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Promoting, Financing and Advising on Solar Powered Irrigation Systems – Manual and Tools for Development Practitioners

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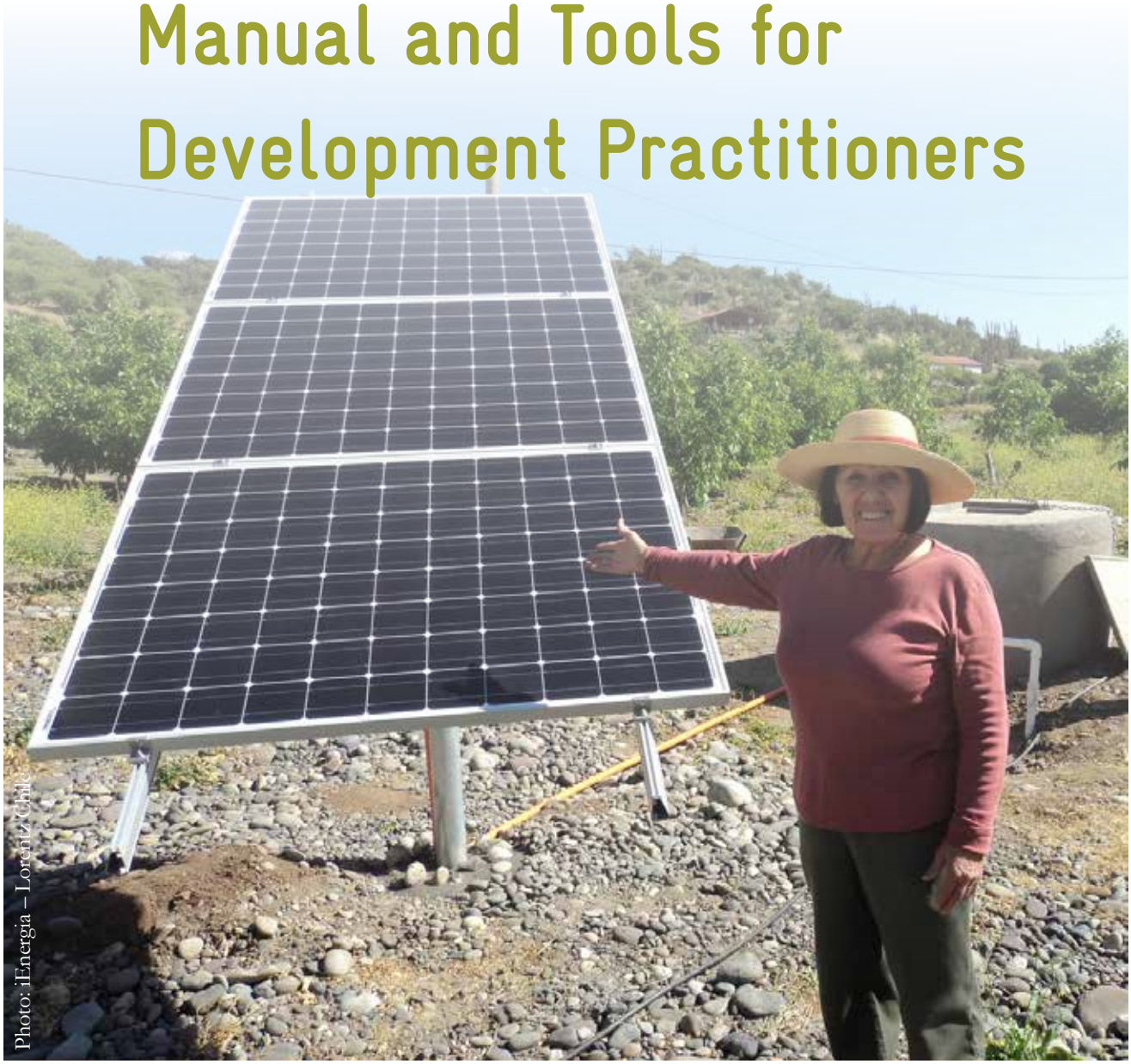

Photo: iEnergia – Lorentz/Chile

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ABBREVIATIONS

Ah	Ampere Hour
DC/AC	Direct Current (Sources) / Alternating Current (Sources)
EVA	Ethylene-Vinyl Alcohol
FAO	Food and Agriculture Organisation of the Unites Nations
FAT	Factory Acceptance Test
Gd	Daily Global Irradiation
GIZ	German Technical C
GIWR	Gross Irrigation Water Requirement
GPFI	Global Partnership for Financial Inclusion
GSM	Global System for Mobile Communications
HERA	GIZ Programme "Poverty-oriented Basic Energy Services"
HT	Total Head
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IRR	Internal Rate of Return
IWR	Irrigation Water Requirement
MPPT	Maximum Power Point Tracking
NGO	Non Governmental Organsiation
NIWR	Net Irrigation Water Requirement
NPV	Net Present Value
m2	Square Meter
PV	Photovoltaic
PVP	Photovoltaic Pump
SAT	Side Acceptance Test
SPIS	Solar Powered Irrigation System
STC	Standard Test Conditions
TC	Temperature Coefficient
Vd	Diode Voltage
W	Watt
Wp	Watt Peak

BACKGROUND & ACKNOWLEDGEMENTS

The present manual was developed in an effort to contribute to the goal of the international initiative 'Powering Agriculture – An Energy Grand Challenge for Development'. It seeks to support the introduction of Solar Powered Irrigation Systems as one technology option to sustain and increase agricultural production in developing countries. The development of the manual was commissioned by the program 'Powering Agriculture – Sustainable Energy for Food' of the German International Development Agency (GIZ on behalf of the German Federal Ministry for Economic Cooperation and Development).

The manual was developed based on the "Stocktaking and Analysis Report" prepared as a result of desk research and case studies in Chile, India, Morocco and Kenya. These were enriched by results obtained from exchanges and discussions with stakeholders from the public and private sector, and civil society organizations.

The study was carried out in close co-operation with the GIZ sector program Poverty-oriented Basic Energy Services (HERA), which has more than three decades of experience in the field of energy access. The HERA-team provided a wealth of information and was instrumental in the organization and facilitation of the stakeholder workshop in March 2015 and a workshop at FAO in May 2015.

The study benefitted from the contact management and facilitation of GIZ Country Offices in Chile, India, Kenya and Morocco. The study team could also largely benefit from support and fruitful discussions with key GIZ staff of the Program for Renewable Energies and Energy Efficiency in Chile, the Indo-German Energy Program in India, the Energizing Development Kenya Country Program in Kenya and the Program Promoting Renewable Energy Sources and Energy Efficiency for Sustainable Development in Morocco.

During the case studies conducted in the four countries, the authors had the opportunity for exchanges and discussions with a large number of representatives of public services related to renewable energies and agriculture.

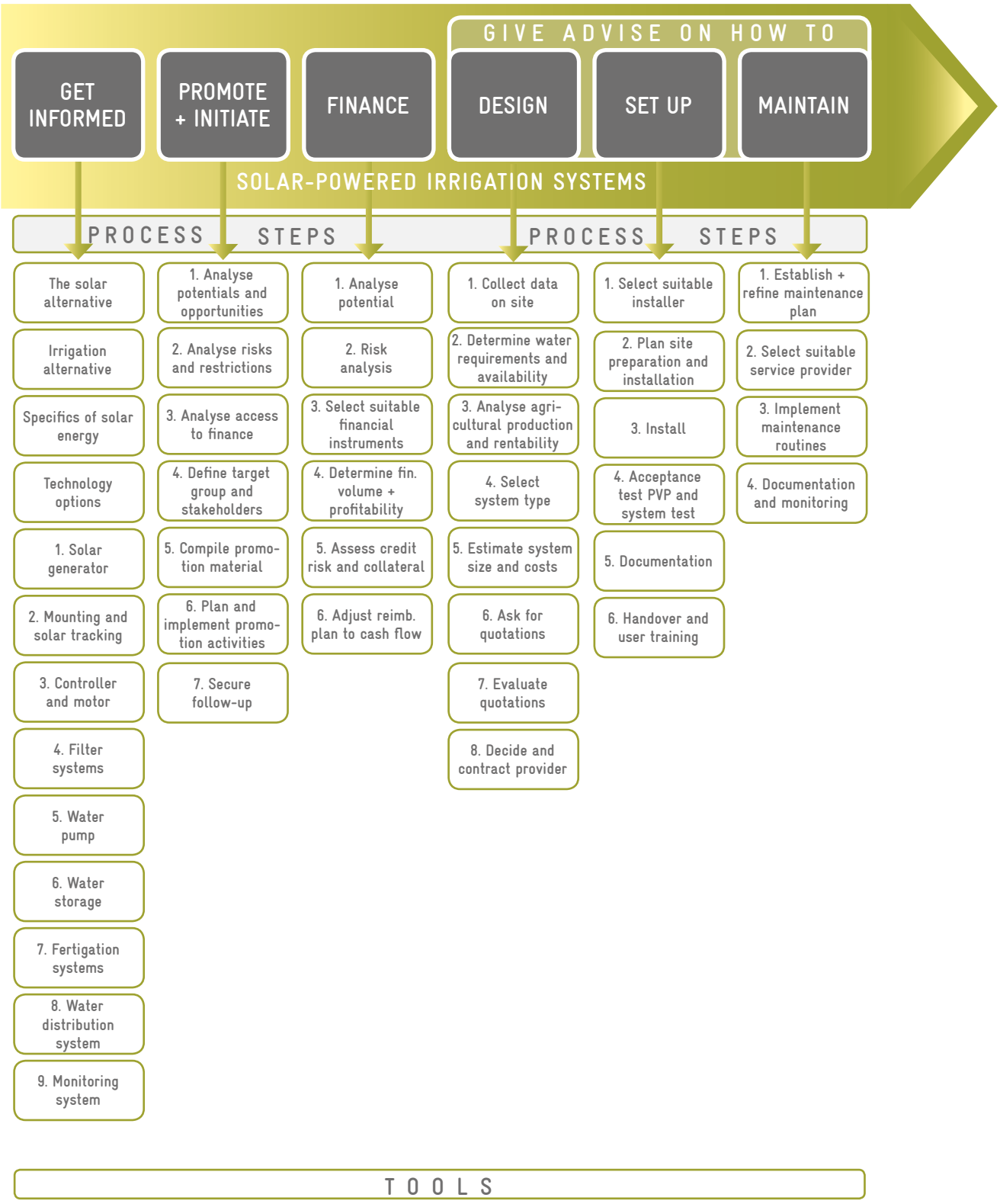
Support to the research and information collection was largely extended by private sector suppliers and service providers in Germany and in the countries selected for case studies. Notably, the companies Lorentz GmbH and Grundfos have supported the study through their international network. Country-based assistance and information was also provided by iEnergia Group (Chile), Claro Energy Pvt. Ltd. (India), Jain Irrigation Systems Ltd., Tata Power Solar Systems Ltd. (India), Center for Alternative Technologies Ltd. (Kenya), Davies & Shirtliff Ltd. (Kenya), SunCulture Ltd. (Kenya) and AE Photonics Maroc S.a.r.l. (Morocco). The conducted visits to solar-powered irrigation systems in these countries would not have been possible without the support and logistical assistance of these companies.

The Delegations of the German Industry and Commerce in Kenya and Morocco also provided valuable information and facilitated further contacts that could be followed up by the study team.

The authors of the study and the manual gratefully thank all stakeholders for their contributions, comments and support.

Hamburg & Niedernhausen, October 2015

STRUCTURE OF MODULES



INTRODUCTION

Most water pumps utilized for irrigation purposes worldwide are powered by engines run on fossil fuels (diesel, petrol, gas) or on electricity supplied from the grid (or electricity generated by generators). Fossil energy sources are limited and emissions from their utilization have negative climate impacts. At the same time, the electricity supply especially in developing countries is often insufficient and unreliable, if not absent in rural areas. This provides for a large potential to introduce PV technology in irrigated agriculture as a possible viable alternative technology option.

Information on technology options for Solar Powered Irrigation Systems (SPIS), their potentials, limits and risks is often not available for farmers and extension services. SPIS are often designed and planned in a segregated way, resulting in a lacking integration of environmental, agronomic and technical aspects. There is a need for knowledge on site-specific and demand-based design of SPIS to render this technology option viable for the farmer and to avoid negative ecological and economic impacts. At the same time, the availability of comprehensive planning guidelines, manuals and awareness creation and training material is limited.

SPIS are only promoted by few stakeholders and the response of technical and financial service providers to related needs is often slow. While the technology can be a viable alternativ to conventional ways of powering irrigation, it is not very prominently considered in sector policies and strategies and extension approaches.

This manual aims to overcome some of these shortfalls. It provides information, guidelines and practical tools for those who give advice or finance SPIS in small or medium sized agricultural enterprises; **these being agricultural (irrigation) extension staff / advisor and credit officers / risk managers in financing institutions**. It is a valuable source of information for stakeholders promoting modern and efficient irriagtion technologies. The manual strives to help finding the optimal design of a system, thereby avoiding risks related to system efficiency, financial viability and the unsustainable utilisation of water resoucres.

The manual follows the process when giving advice on developing a Solar Powered Irrigation System in an agricultural enterprise. It consists of six modules. The modular approach enables the user to explore the manual according to the specific situation and process step for which information and guidance is needed:

GET INFORMED specifies the components of a SPIS and its major technological aspects. Each component is described in detail.

PROMOTE & INITIATE is useful when starting a SPIS or promoting the technology. It focuses on the analysis of potentials and risks, the stakeholders involved, dissemination strategies and suggests promotion activities.

FINANCE provides information and tools for financial service providers already financing or planning to finance SPIS. The module addresses two groups: those at management level, deciding on credit policies and loan officers assessing single loan applications for financing SPIS.

DESIGN helps to select the suitable system configuration for a specific situation. A set of tools supports preselecting the appropriate system type and the estimation of the size and the costs of the chosen SPIS on farm level.

SET UP provides information and tools to enable the installation of a SPIS. It focuses on the selection of installers, acceptance and system tests as well as documentation and hand over of the system.

MAINTAN elaborates on maintenance plans, the selection of service providers, regular routines and on documentation and monitoring.

Module structure

The first module describes all **components** of the SPIS. Each of the following modules describes the **module aim** and the corresponding **process**. An image visualizes the content of the module by process steps. Steps are numbered and can be found on the following pages of each module.

Structure of each step

Each step in the process of each module is subdivided into five blocks:

- Description of the process step
- People and stakeholder for which this step is relevant
- Data requirements needed to work through the step
- Outcome/products, which are results to be achieved by completing the step
- Important issues which summarise additional aspects to be considered

Each module is closed by a page on **further readings, links and tools**. As a last part, a **toolbox** provides a collection of excel sheets, forms or checklists to be used when promoting, financing or advising on SPIS. These give examples for practical tools that should be adapted to the specific need of the user.

GET INFORMED

Photo: Andreas Hahn

MODULE AIM

Solar-powered irrigation systems provide new possibilities for pumping irrigation water for agricultural production .for any farm size, thus also for smallholder farms and group farming schemes, provided the underlying agricultural production can be intensified. SPIS still constitute a rather unknown technical option, especially in many developing countries. Low awareness of SPIS technology and its potentials is often the main reason for limited demand amongst farmers and the reluctance of financial institutions to finance this competitive technology option.

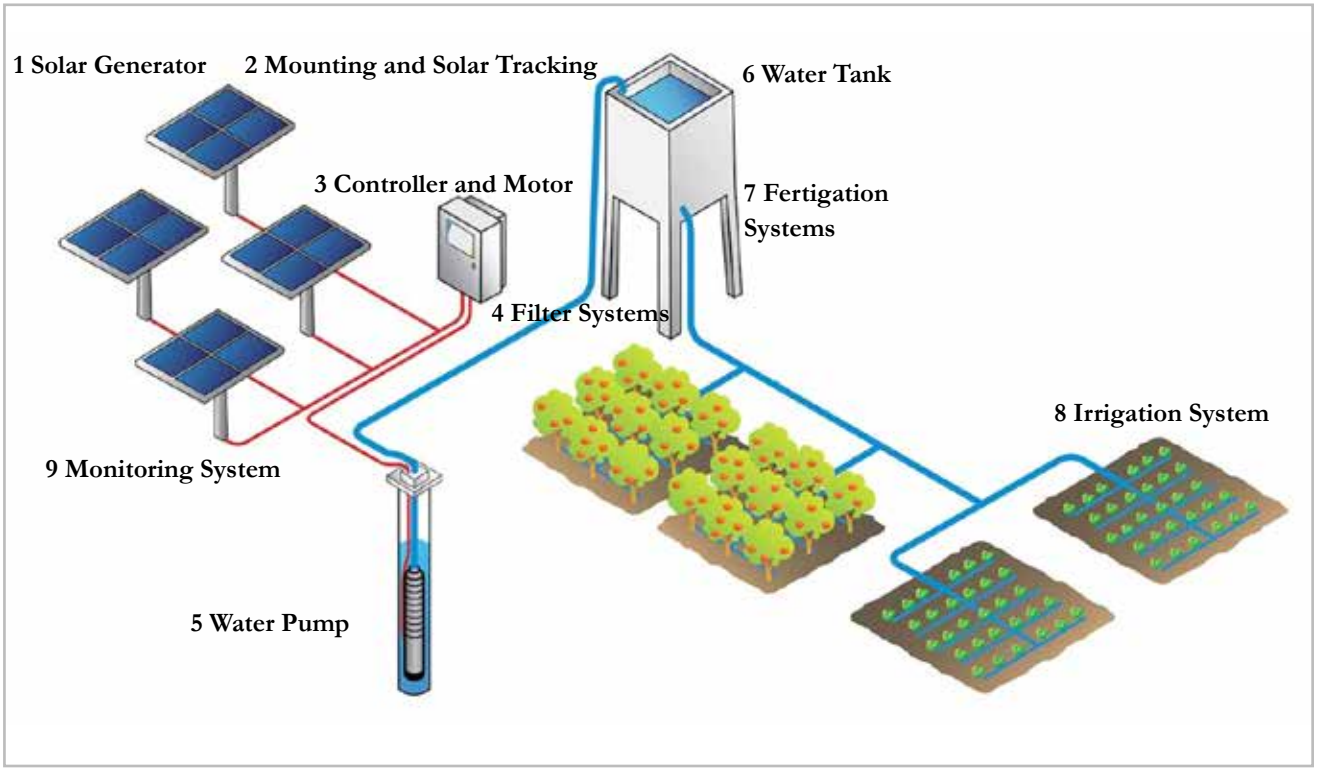
The GET INFORMED module provides essential information for agricultural advisors and financial service providers on major technological aspects, potentials and risks of SPIS. The reader will be enabled to understand the operating principle of SPIS and to differentiate between the individual system components in order to be able to support potential users of SPIS in getting aware of the technology, what it could offer for their farm setting and what needs to be observed to avoid risks.

BRIEF DESCRIPTION OF MODULE

Compared to conventional energy systems, the use of solar energy has some specific characteristics, which are important to know and which must be considered when planning a solar-powered irrigation system (please refer also to the module DESIGN).

The following steps describe in detail the available technology options and individual system components of an SPIS that have to work under constantly varying conditions due to daily and seasonal fluctuations.

To properly operate and manage a solar-powered irrigation system, some measured data is required. In order to provide the farmer with a minimum of system information, the deployment of a basic monitoring system is highly recommendable. Possible monitoring solutions are presented in the last part of the GET INFORMED module.



Main Components of a solar Powered Irrigation System (SPIS) / *Source: iEnergia – Lorentz Chile iEnergia – Lorentz*
Note: The components „Solar Tracking System“ „Filter System“, Water Tank“, Fertigation System“ and „Monitoring System“ are optional in a system set-up.

THE SOLAR ALTERNATIVE

In non-electrified parts of the world, solar energy could help to provide access to an environmentally sound and reliable energy supply. Especially in developing countries, the perspective of grid extension and the establishment of a reliable, uninterrupted electricity supply into rural areas is a distant vision. Rural electrification in economically weak rural areas of Africa, Asia and Latin America will be largely based on investments into local off-grid solutions.

In regions with high solar insolation levels, photovoltaic water pumps are always an alternative worth considering when the objective is to pump irrigation water to crops at locations with no or only limited access to grid power.

If traditional pumping technologies, such as manual or animal-powered pumps, reach their technical limits, the customary means of pumping irrigation water are diesel-, gas- or petrol-driven pumps. Such conventional pumps, however, have the double drawback of requiring much and expensive maintenance and depending on a regular supply of fuel so that unattended operation is not possible.

Particularly in remote areas of developing countries with inadequate spare parts and maintenance structures, conventional pumps can repeatedly suffer outages of several days' duration. The resulting lack of water can result in yield depression or failure. The use of conventional pumping systems may therefore imply an economic risk. With the introduction of photovoltaic water pumps in horticultural and agricultural production, these economic risks may be reduced, as the maintenance intensity of PV-installation is lower as compared to conventional systems. This however, requires the availability of a qualified service structure..

Photo: Andreas Hahn

Old diesel pump

Photo: Andreas Hahn

PV-based water pumping is already widespread in India

Since 2010, solar pumps for irrigation are gaining importance. India, for example, has a large SPIS technology market. There are more than 12 million electric and 9 million diesel irrigation pump sets in operation to provide water for about 39 million hectares of irrigated land. If only 50% of these diesel pumps were replaced with solar PV pump sets, diesel consumption could be reduced to about 225 billion litres/year.

An off-grid solar system which replaces a typical diesel generator unit will save about 1 kg of CO_2 per kilowatt-hour of output. This already takes emissions during the lifecycle of the PV system into account.

PV-powered water pumping also helps avoiding the danger of soil and ground water contamination with fuels and lubricants. A diesel engine produces about 300 kg of waste oil over its lifetime. An environmentally sound disposal of this waste is not everywhere guaranteed. At the same time the availability of PV-pumping technology increases the risk of unsustainable water resource exploitation, if systems are not adequately sized planned.

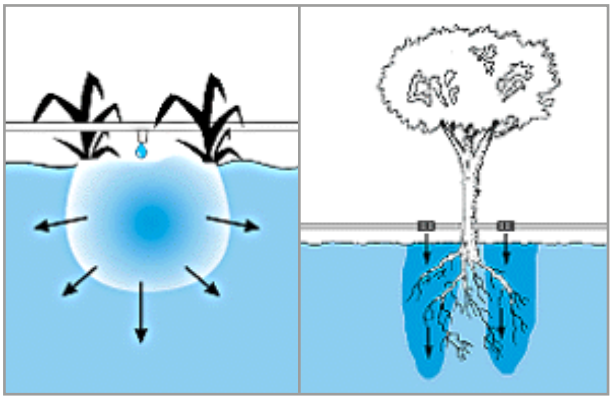
IRRIGATION PRINCIPLES

Irrigation is the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall. By irrigating, the soil water storage in the plant root zone is replenished. Irrigation water is brought to cultivated land through artificial means, such as pipes, hoses or ditches. Irrigation may be applied to provide only a partial or even the entire water requirement of a crop – each farm and crop has its specifics. Water used for irrigation might be taken from nearby lakes, reservoirs, rivers or wells, but also from non-conventional sources like treated wastewater, desalinated or drainage water.

Water quality used for irrigation influences the yield quantity and quality of crops, soil productivity, and the environment. For example, soil structure (stability of aggregates) and permeability are very sensitive to the type of exchangeable ions present in irrigation waters. Sediments in the irrigation water may require filtering and may influence the technology choice. Irrigation requires proper planning and skills as negative and unwanted envirionmental impacts such as soil salinisation and water resource depletion may result from inappropriate practices.

Various methods can be used for irrigation (starting from simple watering plants), and each method needs an experienced farmer to determine the quantities of water to apply and the timing of the irrigation. The three commonly used modern irrigation methods are:

- surface irrigation;
- sprinkler irrigation;
- drip irrigation.



Patterns of soil wetting under drip irrigation
Source: Food and Agricultural Organisation of the United Nations (FAO), 1997

Drip irrigation pipe

Irrigation efficiency

Surface irrigation methods are suitable only for some crops. Basin irrigation for example, is suitable for fodder production, cereals including paddy and maize and leguminous crops, but not for vegetables and other cash crops with a higher sensitiveness to water logging. Theses require furrow irrigation, which again is not a feasible solution for broadcast crops (cereals, leguminous crops). The very high crop water requirements of modern high value crops should force farmers to consider the efficiency of their irrigation methods, thereby managing costs related to water pumping and distribution and a sustainable management of water resources. In terms of irrigation water usage, the field application efficiency is highest with modern drip irrigation methods. On average, 90% of the supplied water can be used by the plant. Sprinkler irrigation systems achieve average field application efficiency of 75%, whereas surface irrigation approaches (furrow, basin and border) do not achieve more than 60% field application efficiency.

Water requirements

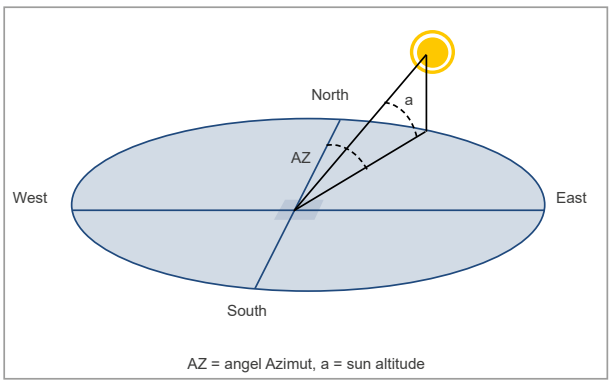
The quantities of water required for irrigation varie with site conditions (climate, soil, surface), crop and production intensity and technique. The specific demand of a crop is expressed as Crop Water Requirement (CWR) using millimetres, litres or cubic metres per square metre or hectare [mm/m^2, l/m^2, m^3/ha]. It requires a site-specific calculation, but the data can often also be provided by extension services. Details of this assessment are described in the DESIGN module.

Irrigation farms move many cubic-meters of water every year with application rates for different crops ranging from 2 to 10 m^3 per square metre. Water is a priced commodity (water fees, pumping costs) and a scare resource. Irrigation design and planning needs to take economic and ecological factors into account. Neglecting these principles may result in a lacking financial and ecological viability.

SPECIFICS OF SOLAR ENERGY

Solar radiation

Solar energy has some specific characteristics, that must be considered when planning a Solar Powered Irrigation System. Solar radiation captured by a solar panel is never constant due to daily and seasonal variations of solar radiation. The intensity of solar radiation on a surface is called irradiance (S). The irradiance is measured in watts per square meter [W/m²]. Solar irradiance varies over the course of the day with maximum values of about 1,000 W/m² at around noon. The energy carried by radiation on a surface over a certain period of time is called global solar radiation (G). The global solar radiation on a horizontal surface is measured by a network of meteorological stations all over the world and is expressed in kilowatt hours per square meter [kWh/m²]. Depending on the site location, seasonal changes and differences in solar radiation between winter and summer months can be significant. By inclining solar panels, the energy yield can be increased. As the optimum tilt angle is site-specific, usually tilted values of the daily global radiation are not measured but have to be calculated. This can easily be done with the help of software tools such as the meteorological data base METEONORM, which provides climate data for almost any location in the world.



Change of global radiation over the course of the year on a horizontal and tilted surface*

Orientation of the solar generator

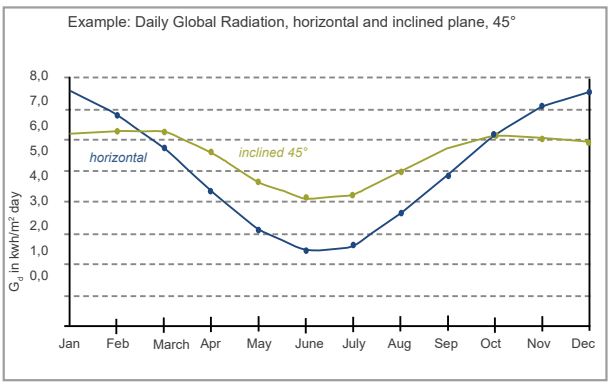
Most solar panels are installed with a fixed tilt angle. In the northern hemisphere, the panels should be facing south to maximize the energy yield, whereas in the southern hemisphere panels should be facing north. Deviations from true north/south are possible but will result in a reduced energy yield. The solar generator is always inclined at the tilt angle α which allows optimizing the solar radiation capture on the panel surface. The tilt angle α should be selected in accordance with the latitude in which the pumping system is installed. Typical values for the tilt angle can be estimated to:

α = absolute value of geographic latitude + / - 10º

To allow rain water and accumulated dust to run off the panel surface, the tilt angle should be at least 15°, even if the system is installed close to the equator.

For applications with focus in winter months, the tilt angle might be increased up to +10º, for summer months the tilt angle might be reduced up to -10º. Another method to further increase the energy yield of a solar generator is the so called solar tracking which will be described in detail in part two of this module MOUNTING AND SOLAR TRACKING.

**Source: Reinhold Schmidt, Aplicaciones de Energía Solar Fotovoltaica; Diseño, Implementación, Experiencias, Junio 2012*



Daily movement of the sun in southern hemisphere*

TECHOLOGY OPTIONS

Operating Principle: The operating principle of a photovoltaic irrigation system is simple. A solar generator provides energy for an electric motor pump, which in turn pumps water into an elevated water tank or injects water directly into an distribution system. A specific characteristic of PV pumping systems is that generally no battery back-up is required. A water storage tank can be employed for storage, thereby reducing maintenance costs and increasing the overall system reliability. Common to most system configurations is that they require only little maintenance.

SPIS with Storage: In this typical configuration of a solar powered irrigation system the solar generator (via the controller/inverter), provides electricity for a submersible motor pump unit, installed in a well. The pumped water is stored in a water tank and irrigation is done by gravity. The irrigation system pressure depends on the position of the tank and the height of the water level in the storage tank.

In order to secure a safe system operation, two safety means are necessary:

- awater level sensor, installed in the storage tank, in order to avoid an overflow by switching off the pump;
- a second water level sensor, installed in the well, to avoid dry running of the pump.

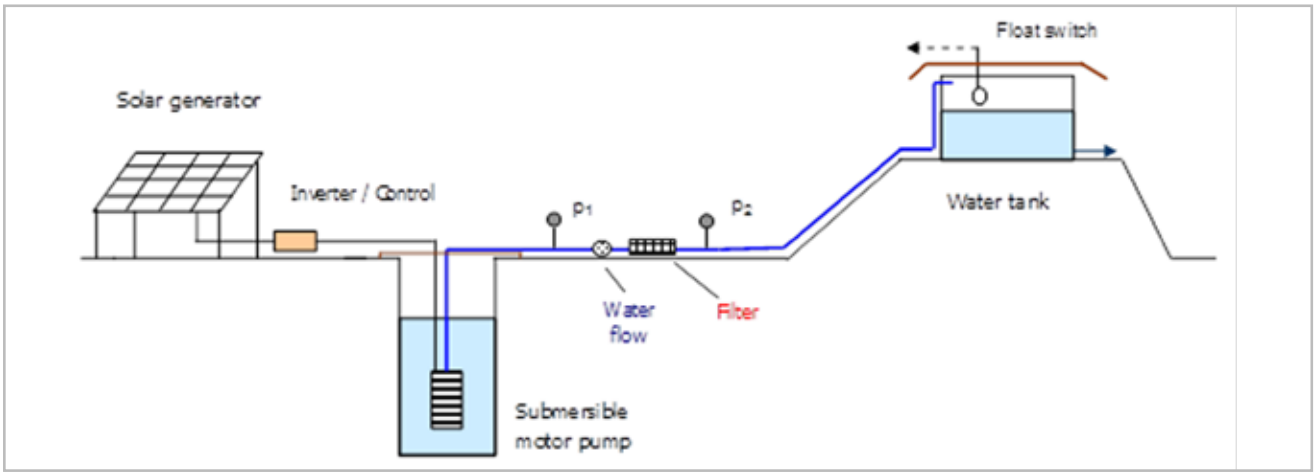
SPIS without Storage: In this configuration, the solar pump is directly connected to the irrigation system thus, the solar water flow and the irrigation water flow are the same. If a solar generator with fixed installation is chosen (see also module part on SOLAR GENERATOR), the irrigation water flow corresponds to the actual solar irradiance. As a result, water flow and pressure in the irrigation system will vary over the course of the day. The main advantage of this configuration is the simple installation and the possibility for cost reduction. However, the direct connection of the solar pump and the irrigation system leads to a dynamic and varying hydraulic load. In this case, planning and operating is far more complex as compared to the tank system.

Furthermore, the use of an additional electric dosing pump for fertigation is advisable.

Irrigating with a variable water flow and pressure is not a good and practical solution for the farmer. The following alternatives can be taken into account:

Automatic irrigation with water volume control: The irrigation process is usually time controlled (e.g. irrigation of plot 1 for 2 hours/day). Nevertheless, applying the correct amount of water at variable conditions is difficult. A possible solution is the installation of an automatic irrigation system with water volume control. The farmer determines the required irrigation water amount per plot and automatic valves close as soon as the target value is reached. Although an automatic volume controlled irrigation management should be recommended for direct driven SPIS, only few systems are yet available. Furthermore, for smallholders located in remote areas of developing countries, automatic irrigation is probably not a viable option.

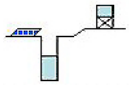
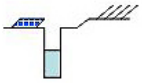
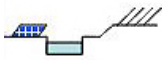
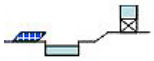
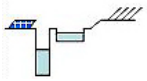
Adapting the irrigation field size: It is possible to adapt the size of the irrigated area to the variable output of the solar pump (which corresponds to the available irrigation



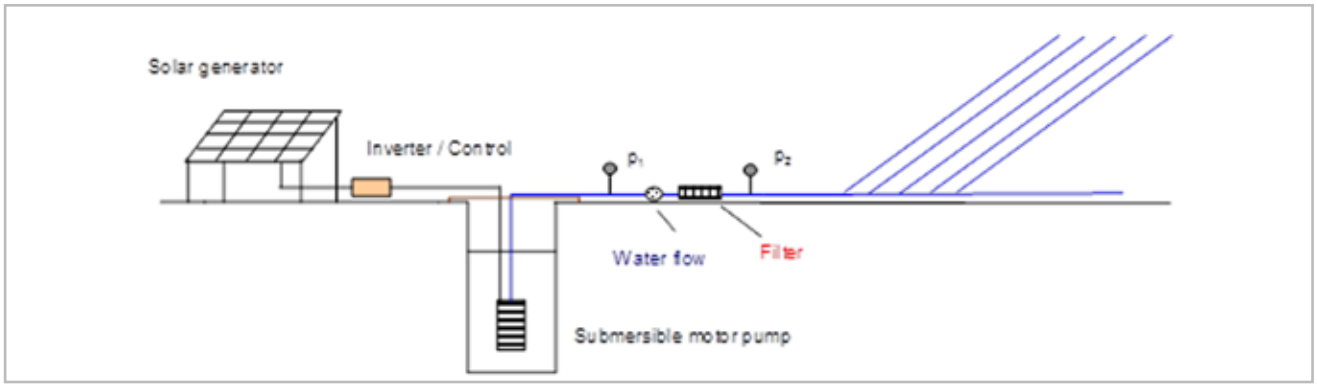
SPIS with Storage / *Source: Reinhold Schmidt, Aplicaciones de Energía Solar Fotovoltaica; Diseño, Implementación, Experiencias, Junio 2012*

water supply). This means that in the morning and afternoon with lower solar irradiance only smaller plots will be irrigated. Irrigation of larger plots is possible around noon when more solar power is available. This solution is quite demanding in terms of technical understanding and irrigation management.

Solar Tracking: Solar tracking is the best technical solution if the task is to directly pump water into a distribution system (refer to part 2 of this module on MOUNTING AND SOLAR TRACKING). The hydraulic load of the irrigation system should be adapted to the motor pump capacity and that a high uniformity of water distribution on the field is achieved. This is part of the technical design process of the SPIS, described in the DESIGN module.

						
Type	**well watertank**	**well direct irrigation**	**surface direct irrigation**	**surface watertank**	**well, surface direct irrigation**	**PV on-grid irrigation included**
Main characteristics	low head steady pressure night reservoir	head varies changing pressure only daytime	head varies changing pressure only daytime	low head steady pressure night reservoir	head varies changing pressure longterm reservoir	system pressure 24h/7days
Irrigation	gravity fed drip / micro	directly operated by pump drip-sprinkler	directly operated by pump drip-sprinkler	gravity fed drip /micro	directly operated by pump drip-sprinkler	gravity or direct by AC pump drip-sprinkler
Solar generator	fixed installation	solar tracking or other methods	solar tracking or other methods	fixed installation	fixed installation solar tracking or other methods	fixed or tracked
Fertigation	additional equipment necessary	additional equipment necessary	simple, on suction side	simple, on suction side	simple, on suction side	suction or additional equipment necessary
Motor pumps	submersible	submersible	surface	surface	submersible / surface	any AC pump

Most common configurations of SPIS* *(Fertigation is the injection of fertilizers, soil amendments, and other water-soluble products into an irrigation system)*



SPIS without Storage*

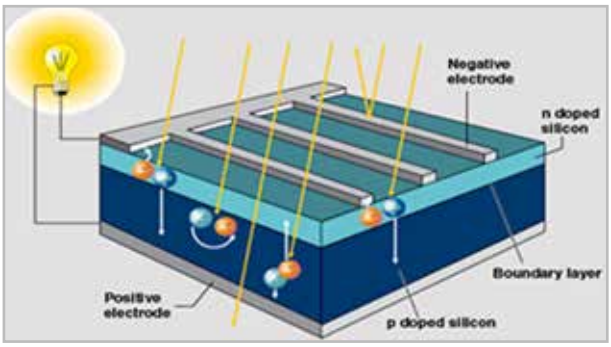
1 SOLAR GENERATOR

The solar generator provides the necessary energy to operate the motor pump unit. It is made of individual solar cells, which make use of the so called photovoltaic effect that converts solar radiation directly into electricity. Solar cells are made of specially prepared semiconductor materials such as crystalline silicon. When light falls onto the surface of the semiconductor, an electric field develops. By connecting a wire to the back and front side of the solar cell, the voltage of the electric field causes a current to flow, which can be used to drive a load.

To protect the cells against mechanical stress and humidity, the cell strings are embedded in a transparent bonding material (e.g. EVA), which also insulates the cells electrically. For structural stabilization and electrical insulation, embedded solar cells are usually placed between a plastic cover on the rear side and a glass cover on the front side. Panels fabricated in a laminating process are also described as laminates. To protect the fragile laminate and to provide a mounting possibility, standard solar panels usually come with a rigid aluminium frame. Depending on the required electrical output (voltage, current and power), several solar panels are connected in series and/or in parallel to form the solar generator.

Solar panels are usually certified to International Electronical Commission*. These approval certificates have become generally accepted worldwide as one of the quality marks for solar panels. IEC standard testing, however, does not assess the durability of solar modules for 25 years. Therefore, additional testing of the solar modules is preferred. Some manufacturers even exceed IEC standards and simulate the aging of solar panels in climate chambers to ensure that modules satisfy the highest quality criteria upon leaving the production line. Standard panels typically come with a 10 year product guarantee and a linear 25 year performance warranty which guarantees at least 80% power output by the end of the 25th year.

IEC - International Standards and Conformity Assessment for all electrical, electronic and related technologies



Functional principle of a solar cell
Source: Solarpraxis AG, 2015

Solar panels are rated in peak watts (Wp) according to their output under internationally defined Standard Test Conditio:
STC: irradiance = 1,000 W/m²
Cell temperature = 25°C
Air mass (AM) = 1.5)

The panels' electrical power mainly depends on the solar irradiance captured by the panel and the solar cell temperature. Solar cell temperatures increase significantly under normal operation and may easily reach 40 - 65 ºC, depending on the site-specific conditions. This leads to a lower electrical power output, as compared to STC. The so called temperature coefficient (TC) describes the power reduction for each degree Celsius increase in temperature, and for crystalline silicone cells it is approximately -0.5 % per ºC.

2 MOUNTING AND SOLAR TRACKING

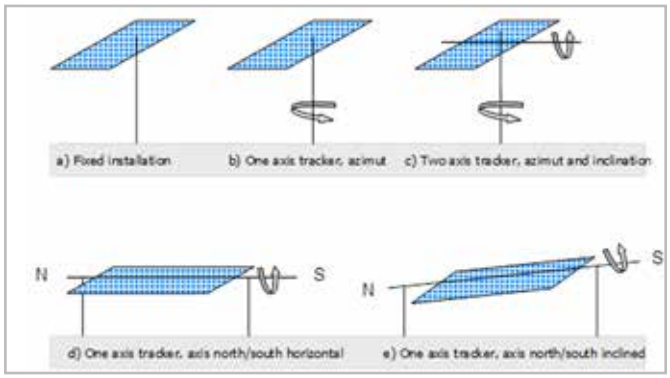
Apart from the irradiance and cell temperature, the output of a solar panel is also dependent on the orientation and tilt angle of the panel surface. To maximize the output, a site-specific optimal orientation has to be found.

Mounting options: Solar panels are usually mounted on a metal structure with the following alternatives:

- Installation with a fixed tilt angle with orientation north or south;
- installation on a solar tracker with varying orientation;
- installation with a fixed tilt angle with orientation east and west.

The fixed installation of solar panels is the typical and most reliable way. Metal supports that are pile-driven into the ground are generally recommended for larger systems. They make the utilization of concrete foundations redundant and save labor and material cost. However, in developing countries simple concrete foundations are often used for smaller installations and represent an appropriate solution if static requirements are met.

To brake galvanic corrosion, select materials with similar corrosion potentials or to break the electrical connection by insulating the two metals from each other. If these basic rules are observed, fixed mounting systems will have a high reliability and a similar lifetime such as the solar panels (+25 years).



Technical options for solar tracking
Source: Reinhold Schmidt, Aplicaciones de Energía Solar Fotovoltaica; Diseño, Implementación, Experiencias, Junio 2012

Tilted single-axis tracker
Source: Reinhold Schmidt

Solar tracking has two advantages:

- Gain of additional solar radiation – the amount of solar radiation received by the solar panels increases between 25 – 35% (annual mean value), depending on solar tracker type and installation site.
- Even distribution of solar irradiance over the day – the generated electricity and thus, the pump's water flow is almost constant over the day. This is quite important for direct driven solar irrigation systems (without water storage tanks).

Disadvantages of solar tracking: While higher yields and almost even water flow are advantages of solar trackers, disadvantages are:

- Solar tracking is quite costly and increases substantially the overall system cost;
- the mechanical parts and the electrical motor require regular maintenance and spare parts.

This has to be kept in mind in particular for installations that are planned for remote areas or areas with limited technical services.

Alternatives to solar tracking: A relatively new alternative is to install a solar generator in east and west direction. Here, instead of using a solar tracker, more solar panels are applied facing east and west. With decreasing panel prices, this technical solution could be interesting for regions with lacking maintenance structures and spare part supply. Depending on the tilt angles chosen, the course of solar generator output and water flow is at least similar to an installation with solar tracker.

This alternative is, however, not a vialble option for most small and medium farm sizes due to the high investment costs and is more common in large scale PV installations in the industrial sector.

Mounting structure and theft: The type and the quality of the mounting structure are also a determining factor with regard to the risk of theft of the PV panels. With the increased number of photovoltaic installations worldwide, also the risk of theft is increasing. Especially solar panels are on demand and need to be protected against theft. Fixed mounting strutures with lock-tied nuts, elevated strcutures, fenced areas or floating PV-systems provide a comparably high level of security.

3 CONTROLLER AND MOTOR

Controller

The pump controller is the link between the PV generator and the motor pump and adjusts the output frequency in real time according to the prevailing irradiation levels. Modern controllers incorporate high-efficient power electronics and utilize Maximum Power Point Tracking (MPPT) technology to maximize power use from the PV generator. Additional features to increase system reliability of controllers include over and under voltage protection as well as protection against reverse polarity, over load and over temperature.

Innovations in DC/AC inverter technology have led to the development of specially designed pump inverters that can drive conventional AC motors. Non-compatible inverter/motor combinations may reduce the expected lifetime of the conventional AC motor. Therefore, well matched and tested controller/motor combinations are recommended from a techncial point of view to increase system reliability.

Photo: Andreas Hahn

Pump controller with display and LED fault indicator

Motor

Electric motors of solar water pumps are powered by direct current (DC), or by alternating current (AC) sources. DC-motors are mainly used for small to medium size irrigation schemes, while AC-motors gain importance in applications where higher output/head combinations are required. Since DC motors usually have a higher efficiency than AC motors of a similar size, they are often the first choice of solar pump manufacturers. In particular water-filled brushless DC motors are gaining importance because they are maintenance-free and do not suffer from frequent starts/stops, typical in solar-powered systems. Some solar pumps are still equipped with comparably cheap brushed DC motors. The main disadvantage of brushed motors is that brushes are subject to wear and tear and need to be replaced in regular intervals (approximately every two years). In terms of system reliability, the use of brushed DC motors is not recommended because a regular maintenance in remote areas of developing countries cannot be assured.

Even though brushed DC motors require considerably lower initial investment their lifecycle costs are a disdvantagne due to their vulnerability and short life span. Brushless DC motors are considerably more expensive, but have a three to four time longer life span and are less maintenance prone.

4 FILTER SYSTEMS

A general problem of micro-irrigation systems is clogging – the smaller the diameter of the drippers and mini tubes, the higher the tendency that the narrow passages get blocked. Clogging can be the result of an accumulation process or an immediate impact and is based on unorganic material, like sand and clay, as well as organic material, like algae and bacteria. Filters can reduce or avoid these problems and must be placed after the pump (e.g. at the well head). Filters must be adapted to the flow rate of the pump. It is important that pressure loss, while passing through the filters, is minimized and maintenance is easy. Usually the filters are controlled with two pressure gauges, one at the inlet and the other at the outlet of the filter system.

Filters must be cleaned periodically, depending on the charcteristics and the quality of irrigation water (i.e. sediments, dissolved salts, etc.). Surface water must be cleaned in one to three stages because it is often heavily loaded with sediments, and may start with a sand separator.

Initially, a water analysis can give information on the size and amount of particles and identification of the correct filter technology. This may, however, not be a feasible solution for all farm sites as test kits or laboratories are often not accessible. Different filter types are commonly used in irrigation systems, but not all of them are suitable in combination with a solar pump.

Sand separator

Screen Filter: A filter using a rigid or flexible screen to separate sand and other fine particles out of irrigation water. Typical screen materials include stainless steel (mesh), polypropylene, nylon and polyester. The filter intensity is often expressed in Mesh, which gives the amount of strings per inch (e.g. 160 Mesh = 160 strings/inch). Usually, the pressure loss in screen filters is quite high; therefore they are not recommended for use in SPIS.

Disc Filter: A disc filter element contains a stack of compressed discs with an overlapping series of grooves. Unfiltered water passes through the stack of tightly compressed discs. The water is forced to flow through the interlocking grooves of the disc rings where debris is trapped. Dirt particles are caught on a very large surface, which is the reason for the comparatively low pressure loss. For manual cleaning, the filter rings must be taken out of the enclosure and rinsed with clean water. It is not appropriate to use disc filters as a pre-cleaning unit.

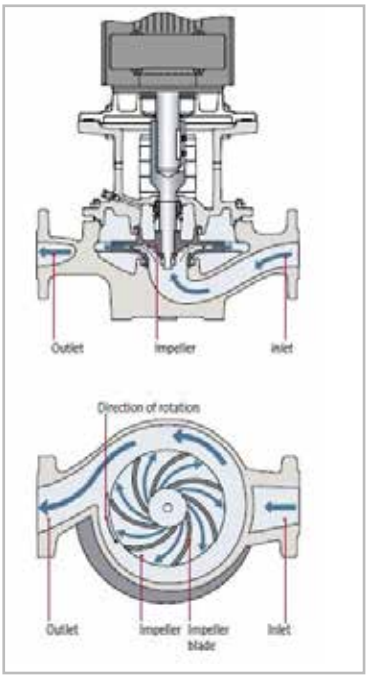
Organic materials can create a thin film around the disc filter and would clog it. Using back flush technology, disk filters may also be cleaned automatically. When using disc filters for SPIS, it is advisable to install the next larger model to reduce the characteristic pressure drop, which is proportional to the flow rate or to install two filters working in parallel. The maintenance intervals should be short to reduce the accumulated pressure loss significantly. Automatic back flush systems work with significantly higher pressure and therefore do not suit the pressure minimizing concept of SPIS.

Granulate/Sand Filter: Filters designed to remove organic debris and particulates from water. Sand filters are simple, effective and require very little attention. The body is a volumetric and typically metallic vessel, which can withstand higher working pressure. Water is routed through the sand-filled tank where the sand traps large and small particles. Eventually the dirt accumulates in the space between the sand particles, making it harder for the water to pass through. This causes the pressure in the tank to rise which signals that the tank needs to be backwashed by reversing the water flow. Backwash water is used to clean the filters and flush out the suspended solids that have been trapped in the media bed. Water for backwashing can come either from the filters themselves or from an external source of clean water (such as a domestic water line or a storage tank).

5 WATER PUMP

Two types of pumps can typically be found in today's solar pumping systems – centrifugal and helical rotor pumps. Depending on the water source, there are two different possibilities for pump installation – submersible or surface. Using control switches (such as float switches in water tanks and wells), submersible pumps can be operated in automatic mode. In contrast, surface mounted pumps usually require the attendance of an operator who regularly checks the priming behaviour of the surface pump. Although the use of primary chambers and non-return valves can prevent loss of prime, in practice self-start and priming problems are experienced. Therefore, surface pumps are regarded less reliable than submersible pumps.

Solar water pumps are generally constructed from non-corroding stainless steel and are designed to pump clean water without any solids and fibres. The lifetime of a submersible motor pump strongly depends on the water and installation quality. If the pump is installed in a drilled well with a proper well casing (and thus reduced sediment intrusion), submersible pumps may reach lifetimes between 7-10 years. In very poor wells and boreholes with high sediment content, the hydraulic part of the water pump may have to be replaced after 2-3 years.

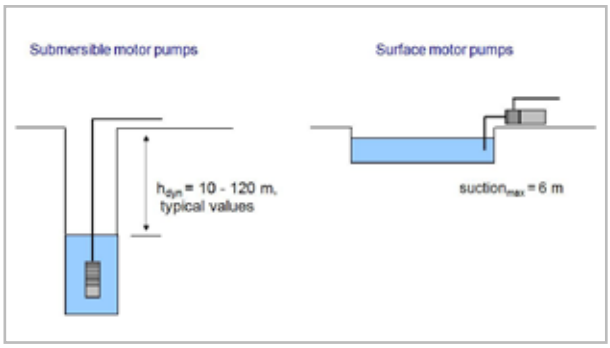


Centrifugal pump
Source: Grundfos, 2014

Centrifugal Pump:
A centrifugal pump creates an increase in pressure by transferring mechanical energy from the motor to the fluid through the rotating impeller. The fluid flows from the inlet to the impeller center and out along its blades. The centrifugal force hereby increases the fluid velocity and consequently, also the kinetic energy is transformed to pressure. The pressure can be increased by simply adding several stages in series. Centrifugal pumps are generally applied where pumping heads are low and water demand is high. For this reason centrifugal pumps are the preferred option for use in irrigation systems.

Helical rotor pump
Source: Dynapumps, Netsch, 2015

Helical Rotor Pump:
A helical rotor pump is a type of progressive cavity pump that works by the rotation of a helical rotor, when sealed against a helix wall, pushing discrete sections of material through the device. This corkscrew-like action provides a pulse free flow, and valves are unnecessary as the helical rotor seals the discrete sections of material. The flow rate is determined by the rotor speed, and is independent of outlet pressure. Helical rotor pumps are typically found in applications with high pumping heads and low water flow rates, such as for drinking water supply.



Options for water pump installation
Source: Reinhold Schmidt, Aplicaciones de Energía Solar Fotovoltaica; Diseño, Implementación, Experiencias, Junio 2012

6 WATER STORAGE

A water storage accumulates the water provided by the pump unit during sunshine hours. There are numerous ways to store the water, which can range from simple open dug reservoirs, concrete and plastic tanks to expensive and elevated metal tanks.

Open plastic foil-lined reservoir

Open reservoirs are inexpensive and relatively easy to construct, but the big disadvantages are the extremely high evaporation losses of water and the easy entry of debris and sediments. Open tanks made of concrete are more advanced but also suffer from evaporation of water, entry of debris and sediments as well as algae growth. These effects can be significantly reduced by covering the tank, e.g. with a plastic foil or corrugated iron sheet. Ready-to-use plastic tanks are available in different sizes, easy to install and often constitute a viable option for small irrigation schemes.

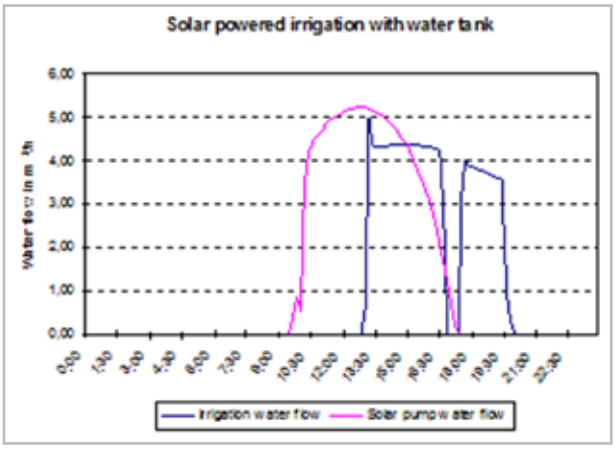
Elevated water tanks: This is the classical configuration of a solar powered irrigation system. The pumped water is stored in an elevated water tank and irrigation is done by gravity. The irrigation system pressure depends on the height of the water level in the storage tank.

In order to secure a safe system operation, a water level sensor should be installed in the water tank to avoid an overflow by switching off the pump. If a submersible pump is installed in a well, a second water level sensor is required to protect the pump from dry running. Such sensors are often already integrated in the motor pump. As water tanks usually store huge amounts of water, it is important that the foundation and support structure of the water tank meets the static requirements.

Covered water tank made of corrugated iron sheets

Once installed, the operation of an SPIS using a water tank is quite easy. The graph shows the daily course of the pump and irrigation water flow (by gravity). The sinusoidal curve (pink) shows that the solar generator is installed with a fixed tilt angle and azimuth – the pump water flow varies over the course of the day, according to the actual solar irradiance.

The first irrigation interval starts at 1:30 pm by opening a valve (blue curve). The irrigation system experiences an almost constant pressure and irrigation water flow. The amount of water flowing is determined by the connected water distribution system. The irrigation pressure is dependent on the water level in the tank. Typical values vary between three and 10 meters (approximately 0.3-1.0 bar). A tank system even allows for night-time irrigation. The second irrigation interval starts immediately after sunset and lasts until 8:30 pm.



Solar powered irrigation with water tank

Source: Reinhold Schmidt, Aplicaciones de Energía Solar Fotovoltaica; Diseño, Implementación, Experiencias, Junio 2012

7 FERTIGATION SYSTEMS

Fertigation is the injection of fertilizers, soil amendments, and other water-soluble products into an irrigation system. Fertigation is practiced extensively in commercial agriculture and horticulture and is mainly used to spoon-feed additional nutrients. It is usually practiced on high-value crops such as vegetables and fruit trees. Especially micro-irrigation systems are well suited to fertigation because of their frequency of operation and because water application can be easily controlled by the farmer.

In order to be injected, fertilizers must be soluble. Fertilizers delivered as a solution can be injected directly into the irrigation system, while those in a dry granular or crystalline form must be mixed with water to form a solution. Liquid fertilizer often adds the hazard of clogging because a chemical reaction with the organic and un-organic matter in the irrigation water happens frequently. It is advisable that after the use of liquid fertilizer an application with pure water is done to reduce the clogging effect.

In a drip irrigation system, fertigation technology can also be used to inject chemicals to dilute debris and other materials which tend to block the outlets or narrow bends. After a certain time, the treated water including the dissolved material is flushed out of each drip line. To adjust the fertigation system to the needs of the individual crops and to find the right fertilizer diluting chemicals requires the assistance of qualified water engineers. Depending on the water quality, a permanent treatment program may be required.

The simplest form of fertigation is the **injection of liquid fertilizer through the suction side of a surface pump**. Initially the liquid fertilizer must be diluted to a water equivalent concentration. Afterwards a hose with a throttle valve must be connected with the suction pipe of the pump and the other side placed into the fertilizer tank. Very often, the liquid fertilizer is corrosive and must match with the material of the pump impeller and body.

Photo: Andreas Hahn

Fertigation system

If submersible pumps are deployed for direct irrigation water injection, or irrigation is done by gravity (e.g. using elevated water tanks), fertilizer has to be applied in different ways. Here, the farmer can chose from a variety of injection equipment, including:

- Differential pressure tanks;
- venturi nozzles;
- electric metering pumps;
- water-powered dosing pumps.

Often SPIS run at comparably low working pressure (0.2-0.5 bar) and the injection technology must cope with it, which is not generally the case.

Differential pressure tanks, often referred to as "batch tanks," are simple injection devices. If a set amount of fertilizer is to be injected and concentration during the injection is not critical, the use of batch tanks may be appropriate. If the chemical concentration must be kept relatively constant during injection, batch tanks are not appropriate for SPIS.

The **venturi nozzle** is a common device for fertilizer injection. It makes use of the "Venturi hydraulic effect". Because of the high pressure loss of Venturi nozzles and the fact that the pressure provided by a photovoltaic water pump is not constant (this would cause a strong fluctuation in the fertilizer concentration), the venturi nozzle is not recommended for use in SPIS.

Electric metering pumps are the most expensive injection devices. If a constant and precise injection concentration is needed, positive displacement pumps are the preferred option for use in SPIS.

For off-grid applications, **water-driven dosing pumps**, installed directly in the water supply line, are suitable for use in SPIS. Water-driven dosing pumps work at comparably low system pressures and the dose of concentrate will be directly proportional to the volume of water entering the dosing pump, regardless of variations in flow and pressure which may occur in the main line. The high dosing precision reduces the risk of overdosing, thus contributing to protecting the environment and optimising the use of fertilizer (and thus reducing production costs).

8 WATER DISTRIBUTION SYSTEMS

Water is the most important input required for plant growth in agriculture production. Irrigation is the controlled application of water through manmade systems to supply water requirements not satisfied by rainfall distribution. Various methods that can be used for irrigation (starting from simple watering plants with a pot or a bucket). The choice of a particular irrigation system mainly depends on the crops to be irrigated, the underlying water availability, irrigation water requirements and energy supply as well as the financial capacity of the farm household.

Each method needs an experienced farmer to determine the quantities of water to apply and the timing of the irrigation. In the design process of a solar irrigation system it needs to be taken into account that demand and supply of irrigation system water will vary throughout the year (see also DESIGN module). If a detailed technical and financial analysis confirms the profitability of the irrigation project, the farmer can choose from three commonly used irrigation methods:

- Surface irrigation;
- sprinkler irrigation;
- drip irrigation.

Almost all existing irrigation methods can generally be used in combination with photovoltaic water pumps. The size of the PV generator is mainly determined by the water and pressure requirements of the irrigation scheme. Water-saving irrigation technologies, working at comparably low operating pressures, are the preferred option in connection with PV pumping systems.

Photo: Jan Sass

Solar-powered drip irrigation is the "marriage" of two systems that have proven to have an enormous independent impact:

- Drip irrigation is an extremely efficient mechanism for delivering water (and fertilizer) directly to the roots of plants. It increases yields and allows for introduction of new (potentially high-value) crops in regions where they could not be sustained by rainfall alone. However, it should be considered that changing to water intense crops may affect the overall water balance.
- In rural off-grid areas, solar-powered pumps save potentially hours of labour, where water hauling is usually done by employing costly petrol or diesel engine-driven pumps. They are durable and immune to fuel shortages and in the medium term to long-term cost less than traditional diesel-powered generators.

When used in tandem in a systematic way, these technologies allow for production of e.g. market garden vegetables during the dry season, with a potential for providing a source of income and nutrition.

Suitability of irrigation methods with PV pumping

Distribution method	Typical water application efficiency	Typical head	Suitability for use with PV Pumps
Flood Irrigation	40-50%	0.5 m	Depends on local conditions
Open channels	50-60%	0.5-1 m	Depends on local conditions
Sprinkler	70-80%	10-20 m	Yes
Drip/trickle	85-95%	1-2 m	Yes

9 MONITORING SYSTEM

A monitoring system is a helpful tool to supervise and manage a Solar Powered Irrigation System. Some solar pump manufacturers have included monitoring systems in their product portfolio.

Farmers, integrating a monitoring system benefit from the:

- Provision of system data for the acceptance test after installation;
- possibility to observe the system's operation and performance;
- control of water provision and consumption;
- management and control of water resources, to avoid negative environmental impacts (e.g. ground water depletion).

Depending on the site-specific conditions and objectives, a monitoring system can be quite sophisticated or simple. In order to provide the farmer with a minimum of system information, the deployment of a basic monitoring system is recommended. Operated by the farmer on site, the monitoring system allows manual readings of pressure, water flow and water level and helps to assess the performance stability of the system.

The basic monitoring system is composed of:

- Water flow meter;
- pressure gauge at the filter inlet (P1);
- pressure gauge at the filter outlet (P2);
- water level dipper.

In case of a direct driven irrigation system, the measured pressure at P2 is the input pressure of the irrigation system. The water level dipper is a simple tool to check the water level in a well. Once the metal electrode reaches the water table, a light will flash and the exact value can be read from the dipper tape. Checking the water level several times over the course of the day gives an indication on the dynamic behaviour of the well. The dynamic water level is an important parameter to determine the total pumping head (refer to DESIGN module).

For more detailed information and deeper analysis of the system performance, the basic monitoring could be supplemented with sensors to measure:

- Solar irradiance (e.g. on horizontal and inclined surface)
- rainfall;
- relative humidity;
- wind speed;
- total pumping head.

The use of water level meters is seldom, but is highly recommended. A simple manual gauge can be a useful alternative to a costly sensor.

More sophisticated and expensive monitoring devices may include automatic data logging. The data logger continuously records and stores all system parameters over a longer period of time. Special evaluation software allows for quick data analysis on site. In remote areas, not connected to the public grid, data loggers are usually solar-powered and may even include modern communication devices (GSM) with the possibility to check system performance via smart phones (also refer to chapter MAINTAIN).

Basic monitoring system

FURTHER READING, LINKS AND TOOLS

Links

- Manual and Tools for SPIS – Stocktaking and Analysis Report
- EPIA, Sustainability Working Group Fact Sheet – The Carbon Footprint
- NREL, Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics, 2012
- Harnessing Solar Energy in India", Report by the Centre for Study of Science, Technology and Policy, 2010
- KPMG, „The Rising Sun – A point of view on the Solar Energy Sector", 2011
- Deutsche Gesellschaft für Sonnenenergie (DGS): Planning and Installing Photovoltaic Systems – A Guide for Installers

Tools

- PVGIS: http://re.jrc.ec.europa.eu/pvgis
- METEONORM: http://www.meteonorm.com/en
- NASA: http://eosweb.larc.nasa.gov/sse
- Some mounting / tracking system manufacturers provide product-specific design tools which can usually be found on the manufacturer's website

Further reading

- Reinhold Schmidt, Aplicaciones de Energía Solar Fotovoltaica; Diseño, Implementación, Experiencias, Junio 2012

Photo: Lennart Woltering

PROMOTE + INITIATE

Photo: Lennart Wolfering

MODULE AIM

The promotion of modern and efficient irrigation technology and approaches requires a proactive promotion effort by development practitioners and agricultural extension service providers. This module of the manual guides through the most important process steps that have to be considered when disseminating or scaling-up technology options such as Solar Powered Irrigation Systems.

Promotion activities are the most visible part of any promotion campaign. No such campaign can be conceived, however, without a thorough preceding analysis of objectives, target group and stakeholders and the related potentials and opportunities, risks and restrictions. In addition, no campaign can be approached without considering a systematic follow-up from the beginning onwards.

This module addresses thus not the farmer in the first place, but the development practitioner and the agricultural extensionist / advisor planning the promotion of an irrigation technology or innovation.

The PROMOTE + INITIATE module does not depart from a given bias or pre-choice of the SPIS technology, which may only be promoted if a number of economic and environmental preconditions are met and if a related analysis confirm the potential of this technology to achieve the expected result.

BRIEF DESCRIPTION OF PROCESS

The module starts with an insight into three important steps of analysis that need to be carried out for any possible technology option prior to its promotion. This analysis is important to clarify objectives and target group of the envisaged promotion campaign. It does not pre-empt the detailed analysis of the viability of the technology in a given specific farm context, which is the aim of the following modules of the manual.

Once objectives and the stakeholders and the target group of promotion interventions have been clearly outlined, promotion material has to be produced and the implementation of the promotion activities have to be planned and approached, thereby focussing on the objectives and the target group.

The initiation of actual projects or investments that have been motivated by the promotion campaign is again a process that requires proactivity of the development practitioner and the agricultural advisor. In the last process steps of the PROMOTE + INITIATE module information is providied on how to pursue this task.

1 ANALYSE POTENTIALS AND OPPORTUNITIES

The objective of the promotion effort is to provide a specific group of farmers with information enabling decision making in view of securing and/or increasing the agricultural production potential by modernising and improving their irrigation capacities. It is therefore important to carry out a preliminary reflection of the possible benefits of a particular technology option, the prospect of its application in the specific targeted rural context and the chances resulting thereof.

Through familiarising himself with the introduction of the SPIS technology in the preceding module GET INFORMED the agricultural advisor or the development practitioner (the **promoter**) will already get a comprehensive overview of the main aspects of the technology. Further reading may be required to deepen the understanding of specific aspects. In a further step, the promoter should obtain information on particular products and system solutions offered on the local market. In most cases, this research will already limit the range of technology options that are available for a potential employment in a given region.

Important: Not all technology solutions and the related services are available everywhere, local markets may be limited in the range of technology options offered. Even within the same country substantial regional differences may be found!

With a good information basis on the availability and specifics of technology options the promoter can start analysing the potentials of different solutions or approaches and reflect on opportunities resulting thereof. This task does not require scientific studies or research.

It is important that the promoter triangulates information that is provided from different relevant sources:

- Manufacturers and technology service providers advertise and market their products intensively and outline their advantages and potentials – this information can be easily obtained from suppliers and system integrators, and via the websites of the manufacturers.
- Farmer organisations may already have compiled or evaluated experiences of their members with a specific technology like PV water pumping and micro irrigation. Through farmer organisations the promoter may also get contact to lead farmers that have already piloted the technology in their context – this information can be obtained by approaching these organisations.
- International and national development stakeholders (including NGOs) may already have implemented and evaluated pilot projects based on the technology – this information should be available in sector working groups etc.

Recommendation: When approaching technology providers, farmer organisations and development stakeholders for information always ask for reference projects. A visit to these projects / installations and an information exchange with the operating farmer is a worthwhile exercise.

The information obtained from different sources should be analysed focussing on a number of **key questions**:

- **Availability and applicability**: Which technology options (and services related hereto) are available in the specific promotion area, and what are the known requirements and limits for their application (water availability, characteristics and depth of water table in the short and long run, solar irradiance, alternative energy sourcing, morphology and soil conditions, security)?
- **Suitability**: What is the stated usual range of farm sizes applying the technology, and what are reasons for a limited suitability for other farm sizes?
- **Comparability**: What are the stated advantages and disadvantages (technical, economic, environmental) of the technology (SPIS) compared to technical alternatives (traditionally powered irrigation systems)?
- **Acceptability**: What are known experiences of different farm sizes / farming contexts with the technology, are there known limits in their acceptance by particular groups, and what are the experiences with costs and benefits of such systems?
- **Supportability**: What are existing or planned support mechanisms and support programmes in the specific area, who can provide which assistance, and are there existing promotion and subsidisation programmes accessible for the farmer? An important aspect is the availability of subsidies for particular irrigation purposes. Subsidies may exist for PV-based modernisation options, but also for diesel or grid-based electricity, which may have a significant impact on the financial viability.

Based on this information the promoter will be able to establish a profile of the different technologies to be included in the promotion campaign. This profile will have to be specific with regard to:

- Possibilities of employing the technology for a specific purpose;
- main benefits for the farmer (impacts on irrigation operation, farm labour, crop production, market access, farm budget);
- main requirements and preconditions (water availability in the short and long run, land resources, works, adaptation of crop production and marketing, adaptation of irrigation operation, training needs);
- support mechanisms and offers (private sector service provision, extension and advisory services, promotion and subsidisation schemes);
- negative impacts of framework conditions on environmental, economic and social aspects.

PEOPLE / STAKEHOLDERS

- Agricultural advisor / development practitioner;
- farmer;
- farmer organisations / bodies;
- technology provider.

OUTCOME / PRODUCT

- Analysis of availability, suitability, comparability, acceptability and supportability of technology options;
- profile of potentials and opportunities of each technology option;
- influencing framework conditions (i.e. water rights, subsidies, etc.).

DATA REQUIREMENTS

- Triangulation of different information sources with regard to technical, economic and environmental information.

IMPORTANT ISSUES

- The availability of a specific technology option may be limited (there may also be sub-regional differences);
- triangulation (using different information sources) is required to obtain a realistic overview of potentials and opportunities;
- visits to reference or pilot projects are a valuable source of information if an exchange with the operating farmer is included.

Irrigation innovation for limited land resources

2 ANALYSE RISKS AND RESTRICTIONS

The collection, compilation and analysis of information along the principles outlined in the preceding step will also reveal limits for an application of the technology and related negative experiences. This information must be further analysed in order to establish a profile on risks and limitations of the technology option. The objective of this exercise must be to include clear statements and unbiased information about possible restrictions and risks in the promotion material and in communications with farmers.

Restrictions are largely determined by technical (availability of technical solutions and services), environmental (availability of water, solar irradiance, morphology) and economic (suitability for specific crops, access to finances, positive return on investment) factors, that are taken into consideration in the design process (i.e. diesel prices, subsidies). Any irrigation system should usually be designed under consideration of these restrictions – it has a calculated optimum range of operation in which it will comply with the restrictions and thus risks are avoided.

Important: Not every irrigation technology is suitable for all crops and production approaches. Besides technical and agronomic restrictions the cost-benefit ratio is a vital aspect to consider!

Risks are largely due to a deviation from the designed operational range and from operation principles. This may result in negative impacts on the environment (excessive water abstraction, overirrigation) and on the cost-benefit ration of the production (lacking adaptation of production and irrigation operation and insufficient water supply causing yield and/or quality depression). System operation outside the design range causes increased maintenance, repair and replacement costs).

The analysis of restrictions and risks should include the following aspects:

- Technical, environmental and economic restrictions for the application of the technology options;
- environmental risks origination from the possibility of an over-exploitation of water resources;
- technical risks originating from a non-conformal operation of the system;
- financial risks related to the cost-benefit ratio of the technology option.

OUTCOME / PRODUCT

- Analysis of technical, environmental and economic restrictions and risks;
- profile of restrictions and risks of each technology option.

DATA REQUIREMENTS

- Triangulation of different information sources with regard to technical, economic and environmental information.

PEOPLE / STAKEHOLDERS

- Agricultural advisor / development practitioner;
- farmer;
- farmer organisations / bodies;
- water resources management authorities (management of water rights, licences);
- technology provider.

IMPORTANT ISSUES

- Each irrigation technology has a limitation with regard to its suitability for crops, which has to be taken into account.
- Irrigation modernisation induces an adaptation of production and irrigation operation.
- Leaving the optimum operation zone of any irrigation scheme is likely to result in negative impacts on environment and/or the cost-benefit-ratio.

3 ANALYSE ACCESS TO FINANCE

In general, the introduction of modern irrigation technology requires comparatively high investments, which often go beyond the financial capacity of a farm household. Solar Powered Irrigation Systems in particular are characterised by comparatively high investment costs. A promotion approach for irrigation technology must therefore consider access to the capital that will be required.

In order to finance irrigation investments, the following sources exist – these sources are often combined:

- Equity of the farm household;
- commercial loans and leasing (market conditions);
- subsidised (soft) loans to end borrower;
- group saving schemes and lending;
- subsidies and development grants;
- sponsoring.

Lack of external finance is often a limiting factor for small and medium sized farm households due to a limited equity and limited credit rating with commercial financing institutes. Financing institutes are usually also very hesitant to open their loan portfolio to new technologies in the agricultural sector as the repayment duration for loans is usually long and risks exist with regard to crop failure. In addition, the lack of conventional collateral signifies an obstacle for banks.

The aspect of access to finance has to be a mandatory part of the initial analysis and information compilation of the promoter. On local level, farmers often do not have access to information on alternative financing options for innovations. These may include partial guarantee schemes and risk sharing facilities as an effective mechanism to foster lending for irrigation modernisation purposes. Farmer groups may also operate group-savings schemes that could be included in a financing concept.

Subsidies to support irrigation information modernisations are widespread and are often the only way to make modern irrigation technology available to small and medium size farm households. Subsidies usually exist for individual components of an irrigation system such as the pumping system (subsidies for PV pumping), water storage (subsidies for water tanks and farm ponds) and the irrigation system (subsidies for sprinkler and micro irrigation systems). They are mostly conditional (water and energy saving, cropping intensification) and time-bound, with a decreasing subsidy percentage over time.

The promoter needs to provide such information as part of his promotion material and as a basis for the later initiating of projects. An important aspect is to not only provide information on the existence of financing sources, but to also provide information on how to access these.

With regard to potential follow-up activities related to the development of the financial sector response to modern irrigation financing the following guidelines are recommended by GPFI / IFC:

- Effective government support should be developed (minimize market distortions, promote private sector involvement, subsidies institutions not be end borrowers, support directed to public goods and financial and physical infrastructures should be approached for systemic benefit).
- Financial Infrastructure should be strengthened (credit bureaus, improved collateral registries, alternative forms of collateral).
- Consistent and reliable data sources should be developed for end borrowers and financial operators (financing options and conditions, agricultural production, supply chains, and market pricing information).
- Farmers and financial service providers should be supported to increase knowledge and capacities with regard to financing modern irrigation solutions.

3 ANALYSE ACCESS TO FINANCE

Photo: Lennart Wolterings

Drip irrigation enablig crop intensification

OUTCOME / PRODUCT

- Financing options information sheet (including conditions, institutions, contact details);
- recommendations for alternative financing options.

PEOPLE / STAKEHOLDERS

- Agricultural advisor/development practitioner;
- financing institutions;
- governmental services;
- donors and donor-supported development projects.

DATA REQUIREMENTS

- Typical Investment costs of technology options;
- information on financing options in the region;
- information on subsidy schemes in the region;
- information on donor and grant schemes.

IMPORTANT ISSUES

- Modern irrigation technology requires (partial) external financing;
- subsidy schemes are often available to support the introduction of modern irrigation technology;
- modern ICT technology and / or regular information dissemination could be used to increase access to finance.

4 DEFINE TARGET GROUP AND STAKEHOLDERS

The analysis carried out in the three preceding steps will outline a profile of potential, opportunities, restrictions and risks with regard to the promoted technology option(s). In addition, the analysis of the access to finance also results in an indication of the realistic access of particular groups of farms to the respective technology. While some farm household may have access to commercial financing services, others may require a 100% subsidy or a grant to introduce the technology to their farm.

Important: When identifying the group of potential investors for the new technology the availability of financing should not be the only and not the determining factor. The significant requirements induced by new technologies for crop production and irrigation operation are often a limiting factor for a large number of farm households to adopt these technologies.

Based on the analysis the promoter will have to define a specific target group for the technology options promoted. In case of the SPIS technology this concerns usually small and medium size farm households with a good market access and a potential to adapt and intensify their production. Large farm enterprises usually obtain the required information directly through private sector service providers and take investment decisions based on their own business planning (and own equity financing).

Smallholders with difficult access to markets and subsistence farm households often cannot cope with the operational requirements and related costs that come with high investments such as induced by SPIS options, even though they may benefit from subsidies or grants. Group schemes with shared pumping installations are an alternative to individual systems in case of smallholders or subsistence farmers. This option can also cater for the need to promote disadvantaged and impoverished farming communities that may only have access to communal land. Such an option is often also an important opportunity for women and young people own land properties (which is often the basis for credit) and equity financing.

The preceding analysis also reveals the identification of important stakeholder for the promotion:

- Technology supplier and service providers;
- financing institutions;
- agricultural extension services and service providers;
- government institutions managing subsidy schemes;
- farmer organisations and groups;
- donors and NGOs.

The identified stakeholders and their role (actual and potential) should be listed as part of the information compilation. Some of these stakeholders may also assume the role as a multiplier of information in the promotion campaign, such as farmer organisations and NGOs.

OUTCOME / PRODUCT

- Defined range (size) of target farm households and additional criteria (market access, intensification potential);
- list of stakeholders with roles and responsibilities.

DATA REQUIREMENTS

- Farm household / enterprise profiles in the promotion area;
- functions and functioning of stakeholders.

PEOPLE / STAKEHOLDERS

- Agricultural advisor / development practitioner.

IMPORTANT ISSUES

- Not every farm enterprise can absorb an investment in modern irrigation technologies due to limits in market access and potential to adapt and intensify production.
- Group schemes with shared pumping facilities can be a feasible approach for subsistence farmers, disadvantaged communities and for women and young people with access to resources.

5 COMPILE PROMOTION MATERIAL

The compilation of promotion material is largely depending on the promotion strategy and the promotion instruments that are taken into consideration for the campaign. In almost any country around the world experience exist with regard to promotion and awareness raising campaigns in the agricultural sector. Successful approaches may be proposed by the extension services and development partners such as donors and NGOs. Appropriate approaches are always target group focussed and culturally sensitive. A particular attention has to be given to information access for disadvantaged communities and in particular women and young people. Dissemination meetings and seminars etc. are traditionally dominated by male household heads and lead farmers.

Promotion activities should include communicative and interactive instruments as the simple dissemination of information sheets and brochures often is not sufficient to reach all target households. Possible activities are for example:

- Farmer field days and farmer technology fairs (this can also be organised in cooperation with technology service providers);
- "village road shows" with technology presentations on village level;
- extension seminars with lead farmers as multipliers.

Recommendation: Wherever possible technology suppliers and NGOs should be incorporated into the promotion concept as they can provided valuable information. An agreement need to be reached as to the impartiality of information provision. It is also advisable to invite representatives of local banks / financing institutes to promotion events in order to contribute to their awareness for the new technologies.

A number of passive dissemination means also exist – these require also a very thorough preparation of materials:

- Rural radio bulletins;
- short bulletins on the local TV;
- preparation of wall posters;
- internet videos (posting via YouTube etc.).

Depending on the promotion approach and instruments chosen the compilation of promotion material can be a significant task. It should include a target group-specific design and layout of documents etc. Sufficient budgetary resources must be available in order to produce good quality promotion material.

Important: When approaching the promotion of irrigation technology, the prime objective of the promotion effort must always provide the farmer with information that enables him to take a decision in view of securing and/or increasing his production potential. Promotion from a development perspective is not marketing of a specific product!

OUTCOME / PRODUCT

- Determination of promotion approach and instruments;
- agreement with relevant stakeholders on cooperation activities;
- design and layout of promotion material.

PEOPLE / STAKEHOLDERS

- Agricultural advisor / development practitioner;
- technology provider;
- farmer organisations;
- donors and NGOs;
- Financial service providers.

DATA REQUIREMENTS

- Experiences with different promotion approaches and instruments (agricultural sector).

IMPORTANT ISSUES

- Promotion activities should include communicative and interactive instruments;
- information access to disadvantaged communities, women and young people has to be considered;
- technology suppliers and NGOs should be incorporated into the promotion concept as they can provided valuable information.

6 PLAN AND IMPLEMENT PROMOTION ACTIVITIES

The implementation of promotion activities should only be started once the required promotion material is developed and available. As ideally an interactive focus is the foundation of the promotion campaign, planning for the implementation of activities must be done well in advance and in a joint effort with the cooperating partners. In larger parts of the year most farmers have very limited time to attend seminars and meetings. The planning should therefore be oriented on the agricultural calendar and the regional work peaks. This way a good participation can be achieved. Particular attention shoud be paid to the limited time resources of women and youth.

Planning should also include the identification of suitable presenters or trainers that have experience with the particular target group. A recommended approach is the inclusion of lead farmers as multiplier and co-presenters for dissemination meetings. In order to access women and young people a balance of gender and seniority must be introduced to the promotion team. The incorporation of staff from local NGOs, for example, may be conducive to the success of the activities. Promoter and presenters should not only be familiar with the promotion material and the objectives and key messages of the campaign, but should also be trained in carrying out extension meetings etc. Local events should be pre-announced locally to advertise for a large participation.

The dissemination of these announcement can be done via:

- Black board announcement at the agricultural extension bureau;
- flyer distribution through local agricultural input providers / shops;
- local newspaper;
- rural radio services;
- SMS-services.

The implementation of the promotion events should always position the farmer into the centre of the extension concept. The objective of each event is not only provide information based on an anticipation of farmers' needs, but to allow for practical demonstration, questions, discussions and a capture of the farmers' expectations and needs.

Feedback from the participants of the promotion and extension events should be obtained in a systematic way to further develop the didactics. A good documentation of feedbacks and interests / needs for further information will enable an efficient and targeted follow-up at a later stage.

OUTCOME / PRODUCT

- Schedule / plan for local promotion and extension events based on agricultural calendar;
- announcements via flyer / posters local media;
- captured feedback and further information and follow-up requests from the farmers.

DATA REQUIREMENTS

- Information on local work peaks in agriculture;
- information on suitable venues / areas for promotion events;
- information on other extension events;
- contact information of important local stakeholders such as banks / financing institutions, farmer organisations, NGOs, private sector associations etc. (to be invited).

PEOPLE / STAKEHOLDERS

- Agricultural advisor/development practitioner;
- farmer;
- technology provider;
- farmer organisations;
- financial service provider;
- donors and NGOs.

IMPORTANT ISSUES

- Farmers should be encouraged to interact with the promoters / presenters to ask questions, provide feedback and to articulate further needs / information requirements;
- farmer feedback and further information requirement should be documented.

7 SECURE FOLLOW-UP

The promotion activities may result in further information requirements and first expressions of interest for the new technology. In many areas the service structure of technology suppliers and their associated installation service providers is not very well developed. Very often, the supplier maintains only a few (if not only one) branches in the country. For many farmers that may be interested in modern technology options such as SPIS it is not feasible to travel to the capital to obtain further information. It is therefore required to properly document contract requests and information needs during the promotion and extension events and to provide the farmers with contact details for further consultation.

The promoter should follow-up with the documented farmer's requests in a systematic way. It is important that the follow-up action takes place in due time after the first contact during the promotion event. With the follow-up after the promotion activity the initiation of a possible future project starts. Here, the promoter has to choose how to pursue the follow-up. Possible scenarios are:

- Initiation of direct information and contact between the farmer and a technology provider / project developer;
- recommendation of follow-up activities to locally operating development partners (NGOs, donors).

The next steps in this initiation process will be a first assessment of the suitability of different technology options in the specific farm context. This requires a physical site visit and a deeper joint reflection process together with the farmer. The following modules of this manual, in particular the DESIGN, SET UP and MAINTAIN processes, assist the advisor and development practitioner to carry out this preliminary assessment.

OUTCOME / PRODUCT

- Contact between farmer and service provider / development partner for follow-up activities;
- initiation of project development activities.

DATA REQUIREMENTS

- Contact details of farmer and service provider/ development partner for project development.

PEOPLE / STAKEHOLDERS

- Agricultural advisor / development practitioner;
- farmer;
- technology provider;
- donors and NGOs.

IMPORTANT ISSUES

- Technology suppliers often do not maintain an extensive network of branch offices, requiring proactive contact management.
- Follow-up activities should be carried out timely after the request for further information to maintain the confidence of the farmer.

FURTHER READING, LINKS AND TOOLS

Links

„Scaling Up Access to Finance for Agricultural SMEs Policy Review an Recommendations“ by Global Partnership for Financial Inclusion (GPFI) and International Finance Corporation (IFC) (2011) at:
http://www.ifc.org/wps/wcm/connect/04da89804a02e2e19ce0fdd1a5d13d27/G20_Agrifinance_Report.pdf?MOD=AJPERES

“Solar Powered Irrigation Systems - Stocktaking and Analysis Report” by German Technical Cooperation Agency (GIZ) (2015) at:

http://

FINANCE

Photo: Lennart Wolterink

MODULE AIM

This module provides information and tools for financial service providers planning to finance or already financing SPIS.

Thereby it addresses two groups: those at management level, deciding upon credit policies of a financial service provider and loan officers who assess single loan applications for financing SPIS.

The module specially focuses on what is special or different when financing SPIS as opposed to "normal" investment loans for irrigation. It focuses on product features for SPIS loans, considering direct financing from financial institution to a small and medium scale agricultural end borrower.

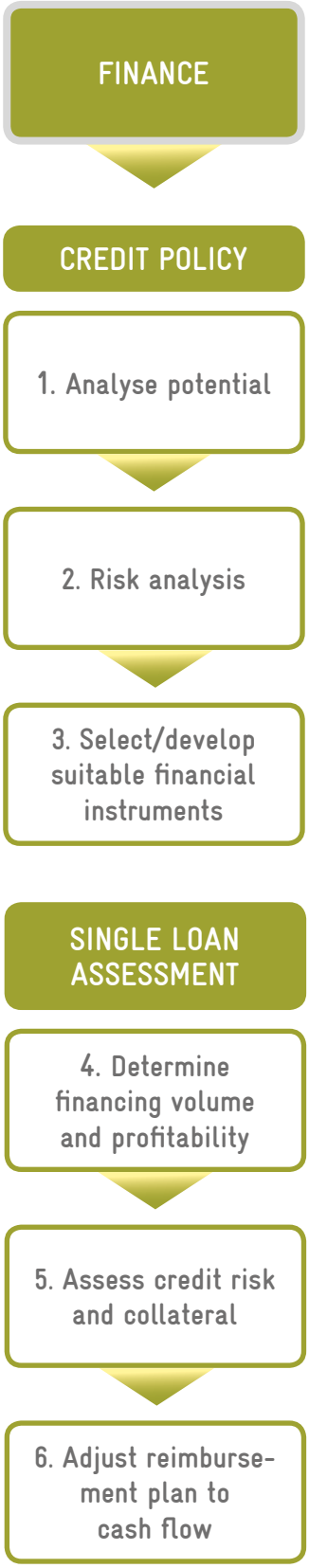
The module does not cater for other possible financial activities that could be developed in the context of Solar Powered Irrigation Systems such as refinancing leasing operations or within the value chain, or the development of non-loan products for SPIS clients.

BRIEF DESCRIPTION OF PROCESS

As a first step, the financial service provider needs to analyse the potential of the SPIS market. Once the decision has been taken at **management level** to go forward with this new market segment, involvement in Solar Powered Irrigation Systems needs to be assessed with respect to involved credit risks. Finally, suitable financial instruments need to be designed.

On the **operations level**, once guidelines and procedures for the assessment and loan products have been defined, the focus lies on the loan assessment process of a single loan application.

Three main steps are elaborated in the manual. Firstly, the determination of the financing volume and calculation of the profitability of the investment. Secondly, the assessment of credit risk and collateral of the potential borrower. Thirdly, the determination of the cash flow and the reimbursement plan for the single potential client, along with loan conditions.



1 CREDIT POLICY: ANALYSE POTENTIAL

Financing solar powered irrigation can be an interesting option for a financing institution in order to diversify its loan portfolio and expand its range of financial products!

Financing SPIS could be attractive because:

- Today, solar-powered irrigation is a technically mature and reliable option and an alternative to conventional irrigation approaches;
- SPIS caters for market-oriented medium to large scale farming, due to the investment and technological know-how requirements. It is not a feasible solution in subsistence farming;
- SPIS has successfully been piloted and proved to also have potential as a technology option for smallholder groups;
- the introduction of SPIS technology is mostly accompanied by an intensification of agricultural production, thus contributing to the development of the financial capabilities of farm households;
- the technology itself is environmental friendly, if used in regions with good groundwater management.

But, PV-based pumping solutions have:

- A comparatively high initial capital investment requirement;
- longer repayment periods or/and significantly higher repayment rates;
- comparatively higher credit risk leading to higher interest rate payments as compared to conventional water abstraction/pumping solutions.

PEOPLE / STAKEHOLDERS

- Management of financial service providers;
- market analysts/consultants;
- research and training institutions;
- public entities promoting or/and subsidizing SPIS initiatives;
- donors refinancing solar powered initiatives;
- associations of farmers / potential borrowers;
- technology providers;
- service providers.

DATA REQUIREMENTS

- Profile end customers (personality, cropping patterns, irrigation techniques, pumping systems, market);
- current offer of loan products available for potential SPIS customer;
- water and energy provision regime in region
- support/advice structures and subsidy schemes (refinancing) available for the region;
- environmental impact assessment (long term perspective).

OUTCOME / PRODUCT

- Study on potential of financing SPIS and recommendations for financial service provider.

IMPORTANT ISSUES

SPIS is likely to be a feasible option in a region if:

- Energy provision for farming is a constraint (e.g. availability or cost of fuel, reliability of grid connection);
- farmers are market-oriented and not working on subsistence level;
- farmers are at least small or medium sized or organized in small holder groups;
- subsidized re-financing options for financial operators are available;
- grant schemes or subsidies are available for the end borrower (farmer);
- farmers aim at a specialized market (e.g. focussing on ecological production, which could give scope for premium pricing);
- technology distributors and system integrators are available in the region;
- water is available and managed adequately so as to prevent ground water depletion on the long run.

2 CREDIT POLICY: RISK ANALYSIS

Every SPIS demands a specific solution, since it combines a new energy providing technology with irrigation and cropping systems which can be manifold in its combination.

Therefore, there are no standard "off the shelf" solutions, a thorough loan analysis is indispensable, especially when starting with this loan type.

SPIS, being based on agricultural activities, follows specific liquidity patterns, such as:
- Irregularity, seasonality;
- Farming-household mix;
- aeveral cash generating activities;
- aystem risks (climate, weather, pest, disease, prices).

This requires specific agrilending tools.

Typical **financial advantages** when changing to solar powered irrigation could be:
- Higher profitability when introducing high value crops and higher degree of irrigation effectiveness;
- reduced and stable current energy costs due to change in energy source (no transport costs or risks for supply of fuel or lubricants);
- environmental friendly technology (avoid water losses, use of water saving technology, prevent diesel pollution, etc.) can give access to subsidized funds or grants.

Introducing SPIS can be financially viable, if combining adequate irrigation technology and cropping patterns as well as aiming at promising market.

Financial viability of a SPIS also depends on the technical design, on the set-up of the system and on its operation and maintenance (see chapters DESIGN, SET-UP, MAINTAIN for further details). Finally scrutinizing a long term perspective on adequate groundwater management is essential. The financial operator should assess these issues.

PEOPLE / STAKEHOLDERS

- Management of financial service providers;
- public entities promoting or/and subsidizing SPIS initiatives;
- associations of farmers / potential borrowers;
- market analysts/consultants;
- technology providers;
- service providers;
- research and training institutions (e.g. environm. agency).

DATA REQUIREMENTS

Research, collect, analyse:
- Specifics to agri-lending liquidity patterns of borrowers;
- asset structure of borrowers (potential for collateral);
- cropping patterns and profitability of crop types (alternative markets and water availability);
- organization & Management reliability (see MAINTAIN)
- technology risks (see DESIGN);
- re-financing options for the region.

OUTCOME / PRODUCT

- Credit risk policy, considering thorough single-case assessment, adequate portfolio management and pro-active closing of the information gap

IMPORTANT ISSUES

Solar-powered water abstraction and conveyance is not always the best solution because it bares risks such as:

Financial Risks:
- High initial capital investment requirement lead to higher credit risk resulting in longer repayment periods and higher interest rates for clients comparing to alternative energy sources;
- financing agriculture as such has specific risks.

Technology Risks:
- High value cropping and water saving irrigation technology is needed;
- pumps have to be "oversized" in order to meet peak water demands;
- management capacities to handle the technology should be available;
- daily operating hours are limited;
- feasible PV-generator and pump dimensioning implies orientation towards low pressure output;
- suitability of location for SPIS;
- over use of water.

Framework Risks:
- Long term availability of water and good groundwater management is indispensable;
- people involved – loan officers, farmers, (gender!) technology and service providers, agricultural advisors;
- theft.

3 CREDIT POLICY: SELECT/DEVELOP SUITABLE FINANCIAL INSTRUMENTS

Loan products for financing SPIS usually:

- Have higher initial investment sums with consequently longer repayment periods and/or high instalment rates;
- need alternative guarantee schemes/ unconventional collateral;
- have higher interest rate payments due to higher credit risk and long investment period;
- focus on innovative clients, usually investing in high(er) value crops;
- should be strictly oriented towards water capacity available and the farm's specific requirements;
- use no blueprint, every farm/enterprise is unique!

In order to **prevent prohibitive loan transaction costs**, consider:

- Guarantee funds with public support or insurance;
- leasing schemes with pumping system providers and others
- group financing approaches for producer groups;
- public subsidies and sponsoring;
- favourable re-financing options for the financial institution (e.g. subsidized interest rates offered by donors/public entities).

In order to **overcome the information gap** in respect of the new technology, introduce additional activities such as:

- Encouraging (potential) clients to get informed and consult technical advice;
- training and sensitization of loan staff on basics about the technology;
- monitoring loan performance closely;
- continuous dialogue with solar power sector.

Note: SPIS clients could become future clients for **other financial products**.

PEOPLE / STAKEHOLDERS

- Management of financial service Providers;
- experienced credit staff (senior, agri-finance);
- associations of farmers / potential borrowers;
- agricultural extension services;
- research and training institutes (e.g. environm. agency);
- providers of service, technology and inputs.

OUTCOME / PRODUCT

Loan Product Features:

- **Who:** market oriented farmers, no subsistence production, farmer groups possible.
- **What:** finance for energy source and pumping system used for irrigation; energy and/or water saving technology.
- **How much:** establish range of loan sum; % own-contribution of farmer; % subsidy.
- **When:** range of loan period (years); repayment frequency (months); disbursement in tranches.
- **Interest rate:** from....% p.a. to .....% p.a. (range).
- **Collateral:** equipment; mortgages; additional collateral (guarantee scheme); non-traditional collateral (future harvest, warehouse); leasing scheme with equipment providers.

Guidelines and Procedures: including assessment and decision guidelines, target key performance indicators (KPIs)

DATA REQUIREMENTS

Research, collect, analyse:

- Comparable clients liquidity pattern in current agricultural portfolio
- See chapter DESIGN for financial projections

Compute, prepare:

- Reimbursement schedules (with varying interest rates, repayment periods and repayment frequencies);
- profitability margins by crops and farm sizes;
- tables for evaluating types of collateral;
- list of eligible crops;
- list of eligible irrigation systems and average investment cost per component (see DESIGN/GET INFORMED);
- list of eligible PV systems and avg. investment cost per component (see DESIGN/GET INFORMED;
- list of eligible types of collateral.

IMPORTANT ISSUES

- Prevent prohibitive transaction costs for borrowers;
- overcome information gap of financial operators;
- standardization potential limited.

4 LOAN ASSESSMENT: DETERMINE FINANCING VOLUME AND PROFITABLITY

Since the cost for PV-based pumping solutions has decreased, the technology is often financially competitive in comparison with conventional pumps. Before financing a specific SPIS this should be carefully assessed and proven. Alternative energy systems based on diesel pumping or grid electricity pumps should be compared to the PV generator approach. In addition different sizing and cropping options of the SPIS can be considered.

For this purpose, investment sums and profitability need to be calculated for all options. Indicators used for comparison are Gross Margin of production, as well as Life Cycle Costs, Net Present Value (NPV) and the Internal-Rate-of-Return (IRR) of the respective investment.

PEOPLE / STAKEHOLDERS

- Loan officers financing or planning to finance SPIS;
- farmer(s) / potential borrower(s);
- management of financial service providers (operational level);
- agricultural extension services and promotion agencies (e.g. for subsidies);
- providers of service, technology and inputs;
- research and training institutes.

IMPORTANT ISSUES

- If applicable: comparison PV with diesel and electric pumps needed (including price trends and subsidies);
- varying profitability of different SPIS (sizes, crops);
- complexity of data requirements;
- lack of data availability and high research need;
- bank transaction cost initially high with some scope for standardization or possible re-financing at favourable rates;
- excellent loan staff required with corresponding background and experience.

OUTCOME / PRODUCT

- Profitability analysis of investment (and alternatives);
- financial projections on investment costs for alternative energy source.

DATA REQUIREMENTS

Research, collect, analyse, cross-check:

- Examples for financial projections of SPIS (see DESIGN);
- prices for components to be financed (see GET INFORMED, DESGIN);
- cropping pattern and crop prices (fluctuation, trends);
- prices for O&M costs and inputs;
- purpose and sums provided as subsidies or/ and through sponsors;
- market analysis.

Compute, prepare:

- Annual income and expenses (O&M, inputs) --> Annual gross margin of production (current and future);
- total/annual sum for investment in SPIS (and alternative system);
- life cycle cost of SPIS investment
- water unit cost;
- net Present Value (NPV) and Internal Rate of Return (IRR) of SPIS investment.

5 LOAN ASSESSMENT: ASSESS CREDIT RISK AND COLLATERAL

Apart from "normal" credit risks applying to agricultural loans, such as variations related to external shocks and an irregular cash flow based on seasonality, financing SPIS brings additional challenges. These are mainly related to technological risks or risks in respect to operation and maintenance. Also, high initial investment costs increase the overall financial risk. Finally over sizing of the pumping system can be an issue.

When **valuing assets for collateral**, the view should broaden by considering the whole farm as well as the overall family situation, and not only specifically the planned investment. The borrower should be encouraged to contribute with own capital and alternative collateral should be accepted more broadly by the financial operator.

Since solar power is considered an **environmental friendly technology**, if using water adequately, there is a scope for external public or donor funded guarantee schemes and subsidies where farmers can adhere to. These opportunities should be actively explored and assessed.

PEOPLE / STAKEHOLDERS

- Loan officers financing or planning to finance SPIS;
- farmer(s) / potential borrower(s);
- management of Financial Service Providers (operational level);
- public entities promoting or/and subsidizing SPIS initiatives;
- sponsors.

DATA REQUIREMENTS

Research, collect, analyse:

- Examples for financial projections of SPIS (see DESIGN);
- market analysis;
- availability of risk guarantee options / opportunities.

Compute, prepare:

- Valuation of farm (and family) assets and liabilities;
- borrowers own (capital) contribution;
- revue of collateral or/and guarantee schemes;
- assessment of technology and O&M risk (see DESIGN, SET-UP, MANTAIN).

OUTCOME / PRODUCT

- Family/farm balance sheet;
- total value of collateral and/or types of guarantees;
- general risk analysis.

IMPORTANT ISSUES

- Lack of collateral or alternative types of guarantees;
- difficult data collection process due to intermingled family-farm economy;
- excellent loan staff required with corresponding background and experience.

6 LOAN ASSESSMENT: ADJUST REPAYMENT PLAN TO CASH FLOW

SPIS, being based on agricultural activities, follows **specific liquidity patterns**, such as:

- Irregularity, seasonality;
- farming-household mix;
- several cash generating activities (agricultural, non-agricultural);
- external shocks (climate, weather, pest, disease, prices).

The determination of specific loan features (disbursement pattern, repayment rate, collateral, repayment frequency) should be based on cash flow projections, taking these liquidity patterns into consideration based on the specific case.

This means for loan analysis:

- In depth understanding of the farm and family economics;
- strong interaction with the potential borrower;
- networking with other sources of information in the sector and region;
- thorough understanding of the market and market trends.

SPIS usually goes along with **high initial investment sums**. This generally implies higher risks if no adequate collateral is available and at the same time higher profitability when combined with the right cropping pattern and irrigation technology, amongst others. Individual loan assessment should take this into consideration and adjust loan features accordingly.

PEOPLE / STAKEHOLDERS

- Loan officers financing or planning to finance SPIS;
- farmer(s) / potential borrower;
- management of financial service providers (operational level);
- public entities promoting or/and subsidizing SPIS initiatives;
- sponsors.

DATA REQUIREMENTS

Collect, compute, prepare:

- Current and projected cash flow (with SPIS);
- total farm and household liquidity analysis (current + projected);
- borrowers own capital contribution;
- repayment potential;
- reimbursement plan;
- loan details.

Examples for financial projections of SPIS (see DESIGN).

OUTCOME / PRODUCT

- Cash flow statement (current, projected);
- tailor made disbursement and reimbursement plan;
- financial risk analysis/adjustment;
- summarized risk analysis;
- tailor made loan details for decision.

IMPORTANT ISSUES

- Tailor made repayment conditions require high interaction with potential borrower;
- difficult data collection process due to intermingled family-farm economy;
- assessment and valuation of alternative energy sources and scenarios is work intense;
- lack of sponsors or subsidies could lead to excessively high risk level categorization and consequently to prohibitive loan costs for potential clients;
- excellent loan staff required with corresponding background and experience.

GLOSSARY

Assets:	position in balance sheet which represents what a company owns.
Cash Inflows:	all cash receipts realised within a given period.
Cash Sales:	cash revenues realised from sales of finished goods/services.
Creditors:	payable occurring from past credit (money owed to suppliers for expenses).
Collateral:	property or other assets that a borrower offers a lender to secure a loan.
Credit Sales:	sales made without receiving cash.
Current Assets:	cash and other assets which are expected to be converted into cash or consumed during the normal operating cycle of a business.
Debtors:	receivables occurring from past credit sales.
Depreciation:	a cost charged against fixed assets for their replacement.
Expenses/ expenditure:	payment of cash or cash equivalent for goods or services received. Cost of resources used up or consumed by the activities of the business.
Finished Good Stocks:	an inventory of final products ready for sale.
Financial Viability:	ability to generate sufficient income to meet operating expenditure, financing needs and, ideally, to allow profit generation. Financial viability is usually assessed using the Net Present Value (NPV) and Internal Rate of Return (IRR) approaches together with estimating the sensitivity of the cost and revenue elements. Both NPV and IRR are the most commonly used decision criteria of a cost-benefit analysis.
Fixed Assets:	assets required for long-term use and for physical use in the business (machinery, buildings, office equipment, cars, etc.)
Fixed Cost:	costs that do not vary with the level of production.
Fixed Investment:	investment made in fixed assets (e.g. machinery).
Gross Margin:	gross income minus gross expenses.
Income:	income is money generated from the activities of the business.
Internal Rate of Return:	gives the discount rate over the life-span of a capital investment; i.e. the profit rate generated by a certain investment (amount) over its life-span. By calculating IRR of a project you can answer the question whether the money is well spent or if less risky investment alternatives might be more profitable in the long run, e.g. putting the money on a bank account to get interest on it.
Liabilities:	claims by creditors against the assets of a business.
Life Cycle Costing:	is a technique for evaluating total cost of ownership to compare different alternatives.
Material Stocks:	an inventory of all raw materials not yet used in production.
Net Present Value:	determines the present worth of an investment by discounting the cash inflows and cash outflows generated by this investment over its life span. For the determination of the NPV you need to define the expected life span of the investment as well as a discount factor, which might be near to the interest rate on deposits. You could also use the NPV for comparison of alternative investment options.
Net Working Capital:	current assets minus current liabilities.
Outflows:	total of all cash payments.
Profitability:	income minus expenses. Is stated in the income statement (or Profit and Loss Statement), which reports a company's revenue, expenses, and net income over a period of time.
Raw Material Purchases:	cost incurred on purchase of raw material.
Variable Cost:	a cost that varies directly with the level of production delivered.

FURTHER READING, LINKS AND TOOLS

Websites

C-GAP on „Rural and Agricultural Finance“ at:
http://www.microfinancegateway.org/library/gateway-guide-rural-and-agricultural-finance (13/8/2015)

„Agricultural Finance Support Facility“ (AgriFin)/ Worldbank at: https://www.agrifinfacility.org/ (13/8/2015)

„Agricultural and Rural Finance“ Making Finance Work for Africa/MicroSave at:
http://www.mfw4a.org/agricultural-rural-finance/agricultural-rural-finance.html (13/8/2015)

Publications/Papers

„Guarantee Funds: A Response to Agricultural Credit Risk – The Latin American Guarantee Fund FOGAL“ by SOS Faim Belgium (2015) at:
http://www.microfinancegateway.org/library/guarantee-funds-response-agricultural-credit-risk-%E2%80%93-latin-american-guarantee-fund (13/8/2015)

„Innovative Agricultural SME Finance Models“ (2012) by IFC/GPFI at:
http://www.ifc.org/wps/wcm/connect/55301b804ebc5f379f86bf45b400a808/Innovative+Agricultural+SME+Finance+Models.pdf?MOD=AJPERES (13/8/2015)

„Scaling Up Access to Finance for Agricultural SMEs - Policy Review and Recommendations“ (2011) by IFC/GPFI at:
http://www.ifc.org/wps/wcm/connect/04da89804a02e2e19ce0fdd1a5d13d27/G20_Agrifinance_Report.pdf?MOD=AJPERES (13/8/2015)

„Resource Book on Designing and Delivering Agriculture Financing Products-The Phillipines“ by: Piyush Kumar Prasoon; Abhay Pareek, Anant Jayant Natu; Jesila Ledesma; Neeloy Deep Barman (2014) at:
http://www.microsave.net/files/pdf/Designing_Delivering_Agriculture_Financing_Products.pdf (13/8/2015)

„Managing Risk in Financing Agriculture – Notes - Expert Meeting“. Convened and co-sponsored by AFRACA, FAO, the Land Bank of South Africa/World Bank (2009) at:
http://www.ruralfinance.org/fileadmin/templates/rflc/documents/ 1267626159472_Proceedings__Managing_Risk_in_Financing_-1391566911.pdf (13/8/2015)

“Developing Rural Finance through Public-Private Sector Cooperation” by SOS Faim Belgium in Zoom Microfinance (2013) at:
https://www.sosfaim.org/be/en/publication/developing-rural-finance-through-public-private-sector-cooperation/ (13/8/2015)

„Credit Risk Models for Managing Bank‘s Agricultural Loan Portfolio“, by Arindam Bandyopadhyay/National Institute of Bank Management, Pune, India (2007) at http://mpra.ub.uni-muenchen.de/5358/1/MPRA_paper_5358.pdf (13/8/2015)

„Credit Risk Models for Agriculture Loan Portfolios“ AgriFin/Worldbank (2007) at:
https://www.agrifinfacility.org/resource/credit-risk-models-managing-bank%E2%80%99s-agricultural-loan-portfolio (13/8/2015)

„Agricultural Finance – Trends, Issues and Challenges“ (2011) GIZ at:
http://www.ruralfinance.org/fileadmin/templates/rflc/documents/06__giz2011-0460en-agricultural-finance.pdf (13/8/2015)

DESIGN

Photo: Andreas Hahn

MODULE AIM

This module provides information and tools for agricultural service providers who need to give advice to farmers on how to estimate the size of a Solar Powered Irrigation System and to select the suitable system configuration for a specific farming situation. It is important to always consider that PV pumping is only one of the possible technology option for an irrigation system – it may not be the most suitable and viable choice for all farms. Different technology options have to be compared and evaluated against each other to arrive at a decision on the technology choice.

A SPIS consists of multiple components that have to work under constantly varying daily and seasonal conditions. It is recommended to leave the complicated technical design process and the planning of the cultivation in the hands of experienced system integrators and agricultural specialists.

For the agricultural advisor, a set of tools supports the pre-selection of the appropriate system type and the estimation of the size and the costs of the chosen SPIS on farm level.

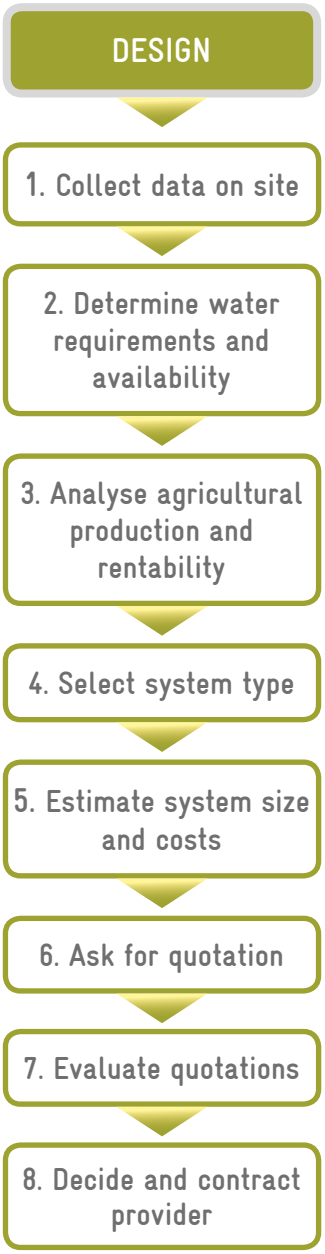
The design of a SPIS lays the foundation for the system's technical, financial and environmental viability. In particular with regard to financial implications and the risk of unsustainable water abstraction a thorough consideration must take place.

BRIEF DESCRIPTION OF PROCESS

Prior to any decision regarding the water pumping technology a detailed farm assessment including water requirements and availability, agricultural production, market requirements and potentials, as well as the financial viability of the farm is essential. If a PV pumping solution was selected as the most suitable solution, a proper design process is essential to match demand and technical solution as closely as possible.

A SPIS with insufficient capacity will not satisfy the farmers' needs and an over dimensioned system will induce unnecessary operation and capital costs. The decision on the suitable system which system configuration depends on the results of site data collection and the specific needs of the farmer. Negligence of the sustainable water yield of water sources may result in a water shortages and a depletion of the water resources, thus having negative impacts on the environment.

The technical design process usually starts with the irrigation system and the determination of the corresponding system pressure and water flow. These parameters, together with the solar radiation, mainly determine the size of the PV generator. To plan solar pump and irrigation system, the technical planner can choose from a number of design methods of varying complexity and accuracy. After checking and assessing the farm-specific situation, system integrators will be asked for a detailed technical design and a quotation on the costs. High-quality systems with good value for money shall always be given preference. Costs should never be reduced by compromising on system quality or by decreasing support services.



1 COLLECT DATA ON SITE

For a proper design of an SPIS, a complex set of data and information is required. This includes data on site-specific and meteorological parameters, soil conditions, water availability and quality as well as on cropping aspects and marketing possibilities. It should be kept in mind that crop water requirements may be different for optional cropping patterns. Any irrigation system should ideally be sized on the basis of the findings from a local data survey. While an on-site survey of solar radiation and other meteorological data would be a worthwhile exercise, most systems are based on existing data derived from nearby reference locations for which . Meteorological data can also be obtained from regional/national maps, or on national and international websites. Data and information on evapotranspiration and crop water requirements can be obtained from agricultural offices or extension services. Other site-specific data, such as the dynamic pumping head, have to be collected on site.

The **Site Data Collection** Tool explains for example, how the total pumping head (with allowance for well dynamics and friction losses) can be determined for tank systems and direct injection of water into the irrigation system.

OUTCOME / PRODUCT

- Detailed description of farm-specific situation, as a basis for the assessment of the technology choice and the technical design;
- determination of the essential sizing data, i.e. the daily crop water requirement Vd [m³/day], the total pumping head HT [m] and the mean daily global solar radiation Gd for the design month [kWh/m²day], to estimate the size and cost of the solar generator;
- pre-selection of a suitable motor pump unit.

IMPORTANT ISSUES

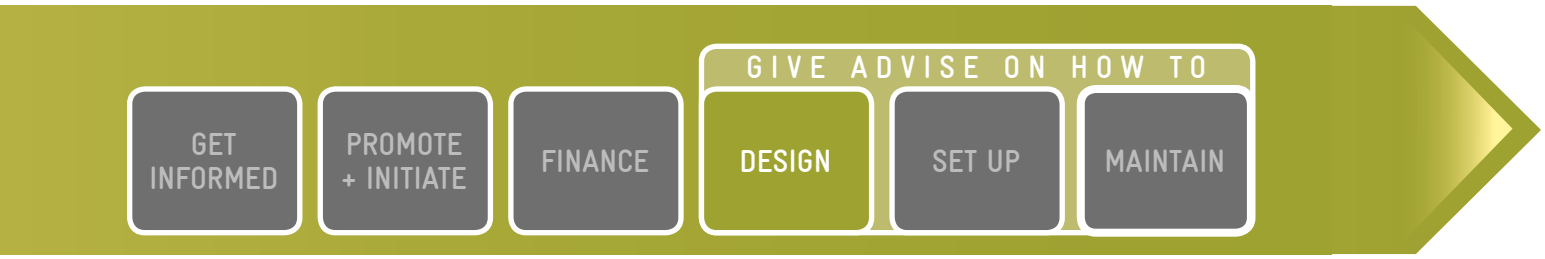
- SPIS-users have to adapt and optimize utilisation of the varying water quantities (daily / seasonal insolation fluctuation) in order to achieve a high utilization rate;
- the draw down of the water level should be monitored to reduce the risk of groundwater depletion;
- insufficient evaluation of water requirements and availability on site often lead to under- or oversized PV systems. This frequently happens in subsidy-driven markets where the system designs are standardized and the size is not scalable.

DATA REQUIREMENTS

- **Meteo Data:** Insolation, temperature, wind speed, humidity, rainfall, evaporation.
- **Site Data:** Longitude, latitude, altitude, water source, pumping head, shadowing, climate, terrain.
- **Crop Data:** Crop type and variety, growing season, crop rotation, crop water requirements, fertilizer, crop protection requirements.
- **Soil Data:** Soil type, salinity, water holding capacity, organic matter content, fertility.
- **Water Data:** Availability, groundwater recharge, water rights, salinity, temperature, algae content, sediment content
- **Market Data:** Demand situation, selling price, seasonality.

PEOPLE / STAKEHOLDERS

- Farmers / farmer groups;
- agricultural service provider;
- water resources management authority;
- meterological service provider;
- system integrator.



METEO DATA	SITE DATA	CROP DATA	SOIL DATA	WATER DATA
Insolation	Longitude	Crop Type/Variety	Soil Type	Availability/Costs
Temperature	Latitude	Growing Season	Salinity	Ownership
Wind Speed	Altitude	Crop Rotation	Water Holding Capacity	Salinity
Humidity	Water Source	Water Demand	Organic Matter Content	Temperature
Rainfall	Pumping Head	Root Depth	Fertility	Algae Content
Evaporation	Shadowing	Plant Protection and Nutritient Demand		Sediment Content
	Climate			
	Terrain			

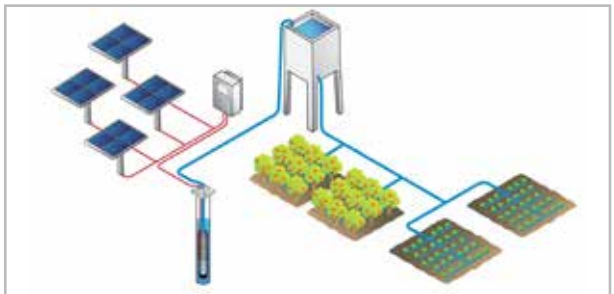
2 DETERMINE WATER REQUIREMENTS AND AVAILABILITY

Water requirements: The assessment of the irrigation potential, based on soil and water resources, can only be done by simultaneously assessing the irrigation water requirements (IWR). Net irrigation water requirement (NIWR) is the quantity of water necessary for crop growth. It is expressed in in millimetres, litres or cubic metres per year and surface unit (1 mm = 1 l/m^2 = 10 m^3/ha). Decisive factors are the cropping pattern, the cropping intensity and the climate. Information on irrigation efficiency is necessary to be able to transform NIWR into gross irrigation water requirement (GIWR), which is the quantity of water to be applied in reality, taking into account water losses. Multiplying GIWR by the area that is suitable for irrigation gives the total water requirement for that area.

Each crop has its own specific water requirements. Net irrigation water requirements (NIWR) in a specific scheme or on a specific plot for a given period of time are thus the sum of individual crop water requirements (CWR) calculated for each irrigated crop. Calculating crop water requirements is a complex task but with the help of useful software tools, such as CROPWAT, experienced agricultural extension workers are able to give advice to individual farmers. CROPWAT is available with FAO after registration and is free of cost (see link below).

Agricultural offices and extension services are usually in a position to provide CWR-data for the most common crops in an area based on the prevailing local climate conditions. Adopting this data is a suitable alternative to a comprehensive calculation effort.

Water availability: In terms of planning and designing any irrigation system, the initial consideration should always be the requirement and the availability of water (access to water, water rights / concession, well / borehole yield). Subsequently, a system can be designed based on the water availability and the most suitable and possible cropping pattern. Water abstraction and irrigation system components need to be adapted to each other in order to achieve the best result in terms of technical, financial and environmental viability.



Source: iEnergia – Lorentz Chile iEnergia – Lorentz

OUTCOME / PRODUCT

- Water availability;
- total irrigation water demand;
- alternative irrigation schedules;
- hydraulic characteristic of irrigation system.

IMPORTANT ISSUES

- CROPWAT includes standard crop and soil data but would require local data input to work accurately on farm level;
- overexploitation or persistent groundwater depletion may occur if groundwater abstraction continuously exceeds the natural groundwater recharge (severe negative environmental impact);
- a proper pump design takes the site-specific well capacity into account;
- precautions and measures have to be taken to avoid groundwater depletion;
- efficient water abstraction monitoring needs to be foreseen.

PEOPLE / STAKEHOLDERS

- Farmer;
- agricultural service provider;
- meteorological service provider;
- water authorities;
- water user association.

DATA REQUIREMENTS

- Local evapotransipration (ETo data);
- rainfall, wind and insulation data;
- crop details (e.g. ETc values);
- soil characteristics;
- type of irrigation system and efficiency;
- water license/rights, well and aquifer capacities on site.

3 ANALYSE AGRICULTURAL PRODUCTION AND RENTABILITY

Any irrigation technology has its technical and economic limitations in terms of the range of crops it can support. Investment costs have a significant effect on the range of crops to produce, if the irrigation system is to produce positive financial return on investment. The technology choice impacts on the following factors: investment (capital) and the related financing service costs, costs for operation and maintenance and labour costs. They form part of the production costs of the crops and are part of the farm budget.

Pressurized irrigation systems in general and micro irrigation systems in particular are more capital-intensive than traditional surface irrigation systems. Combined with PV-based pumping, the initial investment costs are even higher – costs for operation and maintenance of the pumping system are comparatively lower as for other pumping methods, though.

Refinancing these costs depends on the financial return of the production – the margin generated from crop production has to cater for the costs of the system and the income or profit expectations of the farm household.

Each crop has its own financial budget or gross margin that considers the revenue generated by the production and the cost of this production, thereby including all variable cost factors including labour. In addition, fixed costs related to the production have to be considered. The financial viability of any investment option depends on the result of this equation. As a general rule, the higher investment and operation costs, the more the farm has to increase of the area under cultivation, and/or intensify the production of high value crops to optain a positive financial return on these costs.

The agricultural production of the farm has to be analysed with regard to its suitability for the specific technology choice and its potential to generate the desired financial viability.

Financial viability is the ability to generate sufficient income to meet operating expenditure, financing needs and, necessarily, to generate profit. It is usually assessed by means of a cost-benefit analysis using the Net-Present Value (NPV) and the Internal Rate of Return (IRR) approaches together with estimating the sensitivity of the most important cost and revenue elements. The **Farm Analysis Tool** helps the agricultural extension worker and the farmer undertaking this based on farm level data. The analysis should always be done for the scenario with the planned investment, and without.

DATA REQUIREMENTS

The data required for the analysis of the agricultural production and the financial viability is available from the farms own bookkeeping and its external service providers:

- Compilation of all crops in the farm's actual cropping pattern;
- yield level and market price for crops;
- production costs (seed, fertilizer, plant protection, labour, traction, transport, labour, services);
- capital costs of irrigation system options;
- operation and maintenance costs of irrigation system options;
- financial service costs (loan/lease costs, subsidies/grants).

PEOPLE / STAKEHOLDERS

- Farmers/farm household;
- agricultural extension services;
- technology and service providers.

OUTCOME / PRODUCT

- List of suitable crops and rotation based on choice of irrigation technology and local requirements;
- crop gross margins for existing and future production;
- capital and operational cost choice of irrigation technology;
- cost-benefit analysis of irrigation technology options;
- additional parameters based on needs (e.g. Life-cycle costs of irrigation technology options).

IMPORTANT ISSUES

- Life cycle duration of the different irrigation system components differ and need to be determined;
- there always exist multiple options to optimise the farm-production;
- capital costs and costs for financial services (loans, etc.) need to be considered in order to cater for future replacement /modernisation requirements ;
- insufficient consideration of depreciation / replacement will endanger investment sustainability.

4 SELECT SYSTEM TYPE

Depending on the available water resource (ground or surface water) and site-specific conditions, different technical system configurations are possible. They differ in the following main aspects:

- Type of water source (surface source, well, borehole);
- motor pump installation (submersible or surface);
- use of water tanks (irrigation by gravity);
- direct irrigation (without water storage);
- type of irrigation water distribution.

Based on the results of site data collection and analysis, the best system configuration should be selected jointly with the farmer. The suitability of a particular system configuration for a given farm depends on the water availability, the farm's specific water requirements, its agricultural production and the skills of the farmer. An overview and description of different plant configurations is given in the table on page 16.

Almost all existing irrigation methods can be used in combination with photovoltaic water pumps. The size of the PV generator is mainly determined by the water and pressure requirements of the irrigation scheme. Water-saving irrigation technologies such as drip irrigation, working at comparably low operating pressures, are the preferred option in connection with PV pumping systems.

OUTCOME / PRODUCT

- SPIS plant scheme.

DATA REQUIREMENTS

- Results of on-site data collection;
- results of comparative financial analysis.

PEOPLE / STAKEHOLDERS

- Farmer;
- agricultural service provider;
- technology providers/system integrators.

IMPORTANT ISSUES

- PV water pumping works best with low pressure micro (drip) irrigation systems;
- the main disadvantage of a storage tank systems is the high initial investment costs ;
- system concepts without storage tank (direct irrigation) have been developed to reduce investment costs;
- the direct connection of the solar pump and the irrigation system leads to a dynamic and varying hydraulic load (planning is more complex);
- solutions to the problem of varying hydraulic loads are (a) automated irrigation with volume control, (b) adaptation of irrigation field size (c) and solar tracking;
- combining PV-based water pumping with traditional surface irrigation methods is often financially not viable.

5 ESTIMATE SYSTEM SIZE AND COSTS

To determine the costs of a PV pumping system for a selected site, the required size of the PV generator is estimated first. For this, essential sizing data is required:

- Daily crop water requirement V_d [m³/day]
- Total pumping head H_T [m]
- Mean daily global solar radiation Gd for the design month [kWh/m²day]

A simple arithmetic formula that takes the individual system component efficiencies into account, can be used to estimate the required solar generating power P_{peak} [Wp]:

$$P_{peak} = 8{,}0 \frac{H_T \times V_{day}}{G_d}$$

Example: According to this equation, a 2.4-kWp PV generator is required to deliver water at the rate of 30 m³/d at a head of 50 m based on a daily total global irradiation of 5 kWh/m²day. The approximate cost of the planned PV system can be calculated by multiplying the country-specific average system cost [currency/kWp] and the calculated PV generator power (P_{Peak}). For a more exact and comfortable system sizing, a System Sizing Tool (EXCEL-based worksheet) that allows for input parameter variation of daily global radiation, pumping head and water requirements has been developed as part of this manual. After entering the main system parameters, the required PV generator, the pump motor size and the daily water flow are calculated. The tool includes a data base of 100 solar pumps available on the market to allow for a pre-selection of the motor/pump unit by the agricultural advisor. Data from the **System Sizing Tool** can be inserted into the **Farm Analysis Tool** in order to incorporate costs for investment and operation and maintenance into the analysis. The tools also provide some useful parameters that may be used to compare technology options (life cycle costs, costs of water per m³ and m⁴ (cubic meter of water conveyed multiplied by pumping head) produced, annual system costs, annual operation and maintenance costs). The final design of the PV pump and irrigation system should be left to experienced system integrators who use computer-based system sizing and simulation tools such as COMPASS, WinCAPS and PVSYST, HydroCALC, GESTAR. At the end of this step the principal analysis steps to support decision making have been completed. The technical, agronomical and financial aspects of the possible SPIS configuration (and alternatives) are available. To verify if all crucial aspects have been considered, the tool **Suitability Check List** could be employed. It provides the farmer and the advisor with a number of questions and an evaluation matrix to help summarising the basis for decision.

OUTCOME / PRODUCT

- Required PV generator size;
- pre-selection of motor/pump unit;
- motor/pump characteristics;
- layout of water distribution system;
- daily course of solar irradiation and water flow;
- system cost estimate;
- system cost parameters;
- suitability check list / evaluation.

DATA REQUIREMENTS

- Daily crop water requirement Vd [m³/day];
- total pumping head HT [m];
- mean daily global solar radiation Gd for the design month [kWh/m²day];
- country-specific cost of PV pump [Currency/kWp].

PEOPLE / STAKEHOLDERS

- Agricultural service provider;
- experienced system integrator.

IMPORTANT ISSUES

- There is currently no commercially available software solution on the market that integrates design for the PV pump and the irrigation system;
- demand for irrigation water will vary throughout the year;
- peak demand during the irrigation season is often more than twice the average demand;
- SPIS usually have to be oversized to meeting these peak demands, resulting in a comparably low degree of system utilization;
- the drawback of PV pumps for seasonal irrigation can be balanced by adapted crop rotations (including permanent crops) and irrigation management to reduce the oversizing effect.

6 ASK FOR QUOTATIONS

Supplier Pre-Selection: The market for solar water pumps for irrigation is still developing, therefore, these pumps are mostly not found in the portfolio of traditional agricultural service providers. Instead, PV pump manufacturers often select specialized PV distributors and system integrators to market their products. A few aspects need to be considered when short listing potential suppliers/system integrators:

- Look for leading brands in the service provider's portfolio;
- check long-term experience in the field of solar water pumping;
- check if a project reference list is available which clearly indicates SPIS experience;
- check if a regional distribution network and a functioning spare part supply exists.

Holistic solutions, which include the photovoltaic pump **and** the water distribution system can only rarely be found on the market, although it is useful to have an integrated system configuration to increase the overall system efficiency and reliability of SPIS. Suppliers offering turn-key solutions should be preferred, if they are able to adopt all system components to the site conditions and to the farmer's needs.

Quality and Safety Requirements: A precondition for a safe operation and longevity of the SPIS is that all system components fulfil minimum quality and safety standards. In request for quotations and tender documents, it should be clearly stated that only high-quality products, which meet international standards (e,g, IEC, ISO), shall be offered. Corresponding certificates have to be provided by the system integrator to proof system quality. The request for a quotation / offer should also include an obligation of the service provider to state and price after sales warranty and service details and costs.

It is important to assess whether the service providers maintain a local representation in the area of the farm, enabling swift reply to maintenance and repair requirements, including spare part supply. Log service response times can result into crop damage during system breaks.

Design Data and Timing: A complete set of high quality design data has to be included in the request for quotation or tender document. The accuracy of the site-specific sizing data (Vd, HT, Gd) needs to be assured. A submission deadline for quotations/offers should be set by leaving sufficient preparation time (e.g. 4 weeks).

Photo: Andreas Hahn

Showroom of technology distributor

OUTCOME / PRODUCT

- Request for quotation;
- if a tender process is preferred to a straightforward dealer/buyer arrangement: Set of tender documents, including a comprehensive description of system requirements;
- system cost and after sales service quotations / offers.

DATA REQUIREMENTS

- Results of on-site data collection;
- information on product portfolio and ; experience of potential suppliers/retailers.

PEOPLE / STAKEHOLDERS

- Agricultural service provider;
- farmer;
- suppliers / system integrators.

IMPORTANT ISSUES

- Integrated design of SPIS including pumping and irrigation system is usually not done – system components need to be harmonized to provide the best result;
- large quality differences exist in all system components available on the market.

7 EVALUATE QUOTATION

On the submission date, the quotations / offers of different suppliers will be opened and need to be evaluated with regard to technical and financial aspects. The following aspects should be taken into consideration:

- For the comparison and evaluation of the different quotations / offers, it is advisable to prepare an EXCEL worksheet in which features and prices of the individual system components and services are registered
- The definition of evaluation criteria and weighting of technical and financial aspects facilitate the assessment.

The following aspects help to assess the quality of system components offered:

Warranty Period
An important assessment criterion is the given warranty period. An overall system warranty period of e.g. 5 years. Individual system components, such as solar panels, usually come with a 10 year product guarantee and a linear performance warranty which guarantees at least 80% power output by the end of the 25th year.

Solar Generator/Quality of Solar Panels
Installed under harsh environmental conditions, solar panels are constantly exposed to high temperatures and UV-irradiance, dust, humidity and rain. This puts a lot of stress on embedding materials and electrical connections. Therefore, only high-quality products that meet the standards of the International Electro-Technical Commission (IEC) should be offered.

Cabling
For the electrical installation of a photovoltaic system, wiring and cabling should be used that meet the requirements for this application. For DC connections, single-wire cables with double insulation are a practicable and reliable solution . They should be UV and weather resistant and suitable for a wide temperature range.

PV Array Combiner Box
The combiner box should be made to Protection Class II and demonstrate a clear separation of the positive and negative sides within the box. If mounted externally , it should be protected to at least IP 54. Ingress Protection rating to a piece of electronic equipment or to an enclosure for electronic equipment.

The protection class after EN60529 are indicated by short symbols that consist of the two code letters IP and a code numeral for the amount of the protection. The first digit represents limited protection against dust ingress (no harmful deposits). The second digit represents protection against splash water from any direction.

Mounting Structures
In most solar-powered irrigation systems, PV panels are installed in the open-field and therefore require a sturdy and weather-resistant mounting structure. Quality mounting systems are made of galvanized steel or aluminium profiles. For fixing of PV panels and profiles, specially developed brackets, screws, washers and nuts are used (this alos contributes the a reduced theft risk, which should be part of the evaluation criteria). To avoid galvanic corrosion, it is important to select materials with similar corrosion potentials or to break the electrical connection by insulating the two metals from each other.

Pump Controller/Inverter
Modern controllers must incorporate high-efficient power electronics and utilize Maximum Power Point Tracking (MPPT) technology to maximize power use from the PV generator. Additional features to increase system reliability should include over and under voltage protection as well as protection against reverse polarity, over load and over temperature.

Motor-Pump
Solar water pumps must be constructed from non-corroding stainless steel. Since DC motors tend to have overall higher efficiency levels than AC motors of a similar size, they are often the first choice of quality solar pump manufacturers. Some solar pumps are still equipped with comparably cheap brushed DC motors. The main disadvantage of brushed motors is that brushes are subject to wear and tear and need to be replaced in regular intervals (approximately every two years). Therefore, in terms of system reliability, the **use of brushed DC motors is not recommended** because a regular maintenance in remote areas of developing countries cannot be assured.

Water Distribution System
Water-saving irrigation technologies working at comparably low operating pressures, are the preferred option in connection with PV pumps. To assess the suitability of the distribution systems, the knowledge of the hydraulic characteristic is important and details should be provided be the supplier / system integrator. The performance under low operating pressures (e.g. in the early morning

and late evening) and the uniformity of water distribution across the field is of particular interest.

After a first technical evaluation

- Results should be discussed with other technical experts (agricultural advisors, research institutes etc.);
- quoted prices of suppliers and related services offering similar products need to be compared;
- the providers with the best quotations / offers should be invited for individual presentation and negotiation.

OUTCOME / PRODUCT

- Structured comparison of qualified quotations / offers;
- ranking of quotations / offers;
- invitation of potential suppliers / system integrators for presentation and negotiation.

DATA REQUIREMENTS

- Quotations / offers consisting of a technical and financial part;
- unit price listing;
- quality and safety certificates;
- technical data sheets of system components;
- hydraulic characteristic of irrigation system;
- information on warranty and after sale services.

PEOPLE / STAKEHOLDERS

- Farmer;
- agricultural service provider;
- supplier / system integrator.

IMPORTANT ISSUES

- High-quality systems with good value for money shall always be given preference;
- costs should never be reduced by compromising on system quality or by decreasing support services.;
- a conclusion of maintenance contracts between the farmer and the service provider is recommendable but not very common;
- system integration in the form of turn-key solutions is preferable, yet still very hard to find.

8 DECIDE AND CONTRACT PROVIDER

In a final step, the best system provider needs to be selected based on cost-quality considerations. In a meeting with the farmer, the agricultural service provider and the shortlisted candidates, the following topics should be addressed:

- Detailed presentation of offer and the SPIS experience by provider;
- explanation of design procedure and used tools (e.g. computer-based sizing);
- product quality and safety certificates;
- warranty, after sales service and spare part supply (e.g. maintenance contracts);
- final negotiation on price, if required;
- implementation schedule;
- contract details and payment conditions.

The contract should only be concluded once all open questions are clarified.

OUTCOME / PRODUCT

- Ultimate quality provider with the best cost-quality ratio;
- supply contract, including after sales services.

DATA REQUIREMENTS

- Technical and financial quotations / offers shortlisted candidates;
- structured comparison of qualified bids;
- clarification of open questions in negotiation.

PEOPLE / STAKEHOLDERS

- Farmer / farmer groups;
- agricultural service provider;
- supplier / system integrator.

IMPORTANT ISSUES

- Quotations/offers often deviate from technical specifications;
- significant differences exist between bidders in terms of services and warranty;
- implementation scheduling needs to be firm and agreed upon.

Be prepared for the final negotiation:

- Define your goals;
- identify negotiation areas;
- look for win-win situations;
- make realistic proposals;
- clear up misunderstandings;
- make a final summary.

FURTHER READING, LINKS AND TOOLS

Links

Meteorological data sources: Getting NASA-SSE data of a particular site is straight forward. Specific site data can be generated on the NASA site at http://eosweb.larc.nasa.gov/sse/ (13/8/2015)

Crop water requirement: CROPWAT: http://www.fao.org/nr/water/infores_databases_cropwat.html (13/8/2015)

System Sizing: https://www.lorentz.de/en/products/submersible-solar-pumps.html (13/8/2015)

System Sizing: http://de.grundfos.com/grundfos-wincaps.html (13/8/2015)

Check the web for local irrigation calculators (e.g.: http://www.irrigationcalculator.com/) (13/8/2015)

Negotiation Trainings available on the web
(e.g. http://www.fao.org/docs/up/easypol/550/4-5_negotiation_background_paper_179en.pdf) (13/8/2015)

Tools

Site Data Collection Tool

System Sizing Tool

Farm Analysis Tool

Suitability Checklist Tool

Photo: Andreas Hahn

SET UP

Photo: Andreas Hahn

MODULE AIM

This module guides through the necessary steps for the installation of the Solar Powered Irrigation System. The process steps of the SET UP module are following the completed design process. Technology choice, system design and the selection of the technology provider are completed and important considerations have to be made for the installation works on site.

The installation of an irrigation system requires planning and decision making by the farmer as the system should be set up according to his preferences and operation requirements.

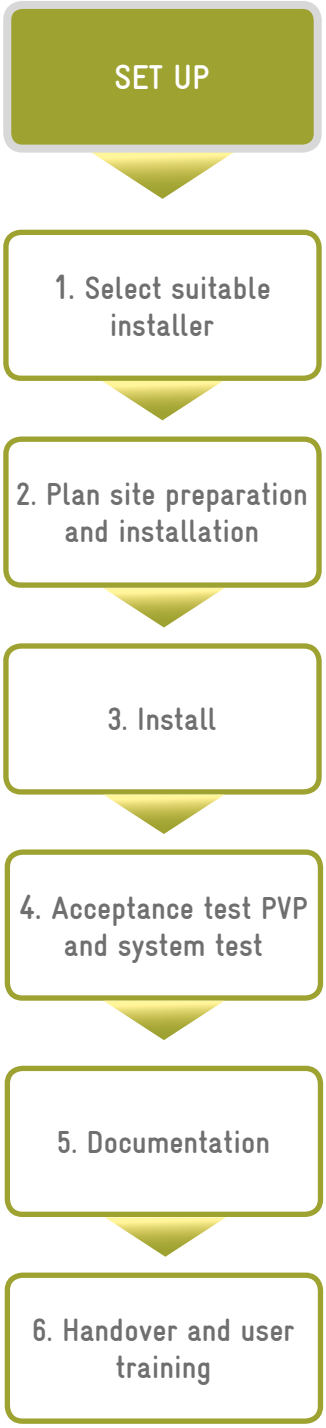
BRIEF DESCRIPTION OF PROCESS

With the conclusion of a contract with a technology provider all decisions concerning the system components have been made. The quotation or offer from the provider includes already a system layout plan in which ideally the specific installation requirements are described.

The practical installation is not done by the farm household itself. A qualified installer is required to assemble and mount the system components as required. The installation under consideration of the specific site conditions lays the foundation for a reliable and trouble-free operation of the SPIS. The installation process requires active decision making by the future user.

The set up or installation starts with choosing a service provider and a planning of the works to be executed. In the installation planning, all requirements the farmer and the installer will be considered. Once the system components are installed, their proper functioning and the systems performance have to be tested.

The farmer as the future user of the system has to follow this process to assure that the SPIS is installed according to the agreed planning and to understand the system's functionality. Upon completion of the installation, the farmer should receive a documentation of the system and an introduction to its operation.



1 SELECT SUITABLE INSTALLER

The aspect of installation should already be considered during the process of selecting the technology provider. The quotation or offer submitted by the providers need to specify the system's installation is included in the offered services. Few technology providers also install their products themselves – they usually maintain a network of associated installation service providers in their market region. If the installation services are already included in the contract for the system components, the technology provider will nominate the executing installer.

If installation services are not included, the technology provider will be able to recommend a qualified installer to the farmer. In this case, a separate contract for the installation services has to be concluded. For this, a pre-selection of qualified installers should be established and quotations or offers for the services should be obtained, evaluated and decided upon (follow step 6 of the DESIGN module). The basis for the required services is the system layout and the system components description as included in the contract with the technology provider.

Installers need to be chosen based on their general qualification and familiarity with the specific products (system components) the farmer has opted for. Technology providers usually provide regular training for installation service providers and certify their qualification for installation of specific products. This is important as the warranty of system components may depend on their installation by a certified service provider.

In order to be able to provide a quotation or an offer, the installer will have to visit the site and review the planned installation together with the farmer.

When selecting suitable installers:

- Check if the technology provider is able to recommend a qualified installer from his network;
- verify if the installer is certified for the installation of the purchased system components / brands;
- check the experience of the installer with installations in your area (reference list, other farmers);
- obtain clarity on the installers' after installation services – ideally, the same service provider is also available for maintenance, troubleshooting and repair.

OUTCOME / PRODUCT

- Shortlist of qualified installers;
- quotations / offers for installation services;
- selection of installer based on cost-quality considerations;
- installation services contract.

DATA REQUIREMENTS

- List of qualified and certified installers from technology provider;
- system layout and system component description (provided in contract with technology provider);
- unit price listing (quotation / offer of installer);
- information on post-installation services.

PEOPLE / STAKEHOLDERS

- Farmer;
- supplier / system integrator (technology provider);
- installation service provider;
- agricultural service provider.

IMPORTANT ISSUES

- Installation services may be included in the purchase contract for the system components, but may also have to be contracted separately;
- it may not be feasible that the same installer is able to install PV generator, pump, storage tank and irrigation system;
- the warranty of the system components depends on their installation by a qualified and certified service provider;
- it is beneficial if the installer is also able to provide maintenance, troubleshooting and repair services.

2 PLAN SITE PREPARATION AND INSTALLATION

The selected installer was required to consider the site-specific conditions in his quotation or offer. In this process step he should already have taken into account the views of the farmer with regard to the location, spacing and protection of the planned system. After conclusion of the installation service contract, a detailed planning of the installation has to take place. For this, a further site visit and joint review of all relevant aspects together with the farmer may be required.

The aim of this installation planning is to:

- Verify site access and material storage conditions;
- determine the exact planned location and the spacing of the system components (PV generator, water pump, control units, water storage tank, water distribution network, irrigation pipes);
- assess the site-specific conditions relevant for the installation (soil / underground conditions, surface profile, water source conditions, security hazards);
- identify preparatory works to be done (deinstallation of old installations, well cleaning / rehabilitation and pumping tests, earth works, site clearing, field preparation);
- schedule preparatory works and installation.

A particular consideration is the land resources required to establish the SPIS. The PV generators and the water storage tank (if part of the system) will occupy land that is available for cultivation after installation. The system components must also be spaced in a way, that the solar panels are not shadowed by neighbouring components.

A proper pre-installation planning avoids delays in the installation process as preparatory works and installation can be timed in succession. The farmer may also have some particular additional considerations with regard to location, spacing and protection of the future system, which has to be taken into account by the installer prior to assembling and mounting the components. Specific site conditions such as exposure to strong winds, flood water, stray animals or risks related to theft or vandalism are factors that influence the installation concept and the accessory materials (joints, bolts, screws, seals etc.) used.

The installation planning must also be harmonised with the cropping calendar and the agricultural work schedule of the specific farm household. Installation works should not disturb the production routine in an unnecessary way. In case more than one installer is required (for example one for the PV pumping system and for the irrigation system components), the planning will have to incorporate this and the different installers must be coordinated.

The planning together with the installer should also result in a clear understanding of both parties on the process of handing over the system and the provision of an orientation / user training upon handover.

OUTCOME / PRODUCT

- Location of each system component;
- list of preparatory works / requirements;
- schedule for preparatory works and installation;
- schedule for handover and user training.

DATA REQUIREMENTS

- System layout plan (provided in contract with technology provider);
- data on well / water source conditions;
- data on soil / underground conditions.

PEOPLE / STAKEHOLDERS

- Farmer;
- installation service provider;
- agricultural service provider.

IMPORTANT ISSUES

- Implementation planning requires a site visit of the installer and a joint review with the famer;
- site-specific conditions and hazards need to be considered;
- land resources are required for the installation;
- preparatory works requirements have to be identified prior to installation;
- preparatory works need to be concluded prior to installation;
- installation planning should include handover and user training timing;
- multiple installers may need to be coordinated.

3 INSTALL

The installation of the different components of a Solar Powered Irrigation System will be carried out by a contracted qualified installer. He will follow the system layout and the technical specifications provided from the system technology service provider (system integrator, supplier) and the considerations of the farmer with regard to location and spacing. In this process step, the farmer has a passive role, provided all preparatory works requirements have been taken care of before.

The installer will temporarily require access to the site and a storage and assembly space to unload and assemble the system components. This should be considered by the farmer in particular on small holdings where uncultivated areas are in short supply.

The actual time required for the assembly and the mounting and connection of the different components of a SPIS depends on the system size and the site conditions. The installer may have to carry out the installation process in several steps. A time consuming partial work is the establishment of a proper foundation for the mounting structure of the solar panels and the water storage tank (if part of the system). These foundations are often established through reinforced concrete foundations that require also prior excavations works.

While the farmer has a passive role during the technical installation it is recommended that he follows the installation process systematically and that he is available for questions and information needs the technicians may have. The farmer and also his agricultural advisor should therefore budget the necessary time to be present during the installation process. Accompanying the installation has the advantage that:

- the farmer is available at all times to provide information and to take decisions;
- the farmer (and his agricultural advisor) can check on the completeness of all components while they are installed;
- the farmer (and his agricultural advisor) obtains an additional understanding of the different system components, their particularities and the location of connections, switches etc. (ask questions!);
- the farmer can monitor the adherence of the installation to layout, plan and schedule.

OUTCOME / PRODUCT

- Complete Solar Powered Irrigation System.

DATA REQUIREMENTS

- System layout plan (provided in contract with technology provider);
- list of components and bills of quantity;
- installation planning.

PEOPLE / STAKEHOLDERS

- Farmer;
- installation service provider;
- agricultural service provider.

IMPORTANT ISSUES

- The technical installation is carried out by the technicians of the service provider, the farmer has a passive role;
- temporary space has to be made available for site access, material storage and assembly;
- installation may have to be made in separate steps if foundation works etc. have to be done;
- the farmer should be present during the installation and accompany and monitor the process.

4 ACCEPTANCE TEST PVP

Upon completion of the installation the functionality and the performance of the system should take place in the presence of the future user (farmer). The testing includes a number of separate analyses. A first and important step is the acceptance test for the photovoltaic pumping system (PVP), which includes the PV generator, the mounting and tracking system (if part of the system), the controller and the water pump. These components are the "engine" of the SPIS, their performance is vital for the successful employment of the irrigation system chosen.

This acceptance test (also referred to as Side Acceptance Test, SAT) is the second level of material testing in view of quality management. Manufacturers of system components are obliged to run a Factory Acceptance Test (FAT) prior to releasing products to the supplier. Both levels of testing should be mandatorily when setting up a SPIS.

The acceptance test for the PVP includes the following main steps:

- Visual check of all main components and their joints / connections;
- Visual check of wiring and insulation;
- mechanical check of mounting and tracking system;
- functional check of PVP operation;
- existence of system documentation (technical data sheets, electrical wiring plan, operational procedures);
- measurement of solar irradiance, electric power, pumping head and water flow.

The measurements are usually carried out in the following sequence:

Measurement of solar irradiance (S) → Calculation of electrical power output (P_{el}) → Measurement and calculation of total pumping head (HT) → Measurement of actual water flow (Q_{meas}) → Comparison of measured and design water flow.

The different measurements should be carried-out within a short time interval under clear sky conditions. At least, two acceptance test runs are advisable, measuring at high irradiance (800 – 1,000 W/m²) and low irradiance levels (approx. 500 W/m²). The equipment for the test will be provided by the installer.

Important: Check on the tightness of seals and joints, screws and bolts! Record any deficiency and malfunction and discuss their amendment with the installer!

The results of the acceptance test should be compared with the design performance of the PV pumping system. The PV Acceptance Test Tool could be used to record the most important data and to compare it with the design values. The acceptance test protocol should be signed by the installer and the farmer.

OUTCOME / PRODUCT

- Completed acceptance test for the photovoltaic water pumping system;
- comparison of actual performance to design performance;
- acceptance test protocol.

DATA REQUIREMENTS

- Measured solar irradiance, total pumping head and water flow;
- calculated electrical power output, design pumping head and design water flow;
- observations from visual check.

PEOPLE / STAKEHOLDERS

- Farmer;
- installation service provider;
- agricultural service provider.

IMPORTANT ISSUES

- The on-site acceptance test is mandatory to verify if the PVP systems achieves design performance;
- testing should be done by the installer in presence of the farmer incorporating all criteria;
- testing requires clear sky conditions, a minimum of two measurements need to be done;
- a thorough check on the mechanical parts is recommended.

PVP ACCEPTANCE TEST

1. General information				
Date:				
Location:				
Solar generator:		kWp	Module:	
Motor pump and controller:				
Water source:	well		surface	

2. Acceptance test				
Solar irradiance:		W/m^2		W/m^2
Electric power:		W		W
Water level well / surface:		m		m
H (p1):		m		m
Total pumping head		m		m
Measured water flow:		m^3/h		m^3/h
Theoretical water flow:		m^3/h		m^3/h
$Q_{meas.} / Q_{theoretical}$				

3. Comments:

Irradiance test

4 SYSTEM TEST

In a further step, the functionality of the other system components and their joint functionality must be checked and tested. This testing step should follow the same principles as the preceding PVP acceptance test. It concerns the following components of the Solar Powered Irrigation System:

- Water abstraction and discharge monitoring devices (water meters);
- distribution valves and distribution pipes;
- water storage tank (if part of the system);
- filter system (if part of the system);
- irrigation block / plot connection;
- irrigation pipes and watering devices (emitters, mini sprinklers).

The system test for the aforementioned components include:

- Visual check of all main components and their joints / connections;
- visual check of connections;
- mechanical check of mounting supports for tank and pipelines;
- functional check of water distribution and discharge, storage tank and filter operation;
- functional check of maintenance modus;
- existence of system documentation (technical data sheets, hydraulic plan, operational procedures);
- measurement of water pressure input and pressure distribution in all system sections and water discharge.

Measurements are usually carried out "from head to tail", starting with the release of the water into the supply line (to storage tank or direct injection) and ending with the flushing outlets of the irrigation pipes. Pressure measurements have to be taken at all system joints / distribution knots to assess the hydraulic distribution in all sections. These measurements have to take the pressure variation during the day due to fluctuating irradiance levels into account. The results need to be documented as a hydraulic profile of the irrigation system as an important basis for operation.

Calibration: The water discharge to the field needs to be calibrated in order to manage crop water distribution efficiently. Pressure differences may exist between different sections of the irrigation system and the pressure inputs vary in a PV pumping system without elevated storage, causing water discharge from the irrigation devices to differ from section to section and within the course of a day. The water discharge from the irrigation devices has to be measured at different times of the day to calculate the actual water discharge, which can then be managed by varying the irrigation interval per area unit.

Note: This calibration measurement is a time consuming exercise!

Important: Check on the tightness of seals and joints, screws and bolts! Record any deficiency and malfunction and discuss their amendment with the installer!

OUTCOME / PRODUCT

- Completed system test for the irrigation system;
- comparison of actual performance to design performance;
- system test protocol;
- hydraulic profile of the irrigation system;
- water discharge data for all irrigation sections.

DATA REQUIREMENTS

- Measured pressure and water discharge in all irrigation sections;
- calculated system pressure and water discharge;
- observations from visual check.

PEOPLE / STAKEHOLDERS

- Farmer;
- installation service provider;
- agricultural service provider.

IMPORTANT ISSUES

- The on-site system test is mandatory to verify if the irrigation systems achieves design performance;
- testing should be done by the installer in presence of the farmer incorporating all criteria;
- testing must include pressure and water discharge measurements in all irrigation sections;
- calibration of the irrigation discharge system is important to efficiently manage crop water distribution.

5 DOCUMENTATION

A Solar Power Irrigation System comprises multiple components that each have particular technical specifications and operation and maintenance requirements. In addition, a SPIS comprises mechanical and electrical technology that is vulnerable to defects if operated in a wrong way. Qualified and careful operation of the system not only prevents system failure and costly repairs, but also assures a long lifespan of the different components and parts.

The system will be operated by the user (farmer) autonomously. The user will need to have access to operation guidelines and technical information at any times enabling an uninterrupted irrigation of the crops. A comprehensive documentation of the system and its operation and maintenance needs to be provided by the supplier and the installer and provided to the farmer as part of the acceptance and system test and hand over. Often, this important aspect is neglected! While technical data sheets and installation instructions exist for almost any individual SPIS component in any part of the world, operational manuals covering an entire system are the exception. As any SPIS is not only composed of different components, but has also a distinct individual design, operation and maintenance manuals have to be specifically put together – there is no blue-print.

The provision of a comprehensive documentation of the system and an operation and maintenance manual should be agreed upon the technology provider and/or the installer during contract negotiations. The documentation should cover the following main aspects:

- System layout plan including all components of the water source, pumping system, water storage and irrigation system (and connection and wiring plans);
- technical data sheets for all system components;
- operational guidelines for all system components;
- warranty information and maintenance instructions and schedules for all system components;
- security instructions, health risk warnings and emergency procedures;
- contact details of maintenance / repair services, help desks etc.

Ideally, the operational manual also includes information about the negative implication of excessive water abstraction for the environment. A systematically designed irrigation system operates on the principle of a sustainable water abstraction in line with the available water resources and the underlying water rights / permits.

OUTCOME / PRODUCT

- Documentation of all SPIS components including technical specifications, connection/ wiring plans, security instructions, emergency procedures and maintenance information;
- system operation manual;
- emergency contact details / help desk information.

DATA REQUIREMENTS

- Technical specifications of SPIS components.

PEOPLE / STAKEHOLDERS

- Farmer;
- installation service provider;
- agricultural service provider.

IMPORTANT ISSUES

- The documentation of all system components must be complete and understandable;
- security and emergency instructions should be clearly indicated and visibly attached to the respective system component;
- the installer should provide an operational manual with all relevant procedures and information.

Measuring water flow

6 HAND OVER AND TRAINING

As a final step of the installation process the SPIS will be formally handed over to the user (farmer). The handing over is usually combined with a thorough introduction of the user to all technical aspects of the system and a practical training on its operation according to the designed performance. This step should be thoroughly planned and sufficient time should be budgeted for it as the user should have sufficient time to go through all system components and operation and maintenance aspects together with the technicians of the installer.

Upon reaching this step, all other requirements should have been completed, in particular the PVP acceptance and the system tests and the system's documentation. Ideally, the user could accompany and follow the entire installation process including the testing steps. This way he will already have obtained knowledge about "his" system and will have had the opportunity to get familiarised with the main technical and operational features.

During the testing stages of the installation process, defects or quality problems are identified and recorded and an agreement between the installer and the user is concluded on how and when these defects are corrected. This is laid down in the test protocols. A handing over of the system should not take place before all repairs and amendments are implemented. Upon hand over, the farmer should receive a system that is correctly installed and operates according to the design standards.

The handing over and the related orientation and training usually takes place during a final test run of the system. It should not be done as a theoretical class room exercise. Supporting material for the training should be the operational guidelines and the manual that is provided as part of the system documentation.

Important features of the orientation and training are:

- Introduction to the specifics of all system components;
- operation of the system under different conditions, in particular crop water distribution management based on pressure and supply duration management;
- security precautions and protection of system components;
- health and environmental hazards;
- emergency procedures;
- maintenance works and schedules.

The handing over step should be concluded by signing a hand over protocol that states the condition of the system and all activities carried out to orient and train the farmer.

OUTCOME / PRODUCT

- Hand over protocol.

DATA REQUIREMENTS

- PVP acceptance and system test data;
- aystem documentation and operation manual.

PEOPLE / STAKEHOLDERS

- Farmer;
- installation service provider;
- agricultural service provider.

IMPORTANT ISSUES

- Hand over should only take place if the system is perfectly running, with no remaining deficiencies;
- hand over should be accompanied by a practical introduction and training of the user;
- introduction and training should include information on security precautions, system protection and hazards;
- upon completion of the hand over a hand over protocol should be established.

FURTHER READING, LINKS AND TOOLS

Links

"IRRIG8QUICK Irrigation Calibration Quick Test - Guidelines for Drip Micro Irrigation" by Page Blomer Associates (2009) at:
www.claw.net.nz/resources/irrigation (13/8/2015)

"Solar Powered Irrigation Systems - Stocktaking and Analysis Report" by German Technical Cooperation Agency (GIZ) (2015) at:
http://

Tools

PV Acceptance Test Tool

Photo: Andreas Hahn

MAINTAIN

Photo: Andreas Hahn

MODULE AIM

Solar Powered Irrigation Systems, when compared to systems using other energy sources, can have a long lifespan. Regular maintenance is indispensable to keep the system fully reliable over its long lifetime – up to 20 years for the solar panels and approximately 10 years for the pumping system.

Maintaining a SPIS does not require advanced technical skills and the overall effort is relatively low, when compared to other technologies.

Good maintenance is particularly important for the system's efficiency and thus overall financial viability, considering its high initial investment requirements. In addition, a rigid and systematic monitoring of the system's performance helps to identify maintenance and repair needs at an early stage, enabling the user to react timely to service needs.

Mandatorily included in the routines is also the regular and systematic monitoring of water extraction from the water source and water injection into the irrigation system. This helps to avoid overexploitation of the water resources and the related negative impacts on the environment.

BRIEF DESCRIPTION OF PROCESS

Farms operating a SPIS should have a maintenance plan that is adhered to rigorously and refined as time goes by. The performance of the system should be documented and monitored regularly so as to permit a thorough analysis and to detect reasons for possible irregularities, malfunctions or groundwater depletion. Service and technology providers will need to be involved for specific aspects and trouble shooting.

Photo: Andreas Hahn

MAINTAIN

1. Establish and refine maintenance plan
2. Select suitable service provider
3. Implement maintenance routines
4. Documentation and monitoring

1 ESTABLISH AND REFINE MAINTENANCE PLAN

Before starting operations, an operation manual should be handed over to the farmer (see module SET UP). This manual will need to include guidance for operations, a maintenance plan, specific instructions for trouble shooting and the contact details of the technology/service provider. The maintenance plan should be elaborated in collaboration with the technology/service provider and the agricultural advisor. If possible, the technology/service provider would show most routine activities at least once to the farmer, and revisit the SPIS after a month in operation for the first maintenance check. Together with the farmer and the agricultural advisor the maintenance plan should be revised regularly.

Water source and pump
Solar pumps generally do not need a lot of maintenance if used in clean water, free of sand, sediments or plants. The water source therefore needs to be kept clean. Under these conditions pumps can last up to 10 years.

Solar panels and mounting structure
Solar panels and their mounting structure generally require very little maintenance since there are no moving parts. Panels need to be kept clean and free of shade, mounting structures should be stable. The PV array should be protected from animals and falling objects. Well kept solar panels and mounting structures last up to 20 years.

Electronics and controls
As controllers/inverters are sensitive to overheating, they have to be installed in a place where faultless operation is guaranteed. Factors to be considered include the ambient temperature, the heat dissipation capability and the relative humidity. For service and maintenance purposes, the controller should be easily accessible and it must also be provided with a circuit breaker between the PV generator and controller.

Irrigation System
If drip irrigation is applied, the water must be filtered because the critical diameter for drip elements is much smaller than for sprinklers. Depending on the sediment load of the water, the filters must be cleaned regularly – this can be up to several times a day. This requires a certain level of technical knowledge and skills. In addition, the drip lines must be flushed regularly, and the drip elements must be examined for blockages and replaced if necessary.

OUTCOME / PRODUCT

- Maintenance plan;
- checklists.

DATA REQUIREMENTS

- Checklist on water analysis.

PEOPLE / STAKEHOLDERS

- Farmers / farmer groups (including women);
- agricultural advisors;
- technology and service providers (electricians, companies providing solar power system).

IMPORTANT ISSUES

- Regular maintenance is indispensable for a long lifespan of any irrigation system. Maintenance is important for the system's efficiency and its life time, and thus for the overall financial viability;
- a SPIS is reliable and maintenance costs are low, if maintained adequately;
- insects and small animals such as lizards like to build their nests in junction boxes and may easily destroy electronic components (e.g. by formic acid). Proper sealing of all openings (e.g. with cable glants) is essential;
- maintenance plans should be reviewed regularly together with the technology/service provider and the agricultural advisor.

2 SELECT SUITABLE SERVICE PROVIDER

Maintenance services for PV components include:

- Training/introduction on operations and use of maintenance tools;
- regular inspection and maintenance visits (especially in first months of operation);
- provision of an operation manual and maintenance tools (hardcopies);
- warranty on components;
- trouble shooting service (online, telephone).

Assess installation process with company contracted for provision. Ideally the contract with technical provider and/or company responsible for installation should include maintenance services.

Quotations and how to compare:

- Ask for quotations from different providers;
- determine if prices are quoted for same range/type of service;
- discuss proposals with other technical experts (agricultural advisors, research institutes, etc.);
- discuss proposals with technical providers to understand details.

Decide and contract service provider **before system starts operating**.

OUTCOME / PRODUCT

- Service contract.

DATA REQUIREMENTS

- Quotations from service providers;
- contract details.

PEOPLE / STAKEHOLDERS

- Farmers / farmer groups;
- agricultural advisors;
- technology and service providers (electricians, companies providing solar power system).

IMPORTANT ISSUES

- Technology and service providers can provide valuable assistance/training, ask for it!
- In case of a system failure, do not forget to check if there is warranty on the components and service;
- do not try to repair the defective component on your own => Risk of losing warranty!
- In case of the solar panels, warranty means performance guarantee, which usually decreases with the years (e.g. 90% performance after 10 years, 80% performance after 20 years).

3 IMPLEMENT MAINTENANCE ROUTINES

Suggested regular maintenance activities

Check daily if the system is working.

If the pump is not working:

- Check the water source and pipes (any dirt, blockage, enough water?);
- check the electronics (any burned parts, loose wires, emergency lights?).

Inspect the system once a week with respect to:

- Energy generated by PV system
- pump performance (pumping rate);
- condition of water source (purity of water);
- condition of controller and electronics (visible signs of malfunctioning);
- condition of water storage facility and pipes (leaks, water level);
- condition of solar panels and their mounting system (stability, cleanness).

Clean solar panels every 2 to 4 weeks. For cleaning the panels:

- Clean water and a little scrubbing with a cloth covered sponge or soft brush should remove the most persistent grime;
- clean in the early morning or late evening, when panels are cool;
- do not step or walk on the panels as they could be damaged.

Note: Hot panels should not be sprayed with cold water – they might crack!

Throughout the year (ever two to three months) the PV system should be checked thoroughly and certain maintenance activities implemented, so that:

- No plants grow close to the panel, the mounting structure, water source, controller, junction box, etc.
- there is no shade on the panels (plants, poles, fences etc.), so as to permit maximum radiation;
- the fencing of the solar array is not damaged so that the area is protected from animals or misuse;
- the mounting structures are stable

Note: Inspect your system **always after strong winds, hail storms, lightening or earth quakes** have occurred in your region.

Note: Call your technology provider (panels, pumping, and controller) or electrician (electronics) who installed the system for help – this should be part of the service.

The tool **Maintenance Visit to Farm** can be used to guide the user through the required maintenance routines.

OUTCOME / PRODUCT

- Maintenance plan;
- maintenance sheets;
- checklist for visits to farm;
- weekly inspection sheet;
- bi-monthly inspection sheet.

PEOPLE / STAKEHOLDERS

- Farmers /farmer groups;
- agricultural advisors;
- technology and service providers (electricians, companies providing solar power system).

IMPORTANT ISSUES & DECISIONS

- Maintaining a SPIS does not require advanced technical skills and the overall effort is relatively low, when compared to other technologies;
- it is important to establish inspection and maintenance routines and to schedule them as part of the work plan of the farm;
- observations, results of performance checks and and repairs should be documented systematically (the establishment of a "log book" is recommended).

4 DOCUMENTATION AND MONITORING

During daily operations and regular inspections of the SPIS, the farmer should collect and register data about the system and its performance systematically. This data will be fundamental for a regular analysis, used also by the technology or service providers or agricultural advisors, when working with the farmer.
Some measured data is required to properly operate and manage a SPIS. In order to provide the farmer with a minimum of system information, the deployment of a basic monitoring system is highly recommendable. The main tasks of the measuring system are:

- To provide system data for the acceptance test after installation;
- to observe the system's operation and performance at any time;
- to control water provision and consumption;
- to prevent ground water depletion and connected environmental risks.

Depending on the site-specific conditions and objectives, a monitoring system can be anything from simple to being sophisticated.

A basic monitoring system is composed at least of a water flow meter, two pressure gauges installed at the filter inlet and outlet, and a device to check the water level in the well (such as awater level dipper).

Standard tables should be adapted and are an integral part of the maintenance plan in the operational manual of the system. All data could be collected in one booklet/folder (monitoring booklet).

OUTCOME / PRODUCT

- Monitoring data booklet.

DATA REQUIREMENTS

- Water consumption (m^3/day);
- total Pumping Head [m];
- frequency of pump usage (h/day);
- solar energy generated (kWh/m^2day);
- costs incurred for replacements and services (bills, dates, brief description of cause);
- findings during maintenance visits by agricultural advisors and/or technology/service providers (maintenance check list);
- system failures (date, description).

IMPORTANT ISSUES

- Collecting data should be linked to the maintenance plan;
- data should be compiled regularly;
- farmer might need assistance or/and training initially to enable correct data registration and analysis;
- maintenance efforts can be obsolete however, if groundwater in the region is not managed adequately. Groundwater levels should therefore also be monitored.

PEOPLE / STAKEHOLDERS

- Farmers /farmer groups;
- agricultural advisors;
- technology and service providers (electricians, companies providing solar power system).

FURTHER READING, LINKS AND TOOLS

Tools

Maintenence Visit to Farm

TOOLS

Photo: [illegible] - Lorentz/Chile

OVERVIEW OF TOOLS

DESIGN

Site Data Collection Tool

System Sizing Tool

Farm Analysis Tool

Suitability Checklist Tool

SET UP

PVP Acceptance Test Tool

MAINTAIN

Maintenance Visit to Farm – Check List Tool

SOLAR-POWERED IRRIGATION SYSTEMS

Photo:

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