial and technical training

Aurore has played this role for many years now, and has the skills, experience and contacts to help you find solutions for your energy needs in a sustainable and reliable way.

2.4 Projects completed

Since 1992 Aurore, through the Auroville's Centre for Scientific Research (CSR), has been closely collaborating with IREDA, the Indian Renewable Energy Development Agency, for implementation of several renewable energy projects.

- Around 200 Solar Home Systems
- 36.3 KWp Matrimandir Solar Power Plant in 1997
- Around 650 solar PV pumping systems all around India
- Solar home lighting systems in Ladakh

2.5 Financing the solar system

The most important factor that is holding back solar technology is its high initial cost, especially when compared to highly subsidised grid electricity. To change this situation, some form of support is necessary to encourage this technology.

Fortunately, the Government of India has taken many steps to reduce the end price of various renewable energy technologies, including solar. Indian Renewable Energy Development Agency (IREDA) and Ministry of Non-conventional Energy Sources (MNES) are the responsible agencies for this purpose.

2.5.1 Ministry of Non-conventional Energy Sources (MNES)

The Ministry of Non-conventional Energy Sources covers the entire renewable energy sector, namely Solar, Wind, Hydro, Biomass, Geothermal and Tidal Energy sources. The function of the Ministry is to promote the renewable energy sector in India. The other prime functions of the Ministry include research & development of various renewable sources of energy as well as the promotion and subsidy programmes related to them.

2.5.2 Indian Renewable Energy Development Agency Ltd. (IREDA)

IREDA is a Public Limited Government Company established in 1987, under the administrative control of MNES, to promote, develop and extend financial assistance for renewable energy and energy efficiency/conservation projects. IREDA has evolved into a good, active, financially sound and innovative Financial Development Agency for the Indian renewable energy sector.

Solar installation in Aurore (CSR complex)

It's a win-win situation for all involved. The farmer gets a pump below the cost he would pay otherwise; the manufacturers have the benefit of fairly large orders; the lease company has the advantages of subsidies, soft loans and income tax benefits; the government fulfils its policy; and for Aurore, there is the satisfaction that renewable energy is spreading all over India, with solar pumps installed from Kanyakumari in the south to Midnapur in West Bengal, to earthquake ravaged Bhuj in Gurajat, and to Firozepur on the border with Pakistan.

2.6 Contacting Aurore

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3. Solar pumping

3.1 Introduction

Unlike conventional diesel or electrical pumps, solar pumps are powered by an array of solar panels. Solar pumps are designed to operate on DC power produced by solar panels. These pumps are gaining popularity all over the world wherever electricity is either unavailable or unreliable. Solar pumps are becoming a preferred choice in remote locations to replace diesel pumps. In such places, solar pumps are even viable economically in comparison to extension of grid or running the pump on diesel.

3.2 Advantages

Along with the environmental advantages of solar power, solar pumps offer many other advantages as well.

- **Low operating cost:** One of the important advantages is the negligible operating cost of the pump. Since there is no fuel required for the pump like electricity or diesel, the operating cost is minimal.
- **Low maintenance:** A well-designed solar system requires little maintenance beyond cleaning of the panels once a week. Aurore provides the post-installation service through trained technicians for every cluster, so that the farmers don't need to worry about availability of spares or other related problems.
- **Harmonious with nature:** Another important advantage is that it gives maximum water output when it is most needed i.e. in hot and dry months. Slow solar pumping allows us to utilize low-yield water sources.

The combined installation in Vikas community

- **Flexibility**: The panels need not be right beside the well. They can be anywhere up to 20 meters/ 60 feet away from the well, or anywhere you need the water. So, it offers freedom regarding the placement of panels.
- These pumps can also be turned on and off as per the requirement, provided the period between two operations is more than 30 seconds.

3.3 Limitations

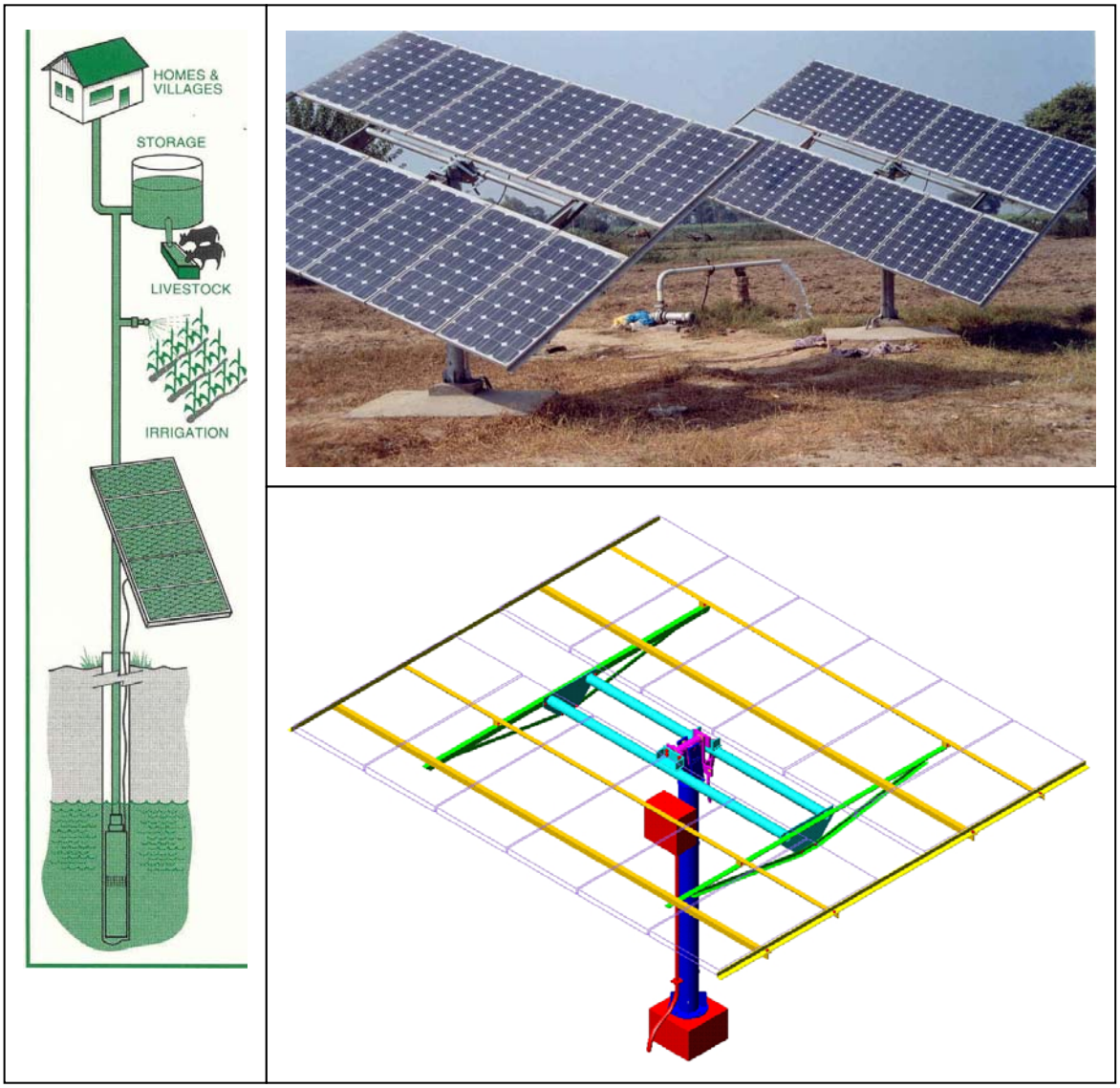
- **Low yield:** Solar pumping is not suitable where the requirement is very high. The maximum capacity available with solar is 2 HP. However, the output of the 2 HP pump is equivalent to a normal pump of 4 HP.
- **Variable yield:** The water yield of the solar pump changes according to the sunlight. It is highest around noon and least in the early morning and evening. This variability should be taken into consideration while planning the irrigation.
- **Dry operation:** The submersible pump has an in-built protection against dry run. However, the surface pumps are very sensitive to dry run. A dry run of 15 minutes or more can cause considerable damage to a surface pump.
- **Water quality:** As with any other pump, solar pumps work best if the water is clean, devoid of sand or mud. However, if the water is not so clean, it is advisable to clean the well before installation or use a good filter at the end of the immersed pipe.
- **Theft:** Theft of solar panels can be a problem in some areas. So the farmers need to take necessary precautions. Ideally, the solar system should insured against theft as well as natural hazards like lightning.

3.4 Understanding the system

3.4.1 System components

The whole system of solar pumping includes the panels, support structure with tracking mechanism, electronic parts for regulation, cables, pipes and the pump itself.

- **Solar panels or modules:** Solar panels are the main components used for driving the solar pump. Several solar panels connected together in arrays produce DC electricity. Interconnections are made using series or parallel combinations to achieve desired voltage and power for the pump.
- **Solar pump:** Centrifugal or submersible pumps are connected directly to the solar array using DC power produced by the solar panels. Solar pumps are available in several capacities depending upon the requirement of water.
- **Support structure and tracking mechanism:** Support structure provides stability to the mounted solar panels and protects them from theft or natural calamities. To obtain maximum output of water, a manual tracking device is fixed to the support structure. Tracking increases the output of water by allowing the panels to face the sun as it moves across the sky.
- **Foundations** (array and pump)**:** Foundations are provided for support structures and pump.
- **Electrical interconnections:** A set of cables of appropriate size, junction boxes, connectors and switches are provided along with the installation.
- **Earthing kit:** Earthing kit is provided for safety in case of lightning or short circuit.
- **Plumbing:** Pipes and fittings required to connect the pump come as part of the installation.



Diagrammatic representation of solar pumping system

All the components apart from the pump and panels are called ‘balance of system’. It is necessary to choose these components carefully according to requirements and field conditions so as to make the best use of the system. It must be kept in mind that unlike electricity grid, the solar system provides limited energy. So, solar pumping systems must be managed so that the energy collected by the solar cell module balances the amount of electricity used by the pump.

3.5 Types of pumps

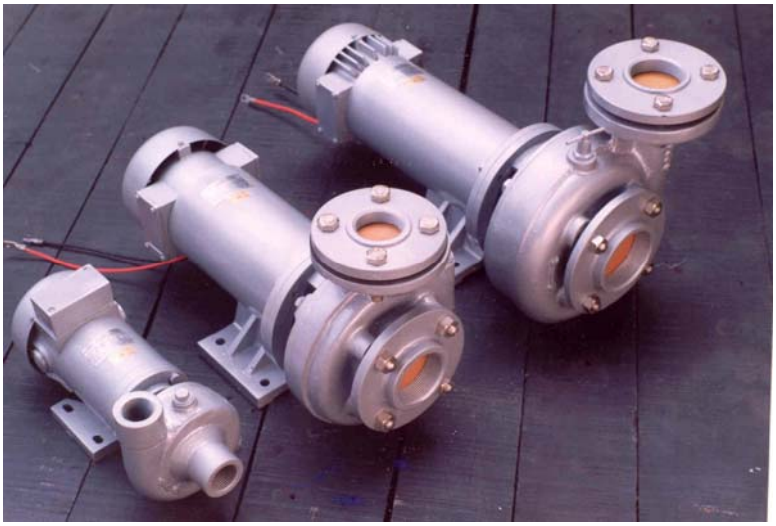
3.5.1 Surface centrifugal pump: Surface pumps are suitable for areas were the water level is within 7 m below ground level. A surface or centrifugal pump is normally placed at ground level. The pump is suitable for pumping from shallow bore wells, open wells, reservoirs, lakes & canals. The solar pump driven by a permanent DC motor is connected directly to an array of solar panels. The pump has a total dynamic head (suction plus delivery) of 14 m. The maximum suction head is 7 m. or 22 feet. The pump will not work if the water table is below 7 m depth.

It is possible to increase the delivery head if the suction head is less than 7m. This enables one to pump water even from deep wells, by installing the pump inside the well; called ‘cut-down’.

Cut down

Specifications

These pumps are designed for high flow rates and low heads. The permanent magnet DC motor driving the surface pump is powered by a matching solar array to maximise efficiency. An enclosed impeller design ensures smooth operation. Made of cast iron, these pumps are finished with anti-corrosive primer, followed by silver coloured polyurethane paint**.**



MODEL	AV-900 RM	AV-1800 RM
Array Capacity	900 Wp	1800 Wp
Solar Panel Size	75 Wp	75 Wp
Solar modules TBP 1275, 75 Wp	12	24
Support Structure	1	2
Pump Capacity	1 hp	2 hp
Maximum total head	14 m.	14 m.
Maximum suction head	7 m.	7 m.
Water discharge size	52 mm	65mm
Water Output @ 10 m head	75,000 lit/day*	1,40,000 lit/day*
Array junction box	1 No.	1 No.
Installation kit	1 Set	1 Set
User manual	1 No.	1 No.
2” HDPE Pipe	10 m	10 m

System performance

India receives average solar radiation of 5.5 kWh/m^2. Therefore, the performance values are based on this average.

Total dynamic head (m)	Water output (lit/day)	
	900 Wp	1800 Wp
6	1,10,000	1,43,000
8	1,04,500	1,37,500
10	75,000	1,21,000
14	68,750	1,10,000

3.5.2 Submersible pump

A submersible pump is one that is immersed in water. It pumps water by displacement. Submersible pumps are suited both to deep well and to surface water sources. Most deep wells use submersible pumps. These pumps are costlier but have a longer life and greater reliability than surface pumps.

Specifications

These pumps are designed for high head and medium flow applications. They multi-stage pump and high efficiency micro-computer based inverter. The inverter optimises the power input and thus enhances the overall system efficiency.

MODEL	AV-1200 GF	AV-1800 GF
Array Capacity	1200 Wp	1800 Wp
Solar Panel Size	75 Wp	75 Wp
No. of Solar Panels	16	24
Support Structure	1	2
Pump Capacity	0.75 hp	0.75 hp
Maximum total head	50 m	50 m
Water Discharge size	40 mm	40 mm
Water Output @ 30 m head	29,000 lit/day*	39,000 lit/day*
Array Tracking Structure	1 No.	1 No.
Array junction box	2 Nos.	2 Nos.
Installation kit	1 Set	1 Set
User manual	1 No.	1 No.
2” HDPE Pipe	50 m	50 m

System performance

Total dynamic Head (m)	Water output (lit/day)	
	1200 Wp	1800 Wp
7	55000	72000
10	50000	67000
25	30000	47000
30	29,000	39,000
50	7000	20000

3.6 Lifespan of the system

The solar panels are sturdy, made to face harsh environmental conditions. They are so reliable that most manufacturers give a 10-year warranty, with life expectancy beyond 20 years. A solar pump has an overall guaranty of 2 years from the date of installation. Spares are provided at the time of installation for maintenance of 3 years. If the pump is well maintained then it can run efficiently for up to 12 to 14 years.

However, the exact life span of the pump varies from model to model. Life-time of pumps is hard to specify. The submersible pumps usually last a long time, since they are made of stainless steel. However, when there is a lot of sand in the water the moving parts will wear out quickly, reducing the life of pump.

The surface pumps are made of much less hi-tech materials (cast-iron and MS steel) and rust a lot. But again, parts can be replaced, and by doing so the life-time of the pump can be extended almost indefinitely.

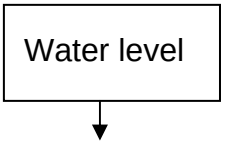
There is a difference between physical life-time and economical life-time. At some point the repairs become so costly, that replacing the pump is more economical. This economical life-time varies depending upon the field conditions and maintenance.

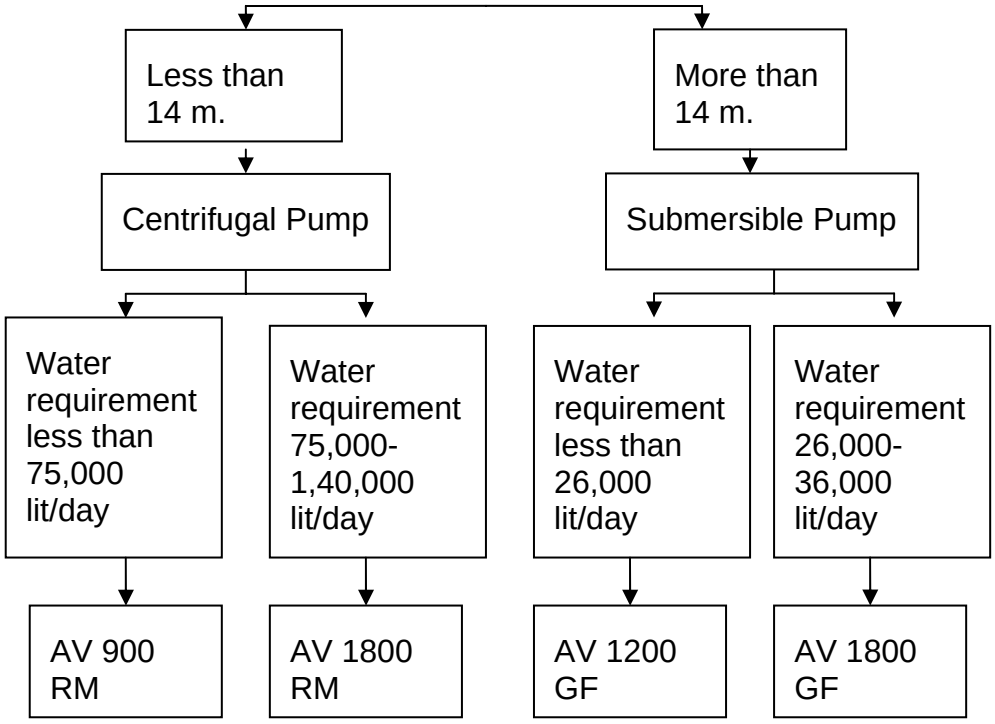
3.7 Choice of pump

Solar pumps are available in different capacities. The surface pumps can be used to lift water from a maximum depth of up to 7m. Sometimes, the pump can be installed inside the well up to 10 m deep. For wells deeper than that, a submersible pump is more advisable.

The choice of solar pump depends on the quantity of water required & the depth at which water is available. Please determine the water requirement and depth of water in your area and consult the diagram below to choose the right solar pump for your need.

To design a system, however, it is necessary to view the whole picture and consider all the resources. So, the final installation must be based on a thorough site study by the experts.




Less than 14 m.
More than 14 m.
Centrifugal Pump
Submersible Pump
Water requirement less than 75,000 lit/day
Water requirement 75,000-1,40,000 lit/day
Water requirement less than 26,000 lit/day
Water requirement 26,000-36,000 lit/day
AV 900 RM
AV 1800 RM
AV 1200 GF
AV 1800 GF

4. Operation and maintenance

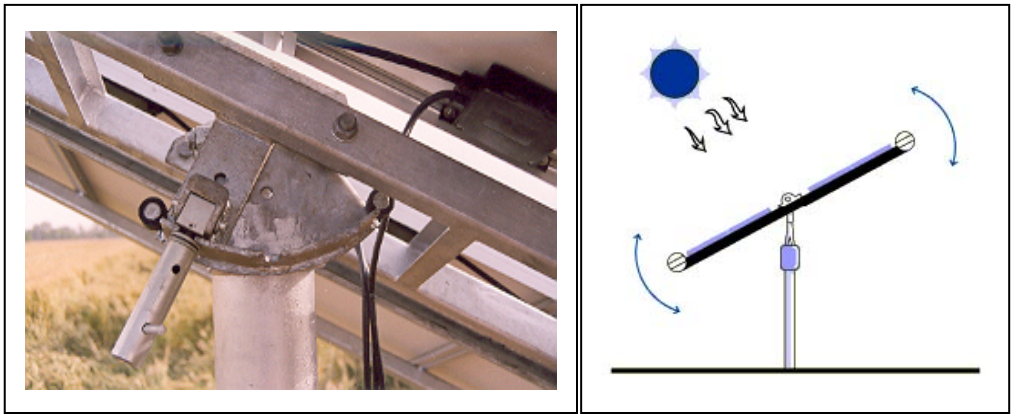
4.1 Operation

Following are some of the important aspects in day to day operation of solar pumping system.

4.1.1 Tracking

Sunlight is the fuel of solar panels. So, more exposure of the solar panels to sunlight means higher energy yield, more efficiency and more water output of the pumping system.

Tracking is a means of achieving the maximum possible exposure. It is a mechanism for moving the panels as the sun moves across the sky.



Tracking mechanisms can be manual or automatic. Though the automatic trackers give much more output, they are very costly. So, manual tracking is usually preferred in India. Tracking can be done daily as well as seasonally. Since the position of the sun changes considerably in winter and summer, seasonal tracking can increase the output by as much as 20%. The tracking mechanism has in-built adjustments suitable for a particular location. The operational instructions are as follows:

Daily sun-tracking: It is an important part of the operation for maximising water output. It is provided to follow the path of the sun throughout the day from sunrise to sunset from east to west. The support structure has provision for tracking in 3 positions:

- Morning: At sunrise the panels should be facing east.
- Mid-day: At noon the panels should be horizontal.
- Afternoon: During the afternoon the panels should be facing west.

Seasonal tracking: It is provided to adjust to the seasonal variations in the path of the sun from north to south. In India, the panels should be facing south. The tilt angle towards the south depends upon the latitude. Seasonal adjustment is done twice a year, for summer (April) and for winter (October). South facing tilt angle should be adjusted as follows:

- Summer position: latitude -15^0
- Winter position: latitude $+15^0$

For example, Punjab is at 30^0 latitude. So, the tilt angle will be 15^0 during summer months and 45^0 during winter months.

Precautions:

- In case of strong thunderstorm or dust storm change the angle to 0 degrees. The array should be moved SLOWLY, when changing its position.
- If it is not possible to tilt the panels every day, they should be fixed in the middle position.

Advantages:

There are many advantages of the tracking mechanism.

More energy yield: The manual tracking improves efficiency by as much as 20-30%, while automatic tracking can often increase the efficiency by more than 50%. By causing the pump to run at full speed through a whole sunny day, tracking can often DOUBLE the daily water yield.

Low cost: The tracking decision is a handy variable in the design process. Often you find a system that produces a little bit less than is needed, but the next larger system costs much more. In such cases, tracking is a low-cost means to increase the yield of the smaller system.

Optimum water output: For solar pumping, tracking offers even greater gains and benefits that can greatly reduce the system costs. It gives optimum yield during the peak watering season when the most water is needed - during long sunny days of the growing season.

Prevention of pump stalling: Tracking also helps in prevention of pump stalling. Many solar pumps experience a disproportionate drop in performance when the sun is at a low angle (early morning and late afternoon). When the PV array output is less than 50%, a centrifugal pump may produce insufficient centrifugal force to achieve the required lift.

4.1.2 Storage

Most systems use water storage rather than batteries, for simplicity and economy. Storage is important, especially when the pump is used for drinking water. Storage for 2-3 days may be required, depending on climate and water usage. A float switch can turn the pump off when the water tank fills, to prevent overflow.

Batteries can be used for storage, but they increase the cost and maintenance significantly. However, they give freedom in timing the irrigation. The excess electricity stored in batteries can also be used for other purposes.

Storage tank in Grace community, Auroville

4.1.3 Daily operation

- The pump should be switched OFF when not required.
- Before switching ON the motor, care should be taken to prime the suction pipe by putting some water in the pipe through the delivery side. The pump should never run dry.
- If the pump is not discharging any water after turning ON and the motor is running, air may be trapped in the suction pipe through the delivery side. In this case air can be released through the air trap valve in the pump. The valve should be tightened after removing the air.

4.2 Regular maintenance

Once a week

1. Cleaning the panels with water, sponge or soft cloth. Water can be splashed on the front-side of the panels without problem. NOT ON THE BACKSIDE!

Once every 6 months

1. Checking for any shadow on the panels, and trimming trees if necessary.
2. Checking the carbon brushes in surface pumps and replacing them if necessary.
3. Applying grease or lubricant oil to the tracking handle and bush bearings to keep them operating smoothly.

Once a year

1. Checking and cleaning the foot-valve.
2. Checking the switches, fuse and connections. Inspecting the junction box on the back to make sure that the wiring is tight.
3. Checking the wiring for breaks, cracks in insulation or any other damage by rodents or insects.

Once every 2 years

The carbon brushes of the surface pumps need to be replaced after 2 years.

4.3 Dos and don'ts

1. Dos:
    a. The panels should be cleaned regularly.
    b. The pump should be switched OFF at night or when water is not required.
    c. No shadow should fall on the solar panels during the day.
    d. The pump should be kept in a shed to protect it from sun and rain.
    e. Care should be taken to avoid any leakages in the pump or pipes.
    f. The panels should be kept in the 0^{o} position in case of strong winds.
2. Don'ts:
    a. The pump should not be switched on and off too often. After switching it off, wait at least 15 seconds before switching it on again.
    b. The cover of the main junction box should not be left open.
    c. Pump level should not be changed once installed. There is a high risk of damage.
    d. No loose wire should be left un-insulated.
    e. The pump should not run on totally overcast/cloudy day.
    f. The pump should never run dry.
    g. The size of the pipes should not be reduced.
    h. The joints should not be left leaking.
    i. The motor should not be covered with plastic sheet as a protection against rain water as it would hamper cooling. Instead, a canopy with sufficient room for air movement should be used around the motor.

4.4 Precautions

- Pump should be rigidly mounted on the base-plate; otherwise excessive vibration would result in undue noise and could even damage the magnetic stator.
- Pump should be covered adequately for weather protection. However, it is necessary to provide an air vent for the motor fan.
- Foot-valve should be of minimum 2" size so as to minimise suction losses.
- Sharp bends should be avoided in the pipe lines.
- The pump should be used daily for at least 15 minutes.
- Under no circumstances should the surface pump be submerged & exposed directly to water.
- The panels should never be covered with any material (e.g. wire mesh). It will reduce the output of the pump substantially.
- Carbon brushes should slide freely in the brush holders, otherwise it will result in failure of the motor. However, excessive play between the brush and the brush holders will also result in sparking. Only recommended grades of carbon brushes should be used.
- Delivery and suction pipe lines should be air-tight.

- **If the solar pump stops working, do not try to repair it yourself. The authorised service unit (appointed by Aurore) should be informed immediately. They will send a qualified technician.**

4.5 Insurance

Just like a vehicle, the system should be fully insured against natural hazards like lightning, fire, cyclones as well as from theft and vandalism for the entire lifespan.

5. Possible applications and case studies

Possible applications

Solar pumping is ideally suited for remote areas where grid electricity is not present or not reliable. It is well suited for areas with low water table and for applications with low water demand like drinking and small scale irrigation. Under such conditions, solar pump can compete with diesel pumps if compared on a life cycle basis. It is also far better environmentally. Some of these applications are explained below.

Drinking and domestic water supply: This is one of the niche areas for solar pumping. It can be used for private homes, villages, medical clinics, etc. The pump can be powered by its own PV array, or by a main system that powers lights and other appliances. An elevated storage tank may be used, or a second pump called a booster pump can provide water pressure.

Irrigation: Solar pumps are used on small farms, orchards, vineyards and gardens. It is most economical to connect the pump directly to a PV array (without battery), store water in a tank, and distribute it by gravity flow. Storage batteries can be used when consistent flow and distribution are required (e.g. for a sprinkler system).

Some other examples are:

- Dairy farming
- Aqua-culture/ Fish farming
- Poultry, sheep breeding farms and other kinds of animal husbandry
- Agro-forestry and plantations
- Horticultural farms and nurseries
- Spirulina farming
- Ornamental water landscapes like fountains

Case studies

Aurore has installed more than 650 solar pumping systems in Auroville and outside. Some of the following examples can give you an idea of the potentials of solar pumping.

5.1 Domestic and drinking water

5.1.1 Raman Ashram, Thiruvanamalai

This peaceful ashram of a Yogi, Shree Raman Maharshi, is located at the base of Arunachala hills. The solar pump installed there is used for the ashram kitchen which serves more than 1000 people every day. During festivals this number can increase substantially.

This area is ideal for solar installation because, as one of the ashram officials puts it, the 3 seasons there are hot, hotter and hottest! Shreedhar, the person responsible for taking care of the pump, says that even during the monsoon, the pump works at least for 4 hours. The only maintenance they have to do is to clean the panels once a week and check the wire connections once in a while.

	Model: Grundfos (0.75 hp, Submersible) Year of installation: 2000 Array capacity: 1800 Wp Total head: 87 m Storage capacity: 12000 lit

5.1.2 Amar Seva Sanagam, Tirunelveli

This residential school for disabled children is situated in the small village of Ayikudi in Tirunelveli district of southern Tamil Nadu. The unreliability and high cost of electricity encouraged the school to buy a solar pump under the government subsidy. Now, the school hostels have a reliable water supply. The pump supplies water to more than 100 residents of the school, including the children, trainees and their teachers.

In fact, the only limiting factor is lack of storage facility. Currently the storage is 7300 lit, whereas the pump has much more potential. The school is planning to increase the storage, which will utilise the pump to its full potential. Another problem, however, is more serious. The ground water level in this region is declining drastically. The school has undertaken rain water harvesting to reduce the impact.

	Model: Grundfos (0.75 hp, submersible) Year of installation: 2001 Array Capacity: 1800 Wp Total head: 50 m Storage capacity: 7300 lit.

5.1.3 Kutch

In the earthquake ravaged village of Dadore near Bhuj, Aurore has installed a solar pump in coordination with a non-governmental organization, Sahajeevan. This pump provides drinking water for the village community of about 200. Aurore has also trained some technicians there to look after these systems.

Another pump is also installed in Kuran, the last village on Indo-Pakistan border.

	Model: Grundfos (0.75 hp, submersible) Year of installation: 2001 Array capacity: 1800 Wp Total head: 50 m

5.2 Domestic and irrigation water supply

5.2.1 Evergreen

Being a green belt community in Auroville, Evergreen is dependant fully on renewable energy sources for their requirement. The combination of solar and wind pump supplies water not only to the residents (2 households) but also to their fruit orchard and afforestation activities. Currently, the pump supports a small nursery of forest trees and a 5 acre plantation of mango, guava, custard apple, star-fruit, gooseberry and sapota.

The residents tried to use a drip system to increase efficiency of irrigation, however the excess iron content in the water lead to clogging of the emitters. Now the trees are irrigated alternate days, using a hose-pipe, a time consuming but comparatively efficient way of irrigation.

According to the residents, it's fantastic and so far there has been no trouble with the pump at all.

	Model: Grundfos (0.75 hp, submersible), AV-45 windmill Year of installation: 1999 Array capacity: 1800 Wp Total head: 45 m Storage capacity: 7000 lit.

5.2.2 Siddhartha Farm

Another farm in the green belt of Auroville, Siddhartha farm uses 2 solar pumps, one surface and another submersible. They provide water for drinking (6), for cattle shed (15) and for irrigation.

Initially the pump was used for afforestation on 20 acres which required irrigation once a week. Now the water is used for vegetables on 0.5 acres using a drip. A portable sprinkler is used for 2 acres of field crops including rice, varagu, ragi, green gram, black gram, sesame and forage crops for two seasons.

One of the notable things on this farm is the large underground storage of 3,00,000 lit. Another notable thing is the seasonal tracking. Herbert, the farmer, has drilled two additional holes in the support structure to allow seasonal tracking. According to him it gives a significant increase in output. However, the surface pump required servicing once and cost was about Rs. 2000.

Siddartha Farm, Auroville

Model	Grundfos (submersible)	Rotomag (surface)
Year of installation	1997	1995
Array capacity	1800 Wp	1800 Wp
Total head	16 m	4 m

5.2.3 Mother's International School, Delhi

Mother's International School, run by the Delhi branch of Sri Aurobindo ashram is one of the top rated schools of Delhi. The school has its own vegetable garden. A solar pump was installed in 2001 in this school to expose the students to renewable energy. This pump now provides water to the vegetable gardens as well as for drinking.

Model: Grundfos
(0.75 hp, submersible)

Year of installation: 2001

Array Capacity: 1800 Wp

Total head: 30 m

5.3 Irrigation: afforestation and nursery

5.3.1 Aranya

The solar pump at Aranya is one of the oldest installations in Auroville. It is used for irrigating the vegetable garden (2 acres), nursery (1 acre) and forest plantation. The panels are also used for drinking water and lighting purposes on the farm. Cleaning every week and tracking 3 times a day is the only maintenance required.

	Model: Grundfos (0.75 hp submersible) Year of installation: 1995 Array capacity: 1554 Wp Total head: 46 m Storage capacity: 38000 lit

5.3.2 Artists' residence

This is a very recent installation. The water is carried over a horizontal distance of 700 m, though pressure is somewhat reduced at the end of the pipe. In all 50 valves in short intervals are used to irrigate a farm of 6 acres which includes plantation of fruit trees, forest trees, ornamental shrubs and a nursery of various forest species, The residents are planning to use it also for rice. The only maintenance they do is panel cleaning and tracking periodically.

The pump also provides drinking water for around 30 people.

	Model: Rotomag (2 hp, surface) Year of installation: 2002 Array capacity: 1800 Wp Suction head: 6 m Delivery head: 0.5 m Storage capacity: none

5.4 Irrigation: orchard

5.4.1 Service Farm

The orchard of 12 acres includes fruit trees of coconut, guava, mango, sapota, star-fruit, custard apple, bullock heart, limes and cashew. All the fruit trees except cashew are irrigated by drip. Maintaining the drip is a critical issue here. Still, according to Mechtild, it is a great way of irrigation and the resulting efficiency and improvement in yield quality are worth the effort.

The maintenance done is daily tracking and cleaning once a month. The storage capacity is 50,000 lit.

The pump also supplies water to the household on the farm. Mechtild, the farmer, says that before, with TNEB, there were too many power cuts, many times even for 6-7 days at a stretch in summer. It was almost impossible to protect the crop. Solar power has really come as a relief! It's wonderful!

Model	Rotomag (surface)	Grundfos (submersible)
Year of installation	1995	2000
Array capacity	900 Wp	1800 Wp
Total head	4 m	50 m

5.5 Irrigation: field crops

5.5.1 Auro Orchard

One of the big farms of Auroville, Auro Orchard uses a combination of solar and electrical pumps. There are two solar pumps, one submersible and another surface pump, used as a booster pump. Various crops are taken here including fruit crops like mango, cashew, avocado, lemon, and vegetables like cucumber, tomatoes, brinjal, gourds, plus cash crops like water melon.

The surface pump has been working for the last 7 years without any trouble. The only maintenance is cleaning the panels periodically, but otherwise, according to Gerhard, the farmer, the system is virtually maintenance free!

Model	Grundfos (submersible)	Rotomag (surface)
Year of installation	1999	1995
Array capacity	900 Wp	1800 Wp
Total head	60 m	1 m

5.5.2 Mehma Sarja, Punjab

The state of Punjab is water-rich with its network of canals and rivers. In many districts ground water level is fairly high (5 m). Since the grid electricity is quite unreliable, many farmers use diesel pumps along with the electrical pumps.

In 2000-2001, Punjab government offered an additional subsidy in order to promote the renewable energy systems. This support proved very valuable, and as a result 1000 solar pumping systems were installed in 6 districts over the last 2 years. Aurore was instrumental in installing 275 systems for leading suppliers like Tata BP solar (225) and BHEL (50).

The village of Mehma Sarja in district Bhatinda illustrates the success of this programme. The village leader Jagatar Singh first installed a solar pump on his field in 2000. Impressed by the technology, he motivated other farmers to follow suit. Today, mushrooms of solar pumping systems dot the landscape of Mehma Sarja. A cluster of 11 solar pumps are installed here. They are used for irrigating crops like potato, rice and wheat.

Model: Rotomag
(2 hp, surface)

Year of installation: 2001

Array capacity: 1800 Wp

Total head: 5 m

5.6 Fish farming, Hansi, Haryana.

Seeing the success of the programme in Punjab, the governments of Haryana and Uttar Pradesh also launched similar programmes in 2001-02.

Out of the total of 200 systems in Haryana, 100 systems were installed by Aurore in coordination with Tata BP solar. These pumps are used for a variety of purposes like drip irrigation, fish farming, orchards, drinking water supply, etc.

The installation in village Hansi in Hissar district is a representative case. It is used for fish farming. This roadside pumping system has become an attraction for passers-by stopping for a meal at the nearby Dhaba.

Model: Rotomag
(2 hp, surface)

Year of installation: 2002

Array Capacity: 1800 Wp

Total head: 5 m

5.7 Spirulina farming, Simplicity, Auroville.

This is a small-scale, low tech and low investment enterprise which serves as a model and training centre for village level Spirulina farming. Spirulina is an edible algae considered to be a super food packed with proteins, vitamins and minerals.

The solar pump solely provides the water required by the farm as well as the community. Maintenance required is daily tracking and cleaning once a month. According to Hendrik, it is pumping thousands of litres every day, running and running for 7 years now.

Model: McDonald 8200

Year of installation: 1995

Array capacity: 900 Wp

Suction head: 7 m

Delivery head: 1.5 m

Storage capacity: 4000 lit

6. Using water wisely

Why efficient use?

The most effective way to minimize the cost of solar pumping is to minimize water demand through conservation. Proper planning of water use can allow reduction in number of solar panels, thus reducing the cost significantly. Therefore, water efficiency is a primary consideration in solar pumping economics.

Efficient drinking water applications

Drinking water is one of the niche areas for solar pumping systems. The need of reliability and low water demand as compared to irrigation makes solar an ideal solution for this. While planning the system, estimation of the exact quantity of water required and adequate facility of storage can help in optimising the system. The following table can be used to estimate the amount of water required. Storage is important because it allows a constant supply and helps in reducing the risk of shortage during rainy days. Normally, storage designed for requirement of 3 days can be sufficient for most cases.

Water requirement in tropical areas

Per person	Lit/day	Per animal	Lit/day
Rural areas	30	Cattle	40
Urban areas	120	Sheep/ Goat	5
		Horse	40

Efficient irrigation

In addition to reducing cost, there are many other advantages of efficient irrigation. Using less water per hectare can help in increasing the net area under cultivation and also in increasing cropping intensity (the number of crops per year).

It also improves soil aeration, uptake of water and nutrient by plants, and reduces nutrient losses through leaching. This saves the inputs and improves the quality of the yield.

Finally it also helps to maintain the soil quality by avoiding any long-term problems like soil erosion and salinization.

How?

There are many ways of increasing the efficiency of irrigation ranging from simple practices like mulching to elaborate irrigation methods like drip. Some of these methods are discussed below.

6.1 Choose your crop wisely

Crops vary a lot in their requirement of water. Spending some time to match the water availability on a farm with the water requirement of desired crops can help a lot in obtaining greater profits with less water. The life cycle of crops and their total as well as daily water requirements are important factors to consider. Crops like melon require less water per day, but their longer life cycle results in higher total requirement. These crops are suitable for the farms which have a low but constant source of water. Fruit trees can also be a good option in such cases. On the other hand, vegetables - especially leafy vegetables require more water per day, but only for a short period. Such crops are

suitable for a farm with fluctuating water supply, where there is ample water in one season and scarcity during another. So, the following points should be considered during the choice of crop.

- Total water requirement of the crop
- Frequency of irrigation required
- Amount of water required per irrigation
- Time span over which water is required
- Sensitivity of crop to water shortages
- The availability of water on farm

Water requirement of crops

Crop	Water requirement (cm)	No. of turns	Crop	Water requirement (cm)	No. of turns
KHARIF			RABI		
Rice	50	6	Wheat	40	5
Jowar	20	3	Gram	30	4
Bajra	20	3	Groundnut	60	8
Maize	30	4	Sunflower	40	5
Pulses	20	3	Safflower	40	5
Groundnut	40	5	Maize	60	8
Chillies	40	5	Vegetables	60	10
Cotton	90	10	Onion	60	10
Onion	40	5	Wheat	40	5
Vegetables	40	5			
PERENNIAL			SUMMER		
Sugarcane			Groundnut	80	10
a. Adsali	400	32	Sunflower	60	6
b. Suru	300	25	Fodder Maize	80	10
Banana	240	24	Vegetables	80	10
Other fruits	200	25	Onion	70	9

6.2 Diversify

While water intensive crops like sugarcane are desired for the cash they earn, they can suffer greatly if there is a water shortage. In any case, a diverse combination of crops is desirable for maintaining the soil quality and reducing risk from market fluctuations and

natural hazards like pest attack. The following table can be used to choose the crops on the basis of risk involved.

Sensitivity of various field crops to water shortages

Sensitivity	Low	Low-Medium	Medium-High	High
Crops	Cassava, Cotton Millet, Pigeon Pea, Sorghum	Alfalfa, Citrus, Grape, Groundnut, Soybean, Sunflower, Sugar- beet, Wheat	Beans, Cabbage, Maize, Onion, Peas, Pepper, Water Melon, Tomato	Banana, Fresh green vegetables, Rice, Potato, Sugarcane

6.3 Zoning

Grouping the crops according to their water requirement (high, medium and low) helps a lot. It makes irrigation far more efficient and easy. Trees like custard apple in the low-water-use zone need supplemental water only during establishment or the first growing season (first 8 to 10 weeks after transplanting), whereas crops like pulses in moderate-water-use zones require water only during periods of limited rainfall when they show signs of stress. On the other hand, most vegetables in high-water-use zones require frequent watering. The crops should be planted accordingly.

The irrigation system can then be designed specifically for each zone.

6.4 Combine (multi-tier system)

The crops vary in their root zones. While most of the field crops take water from the upper 30 cm of the soil, tree roots often go much deeper. So, combining crops which differ in their rooting depths can considerably increase the efficiency and profits. Crops also differ in canopy characteristics, nutrient requirements, uptake pattern, harvesting period and growth pattern. So, if crops are planted considering these points, 5-6 crops can be taken on the same piece of land in the same season. There are friend crops i.e. the crops which improve each others' performance when planted together. For example, areca nut is a good support for black pepper, banana provides shade to growing seedlings of coconut, and so on. In coastal areas, for example, a multi-tier system of coconut, banana, nutmeg and pineapple give excellent output per unit of water and nutrients applied.

6.5 Water quality

Sometimes the water is not suitable for use as an irrigation source. Using low quality water can harm the soil substantially. Major factors in determining water quality are its salinity and sodium contents. Salinity reduces the water uptake. This means that even though

water is present in the soil, plant roots are unable to absorb it due to salinity. Sodium can be especially harmful. It is detrimental to soil structure and plant growth. Therefore, it is wise to get your irrigation water tested and take corrective measures accordingly.

6.6 Wise method of irrigation

Every method has its advantages and disadvantages. Therefore the merit and demerits of each option should be considered carefully beforehand.

6.6.1 Sprinkler

Sprinkler systems are generally more efficient and use less labour than surface irrigation. They can be adapted more easily to sandy and erosion-prone soils on undulating ground. The systems can be used on sloping as well as level areas. Accumulation of salt is avoided as water percolates downward from the surface carrying salts with it.

However, there are some drawbacks. It requires greater and more constant pressure than other methods. Irrigation in a wind of more than 5 miles per hour distributes the water unevenly. If the water is of poor quality, the mist which dries on leaves may deposit enough salt to injure them. Moreover, sprinkler systems require good constant pressure to ensure uniform distribution. Therefore, small portable sprinkler systems are more advisable in conjunction with solar pumps.

6.6.2 Drip

Drip irrigation can reduce the water requirement by as much as 25 to 50 percent compared to conventional irrigation. The main advantage of drip irrigation is that soil moisture remains relatively constant, and air is always available to the roots. In other watering methods there is an extreme fluctuation in water content, temperature and aeration of the soil. With drip irrigation, the water soaks in immediately when the flow is adjusted correctly. There is neither flooding nor run-off, so water is not wasted. All of the water is accessible to the roots as it is applied near the root zone. Watering weed patches, walkways and other areas between plants and rows is avoided. Water lost to evaporation is negligible and interference by wind is minimal. Fertilizers can be delivered directly to the plant roots through drip. This results in increased nutrient efficiency at low fertilizer rates.

Careful choice of the components means half the battle is won. Therefore, the following points should be taken into account when selecting a drip system.

- Ease of installation
- Ease of cleaning the emitters

- Durability
- Type of filters
- Possibility of flow control

Note: When buying irrigation equipment, mixing of brands of fittings, hoses and emitters should be avoided unless they are compatible.

Drip system in Service Farm, Auroville

The life of a drip system can be extended by proper design, proper filtering, avoiding puncture with tillage tools, mulching over plastic lateral drip lines to shield them from sunlight, and flushing and draining lines periodically. The financial investment is reasonably small if you are willing to spend a few hours to plan, assemble and install the system. Savings in water combined with increased yield and quality of vegetables and flowers more than pays for the cost of parts to maintain a drip system.

Selection, number and spacing of emitters

Plant	Flow rate (lit per hr)	Number of emitters	Placement of emitters
Low shrubs (2-3 ft)	4	1	at plant
Shrubs and trees (5-10 ft)	8	2-3	2 feet from tree equally
Shrubs and trees (10-20 ft)	8	3-4	3 feet apart equally spaced
Shrubs and trees (20 ft)	8	6 or more	4 feet apart equally spaced
Ground cover	4	1	at plant
Vegetables (close spaced)	2-4	1	every 16-24 inches
Vegetables (wide spaced)	4-8	one per plant	at plant

6.6.3 Sub surface drip

Subsurface drip irrigation technology is a variation of traditional drip irrigation where the tubing and emitters are buried beneath the soil surface, rather than laid on the ground or suspended from wires. The products being used today in subsurface drip irrigation come

in three basic configurations: hard hose, drip tape, and porous tubing. This method reduces maintenance, injury and vandalism found with surface drip.

6.6.4 Look for local methods

Careful observation of your area can reveal other methods developed locally, which are suitable for the local needs and are often less costly. Some of these systems include trench farming, earthen pipes for field crops or diffusers for fruit crops. (For details see Shreeram Tyle Works in annexure 2)

6.6.5 Manage your system well!

Whatever system you choose, maintenance is the key to success. Every field has different needs. So, the flow rates and time should be adjusted by some experimentation. The hoses, faucets and water devices should be checked periodically for leaks and malfunctions to help avoid wastage. A little bit of regular maintenance can help not only in saving water but also in extending the life of the system.

6.7 Time your irrigation turns

Irrigation should be scheduled when the soil temperature is moderate. In summer it is better to irrigate the field during the late afternoon or at night. It gives the plants sufficient time to absorb water before dry and desiccating weather prevails the next day. During winter water should be applied during the morning hours, when the soil starts warming up.

6.7.1 Critical growth stages

There are critical growth periods of crops when water stress is most detrimental. For fruiting crops, the most critical growth stage regarding water deficit is at flowering and fruit formation. Moisture shortage at this stage may cause premature fall of flowers or young fruits, resulting in heavy yield reduction. For grains, grand growth and tillering stages are also critical. In terms of food production, the period of yield formation or enlargement of the edible product (fruit, head, root, tuber, etc.) is critical for all vegetables, and is the most critical for non-fruiting crops. Moisture deficits at the enlargement stage normally result in a smaller edible portion because nutrient uptake and photosynthesis are impaired.

On the contrary, over-irrigation during the ripening period may reduce fruit quality. Excess water during fruit ripening reduces the sugar content and adversely affects the flavour of crops like tomatoes, sweet corn and melons. Moisture deficits at ripening time do not significantly reduce the yield of most fruit crops. So, the field should be irrigated with extreme caution at this time.

6.7.2 Rotational irrigation

With solar pumps, there is no need to worry about the number of hours of pumping as it will not add to your electricity bill. Use this possibility to your advantage by careful planning.

The usual practice in many areas is flooding the entire field in one day, and then letting it soak for 10 days or so. With a solar pump, it is not possible to irrigate a large field in a single day. The solar pump tends to give less output as compared to the much larger electric and diesel pumps used conventionally. On the other hand, there is no additional cost in running the pump every single day. So, by using a rotational irrigation pattern, whereby only small patches (0.5-1 acre) are irrigated every day, you can cover about 5-10

acres over a 10-day period. By the time you have irrigated the last patch, you can start again with the first one.

6.7.3 Water only as much as needed

Frequent light irrigation is often harmful. It wets only the surface soil to a depth of less than 1 inch. Most plant roots go much deeper. Light sprinkling only settles the dust and does little to alleviate drought. So, it is better to give plants a weekly soaking. When watering, the soil should be allowed to become wet to a depth of 5 to 6 inches. This type of watering allows moisture to penetrate into the soil area where roots can readily absorb it. A soil watered deeply retains moisture for several days.

Excess irrigation can be even more harmful. Too much water in the soil causes oxygen deficiency, resulting in damage to the root system. Plant roots need oxygen to live. When a soil remains soggy, little oxygen is present in the soil. When this condition exists roots die and no longer absorb water. Then leaves begin to show signs of insufficient water. These symptoms can be misleading. So, proper care should be taken while determining the amount of water to be applied.

The thumb rule is to moisten the soil thoroughly at each watering, and then to allow plants to extract most of the available water from the soil before watering again.

6.8 Storage

Storage of water, especially for an orchard or nursery, can improve the efficiency to a great extent. It can enable you to irrigate according to your needs. It can also serve as excellent back up during a dry spell in monsoon. It allows irrigation during early morning or late evening when there is less evaporation, and the plants can make more efficient use of the water.

6.9 Agronomical practices

Many agronomical practices can help in conserving water. Some of them are described below.

6.9.1 Mulch

Natural mulch consists of dead leaves, twigs, fallen branches and other plant debris which accumulates on the earth’s surface. Mulch insulates and protects soil from drying and hard-baking effects caused by evaporation of water. It breaks the force of rain and irrigation water thereby preventing erosion, soil compaction and crusting. Mulched soils absorb water faster. It also helps to control weeds and works as a food for earth worms, microbes and other beneficial soil life by composting at the moist earth surface.

Any plant material that is free of weed seed and disease is suitable for mulch. Weed-free hay or straw, leaves, grass clippings, compost, etc., are all great. Fresh grass clippings are fine for use around well-established plants, but they should be cured for a week or so before placing them around young seedlings.

Mulching in Siddhartha Farm, Auroville

6.9.2 Avoid over-fertilization

The application of excess fertilizers increases the need for water and can lead to soil salinization. If the soil is over-fertilized frequently, especially with chemical fertilizers, the soil life can be greatly hampered, causing decrease in productivity. So, fertilizers should be applied with caution. Fertilizers which contain slow-release, water insoluble forms of nitrogen are preferable to normal fertilizers.

6.9.3 Use organic manures and soil amendments

Organic manures and soil amendments help to build the soil organic matter, one of the key ingredients in soil quality. Soils rich in organic matter hold water well and offer a favourable environment in which the plant roots grow well. So, organic manures should be added to the soil whenever possible. Green manuring can be a great way to improve soil productivity if other manures are not feasible.

6.9.4 Observe and manage the soil well

Maintaining the soil condition improves the water uptake to a great extent. The goal should be to provide the plant roots with a moist, well-drained, and well-aerated growing environment. Proper tillage and appropriate soil amendments improve the structure and water-holding capacity of the soil. Heavy clay soils have a high water-holding capacity and will benefit from adding some type of coarse aggregate, like rice or wheat straw, which will improve the ability of water to move through the soil. Sandy soils, on the other hand, do not hold enough water and nutrients for plant use. Adding fine-textured organic matter to these soils is often helpful. Careful observation can also help to determine the timing and quantity of water applied. The symptoms seen on plants can be misleading.

6.10 Earn water. Catch rainfall as much as possible

This is probably the best strategy in water management, for a country like ours, where we gain water during a brief period of monsoon and then use it round the year. This is especially true when the ground water level is dropping steadily all over the country.

Therefore, every effort should be made to catch the rainwater and store it or allow it to percolate so that it will recharge the ground water reservoir from which the pump takes out water. Field ponds, ditches around the field crops, earthen dams in any stream flowing across the field can substantially improve the water storage. Even simple practices like

tilling the soil across the slope and ploughing the field before and after showers can help the field to retain a lot more water.

Contour cultivation

7. Annexures

7.1 Government agencies and contacts

7.1.1 MNES

Ministry of Non-Conventional Energy Sources,
Block-14, CGO Complex, Lodhi Road,
New Delhi-110 003, India.
Telephone: 91-11-436-1481/2772
Tele/Fax: 91-11-436-2772 (O)
E-mail: secymnes@ren02.nic.in

MNES regional offices

- Ahmedabad, 5th Floor, Sun-Set Drive-In-Cinema, Drive-In-Road, AHMEDABAD, 380054, TELE-FAX No. (079) 7457858 (Head: Shri K. C. Vaghri, Principal Scientific Officer)
- Bhopal, E-1/85, Arera Colony, Bhopal - 462 01. Tele /FAX : 0755-420546 (Head: Shri Padam Singh, Director)
- Bhubaneswar, Plot No. 28, Ashok Nagar, Bhubaneswar - 751 009, Orissa. Tele/FAX : 910-674- 561248 (Head: Shri B. K. Panda, Senior Scientific Officer-I)
- Chandigarh, Kendriya Sadan, Block -IV, 4th Floor, Sector 9-A, Chandigarh-160 017. Tele /FAX : 91-172- 741339 (Head: Shri S. S. Bedi, Director)
- Chennai, E1-B - Block, Rajaji Bhawan, Basant Nagar, Chennai-600090, Tele /FAX: 91-44- 491-8742. (Head: Dr. P. Radhakrishna, Director)
- Guwahati, A.T. Road, Paltan Bazar, (Opposite Panbazar Overbridge), Guwahati-781001. Tele /FAX: 91-0361- 54-3162. (Head: Shri D. R. Das, Principal Scientific Officer)
- Hyderabad, 6-3-1201, Kundan Bagh, Begumpet, Hyderabad – 500016. Tele /FAX :91-040-3413458 (Head: Shri N. B. Raju, Senior Scientific Officer-I)
- Lucknow, A-1/18, Sector H, Aliganj, Lucknow – 226024. Tele /FAX : 91- 0522 – 762634. Email: blrlkmnes@up.nic.in. (Head: Dr. B. L. Ram, Principal Scientific Officer)
- Patna, Jagdev Path, Bailey Road, Patna-800014. Tele /FAX :91-0612-281052 (Head: Shri S. K. Singh, Principal Scientific Officer)

7.1.2 IREDA

India Habitat Centre Complex
Core 4A,East Court, 1st Floor, Lodi Road,
New Delhi - 110003
Tel: (011) 4682214 - 21
FAX: (011) 4682202, 4682204, 4682207
E-mail: mdireda@rediffmail.com, gen@ired.1.globemail.com
Web Site Address: http://ireda.nic.in

7.1.3 Nodal Agencies for Implementation of Programmes

- Managing Director, Non - Conventional Energy Development Corporation of Andhra Pradesh Ltd., (NEDCAP), 5-8-207/2, Pisgah Complex, Namapally, HYDERABAD - 500 001
- Director, Arunanchal Pradesh Energy Development Agency (APEDA) Post Box No.141, Land Survey Hostel Building (1st Floor), ITANAGAR - 791 111
- Director, Assam Science, Technology and Environment Council (ASTEC) U.N. Bezbaruah Road, Silpukhuri GUWAHATI - 781 003
- Director, Bihar Renewable Energy Development Agency , (BREDA) Shikarpur House, Dr.T.N. Banerjee Marg, Chajjubagh. PATNA - 800 001
- Director, Chattisgarh State Renewable Energy development Agency, Department of Energy, Govt of Chattisgarh, 181, D.K.S. Bhawan, Mantralaya, Raipur.
- Project Officer & Member Secretary, Goa Energy Development Agency, C/o Department of Science, Technology & Environment Saligao Plateau Opposite Seminari Saligao BARDEZ - GAO - 403 511
- Director, Gujarat Energy Development Agency (GEDA) IInd Floor, Suraj Plaza II, Sayaji Gunj, VADODARA - 390 005
- Director, Haryana State Energy Development Agency (HAREDA). Department of Non-Conventional Energy Sources SCO No.48, Sector 26, CHANDIGARH- 160 019
- Director, Himachal Pradesh Energy Development Agency (HIMURJA) SDA Block No.-8 - A, Kasumpti, SHIMLA - 171 009
- Director/Chief Executive, J&K Energy Development Agency (J&KEDA) Deptt. of Science & Technology (Govt. of Jammu & Kashmir) Civil Secretariat SRINAGAR (J & K) - 180 001
- Managing Director, Karnataka Renewable Energy Development Ltd. (KREDL) No.1, Coffee Board Building, Dr.B.R. Ambedkar Veedhi, BANGALORE - 560 001
- Director, Agency for Non-Conventional Energy & Rural Technology (ANERT) Pattom P.O. Post Box No. 1094 THIRUVANANTHAPURAM - 695 004
- Managing Director, Madhya Pradesh Urja Vikas Nigam Ltd. (MPUVN) Urja Bhawan, Main Road No.2 Shivaji Nagar, BHOPAL - 462 016
- Director, Maharashtra Energy Development Agency (MEDA) S. No. 191/ A, Phase I, Second Floor MHADA Commercial Complex , Opposite Tridal Nagar Yerwada , PUNE - 411 006
- Member Secretary, Manipur Renewable Energy Development Agency (MANIREDA), Old Lambulane IMPHAL - 795 001
- Director, Meghalaya Non - Conventional & Rural Energy Development Agency (MNREDA) Lower Lachaumiere, Opposite P & T Dispensary SHILLONG - 793 001
- Director, Zoram Energy Development Agency, Govt. of Mizoram AIZAWAL - 796 001
- Director, Deptt. of Science & Technology Govt. of Nagaland KOHIMA - 797 001
- Chairman-cum-Chief Executive, Orissa Renewable Development Agency (OREDA)S-59, Mancheshwar Industrial Estate, BHUBANESWAR - 751 001
- Director/Chief Executive Punjab Energy Development Agency (PEDA) SCO No. 54-56, Sector 17 - A, CHANDIGARH - 160 017

- Director, Rajasthan Energy Development Agency (REDA) E-166, Yudhishtar Marg, C-Scheme JAIPUR - 302 001
- Project Director (NRSE / IREP Cell) Rural Development Deptt. Government of Sikkim Secretariate Tashling, GANGTOK - 737 101
- Chairman & Managing Director, Tamil Nadu Energy Development Agency (TEDA) E.V.K. Sampath Maaligai, Vth Floor, College Road, CHENNAI - 600 006
- Chief Executive Officer, Tripura Renewable Energy Development Agency (TREDA) Bijnan Bhawan, Second Floor, , Gorkha Basti, Assam Rifles Complex AGARTALA - 799 006
- Director, Non-Conventional Energy Development Agency of U.P. (NEDA) Vibhuti Khand, Gomti Nagar (Near PICKUP) LUCKNOW - 226 010
- Director, Uttaranchal; Renewable Energy Development Agency, Zila Panchayat Bhawan, Almora, Uttaranchal.
- Director, West Bengal Renewable Energy Development Agency (WBREDA), LA-Block, B-04, Sector III Salt Lake City, Near Tank No.16, CALCUTTA - 700 091
- Superintending Engineer, Electricity Department A & N Administration Andaman & Nicobar Islands PORT BLAIR
- Project Director, Department of Science & Technology, Chandigarh Administration Additional Town Hall Building Secotr-17 -C, CHANDIGARH
- Director, Delhi Energy Development Agency (DEDA) 37, Institutional Area, Tughlaqabad, New Delhi - 110 062
- Executive Engineer, Department of Electricity, Lakshadweep Administration , KAVARATTI - 682 555
- Project Director, District Rural Development Agency, No.203, Jawharlal Nehru Street, PONDICHERRY - 605 001
- Swami Asaktananda, Secretary, Ramakrishan Mission Ashrama, South 24, Parganas, West Bengal NARENDRAPUR - 743 508
- Chairman & Chief Executive Councillor, Ladakh Autonomous Hill Development Council (LAHDC) LEH, Ladakh (J & K State) 194 101

7.1.4 Solar pumping systems manufacturers in India

(Inclusion in this list does not imply approval or recommendation of any company or its products by the Ministry of Non-Conventional Energy Sources)

DELHI

- Surya Jyoti Devices India (P) Ltd. E/3, Lajpat Nagar II New Delhi 110 024 Tel: 011 - 6834129, 6834822 Fax : 011 - 6839444
- Suntime Energy Limited E-3, Lajpat Nagar II New Delhi 110 024
- Prakritik Lighting & Urja Systems Pvt.Ltd. F-274, Flatted Factory Complex, Okhla Industrial Estate New Delhi 110 020

HARYANA

- M/s Global Solar Energy (India) Ltd., Plot No.2, EHTP Complex, Sector 34, Delhi Jaipur Highway (NH-8) Gurgaon 122 001. Tel. 6827438-43 (Delhi), Fax 6827437

KARNATAKA

- Bharat Heavy Electricals Ltd. Electronics Division Post Box No. 2606, Mysore Road, Bangalore 560 026 Tel : 080 - 624283, 6998553/774 Fax : 080 - 6610137, 624283
- Tata BP Solar India Pvt. Ltd. Plot No. 78 , Electronics City, Hosur Road, Bangalore 561 229 Tel : 080 - 8520082 / 83, 8521016 / 17 / 18 Fax : 080 - 8520972 / 116 E-mail : tatabp@tata.com URL: http//www.tata.com/tatabp

RAJASTHAN

- Rajasthan Electronics & Instruments Ltd. 2, Kanakpura Industrial Area JAIPUR 302 012 Tel : 0141 - 361883, 361 981 Fax : 0141 - 312701

TAMILNADU

- Pentafour Solec Technology Ltd. 332, Arcot Road, Chitra Towers Kodambakkam CHENNAI 600 024 Tel : 044 - 4834292, 4836351 Fax : 044 - 4834517
- Udhaya Semiconductor (P) Ltd. 1/482, Avanashi Road, Neelambur COIMBATORE 641 014 Tel : 0422 - 627545, 887003 Fax : 0422 - 627504, 572675

UTTAR PRADESH

- Central Electronics Limited, 4, Industrial Area, Sahibabad -201 010 Tel : 914771941, 914771945 Fax : 914771843

7.2 Companies for irrigation systems

7.2.1 Drip and Sprinkler Irrigation Systems

Following is a list of some suppliers of drip and sprinkler systems. However, it must be noted that this list is by no means exhaustive.

- Ajay Group of Companies, 4561, Deputy Ganj, Sadar Bazar, Delhi 110006.
- Aquagaurd Plastics & Polymers Pvt. Ltd, A-1/839,G.I.D.C, Makarpura Industrial Estate, Makarpura, Baroda 390010, Gujarat.
- Bharat Irrigation, e-419 road no 17 vkia jaipur rajasthan india phone-91-141-330272,301416 fax-91-141-600909
- Bhinge Brothers, W-62, Midc, Satpur, Nashik 422007, Maharashtra.
- Chemiplast Industries, 55-57,Industrial Area, Sector-1, Distt. Solan, Parwanoo 173220, Himachal Pradesh.
- Coastal Impex, Parijat Co-op. Housing Society, Near Hotel Welcome Inn Panvel 410206, Maharashtra.
- Hasti Sprinkler System (HSS), Harvel Irrigations Pvt. Ltd. 301-304, Maghdoot, 94, Nehru Place, New Delhi:110 019, Tel: 6413370/85365 Fax:6464819.
- Jain Irrigation Systems Ltd. NH.06, P.B.72, Bambhori, Jalgaon, Maharashtra. Phone: 0257-250011/22 **or** Jain House, 2nd Floor, 41-43 Police Court Lane Fort, Mumbai 400001, Maharashtra.
- Krishi Irrigation (P) Ltd, C-184, 2nd Stage, Peenya Industrial Estate, Bangalore 560032, Karnataka.
- National Agro Seeds Corporation, Municipal Market, Alopibaugh, Allahabad 211006, Uttar Pradesh.
- National Organic Chemical Industries Limited, C-1, MIDC Industrial Area Shivani, Akola 444104. Maharashtra.
- Netafim Irrigation India Pvt. Ltd., 1st Floor, 297 C.S.T. Road, Vidyanagri, Kalina, Mumbai 400 098, India, Tel: 91-22-695 2761/2, Fax: 91-22-695 2760, http://www.netafim-india.com
- NOCIL, C-1, MIDC Industrial Area, Shivani, Akola 444104, Maharashtra.
- Finolex Plastro Plason Ltd, Plot no. 399, Urse, Tal Maval, Dist Pune-410506. Phone No. 02114-23273/23687/23766/8/9. Fax: 02114-23770 e-mail: finoplas@vsnl.com
- Renown Irrigation Systems Ltd, 9, J.B. Chambers, Jayshree Road, Junagadh 362001, Gujarat.
- Swastic Industries, 23 A Netaji Subhash Road, Calcutta 700001, West Bengal.
- Vedant Enviro-Agro Irrigation Tech. (P) Ltd., Nagpur. West high court Rd, Opp.Andhra Bank, Dharampeth, Nagpur:440 010, TelL 0712)522368-526541, Fax: 526541.

7.2.2 Miscellaneous

For Diffusers and Jeevan Wahini: Shreeram Tyle Works (Vijay Jogalekar) Kherdi, Chiplun, Dist. Ratnagiri, 415 604. Maharashtra. Phone No. (02355)56265.

For Trench Farming: Kalpavruksha Farm, At & Post Dehri, Coastal Highway, Tal: Umbargam, District Valsad. 396170. Gujrat. Phone No. (026354)2126

For improving the quality of saline well water: Sujala Biosanitizer Dr. Uday Bhavalkar, Bhavalkar vermitech pvt ltd., a-1 padma park, behind padmavati mandir, pune 9. Phone 4225208, 4226916 e-mail:bvpl@vsnl.com, www.biosanitizer.com

7.3 References

Solar Electric Systems for Africa. By Mark Hankins. Publisher: Commonwealth Science Council and Agrotech Zimbabwe.

Product brochures by Grundfos, Rotomag Pvt. Ltd, Dankoff Solar, Mono, Siemens etc.

Proceedings of Solar Photovoltaic Water Pumping Workshop (CSR Publication, 1995)

Operation and maintenance manual by Punjab Energy Development Agency (PEDA)

Installation guide and user manual by Tata BP Solar India Ltd and Aurore.

Water conservation manuals by Texas Agricultural Extension Service

Water conservation manuals by North Carolina State University

Water conservation manuals by University of Georgia College of Agricultural & Environmental Sciences Cooperative Extension Service

“Indigenous fertigation system is a boon to plantations” Agri Vision (Feb 1) A Strategic Press Publication.