GREEN EMPOWERMENT

Solar Pumping Systems (SPS)
Introductory and Feasibility Guide

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1.0 Summary

This guide is intended for local NGO's and the remote communities they represent, striving to improve the reliability and quality of the community's drinking water. There are many ways to help a community to improve their drinking water supply. The information in this guide is meant to assist in examining whether or not a solar pumping solution is viable for your particular community.

Throughout this guide, we stress the ideals of Green Empowerment in our work with local NGO's and communities: the goals of local leadership, social justice, and sustainability and the importance of community needs driving the project. This guide is not to promote the use of solar pumping per se, but is to promote the proper and informed use of any technology that a community decides to utilize in order to reach their self-determined goals. Since solar pumping is one of the technologies that can assist in the all-important area of clean drinking water utilizing renewable energy, we have presented this information in the hopes that it will help with an overall understanding of the technology, and give a road map on how to proceed IF this technology matches with the needs and resources of the community.

This guide is not a complete design and do-it-yourself manual. The goal of this guide is to enable the reader to make an informed decision about solar pumping. If solar pumping is an appropriate solution, this manual will help the designer assemble the appropriate information with which to approach equipment vendors, donors, and technical consultants to proceed to the finalization of the design and initiation of the project.

The guide is broken into 4 main sections: Introduction, Feasibility, Desing, and Budgeting. Each section should build on knowledge and provide checkpoints to help in the evaluation. If you are familiar with some of the information or wish to learn more at any point, follow the symbol to jump ahead. Worked examples and blank worksheets are also provided to assist in the process.

Acknowledgments

This guide was prepared by Walt Ratterman, Jonathan Cohen and Anna Garwood of Green Empowerment, and revised by James Willett. Thanks are also due to members of the Green Empowerment Technical Advisory Council: Windy Dankoff of Dankoff Solar and Matt Hamilton of SunPumps. Photo Credits: KyoceraSolar, Grundfos, Dankoff Solar, WattSun, and Solar4Power.

2.0 Overview 2.a What is a SPS?

As more and more groundwater sources become unsafe for drinking purposes, potable water often needs to be drawn from depths that require some form of pumping. A Solar-Powered Water Pumping System uses solar energy to power a pump to supply a village with potable water. Solar pumping systems are commonly used where it is too far to walk to a well or where the well only provides seasonally usable water. An SPS is most beneficial when a community can come together to organize, build, finance, and manage the project.

2.b Typical Communities Using a SPS

There are several characteristics that make a community a good candidate for a solar pumping project. The following ideas will help you consider how your community's situation compares with qualities of a successful project.

✓ Currently, families must walk a good distance to obtain potable drinking water. Existing wells are too shallow or deeper wells would not work with typical rope pump mechanisms.

✓ The people in the community work well together, with no divisive groups. The proposed project would provide services to ALL community members with no discrimination. There is good local leadership and social justice values are high.

Community Concerns PAGE 14 →

✓ The community is able to come together with a group representative, and organize to build, manage, and collect usage fees.

Water Usage PAGE 18 →

✓ Water is used for drinking, day-to-day uses and perhaps animal watering. While large-scale applications like crop irrigation are generally not supported by an SPS, drip irrigation can be. Not intended to bring indoor plumbing or drastic changes in standard-of-living.

✓ The site has reliable solar resources and relatively expensive, inaccessible, or inefficient alternatives. For example, fuel costs and maintenance for a diesel generator are prohibitive.

Does your project meet the above criteria?
If not, proceed with caution.

2.c SPS Versus Other Pumping Technologies

Although a village may fit the profile above for a higher-technology pumping solution like a SPS, be aware that a SPS still may not be the best technology- consider the chart below to review some alternatives.

SPS Pumping Range section 6d →

	Pros	Cons
Hand Pumping	-Low cost -Simple technology -Easy maintenance -Clean -No fuel needed -Usable for hand-dug wells -Easy to install	-Regular maintenance needed -Low flow rates -Uses community's time/energy -Poor use of machine-dug well
Diesel Generator	-Moderate initial cost -Easy to install	-Frequent maintenance., expertise required -Short life -Fuel often expensive, supply intermittent -Noise, dirt, fumes -Overall (20 yr.) costs higher than SPS
Ram Pump	-Low cost -No fuel needed -Runs 24 hours a day -Low maintenance	-Need appropriate site (falling water at a lower level, to be moved to a higher elevation) -Draws from open ground water
Wind Turbine	-Lower initial costs than SPS -Long life -Effective at windy sites -Clean -No fuel needed	-High maintenance needs -Expensive repair -Parts difficult to find -Wind can vary seasonally -Lower output in calmer winds
Solar Pumping System (SPS)	-Easy to install -Reliable long life -Low Maintenance, simple repair -Clean -No fuel needed -Modular system can be closely matched to needs, expanded.	-Solar energy can vary seasonally -Highest initial cost -Lower output in cloudy weather

3.0 How Does a SPS Work?

A Solar Pumping System uses electricity to power a pump in a well. Solar Photovoltaic (PV) Panels transform the sun's energy into electricity to power the pump. When it is nighttime or very cloudy, the PV panels produce no electricity, so no water is pumped. To provide water whenever it is needed, extra water is pumped during the day and stored in a tank above ground.

> DEFINTION
> **PV Panel**
> An electrical device usually made with silicon that converts sun energy into electrical energy

See the diagram on page 8 to follow the flow of electricity and water. More detailed information about pump components is given in section 3c.

3.a Steps in a SPS

Follow the flow of electricity and water to understand how a SPS works. The process is broken into 4 basic steps:

Electricity Generation: Photovoltaic (PV) panels convert sunlight to electrical flow. The electricity then flows to a controller, which monitors the water level in the well and storage tank to ensure safe pump operation.

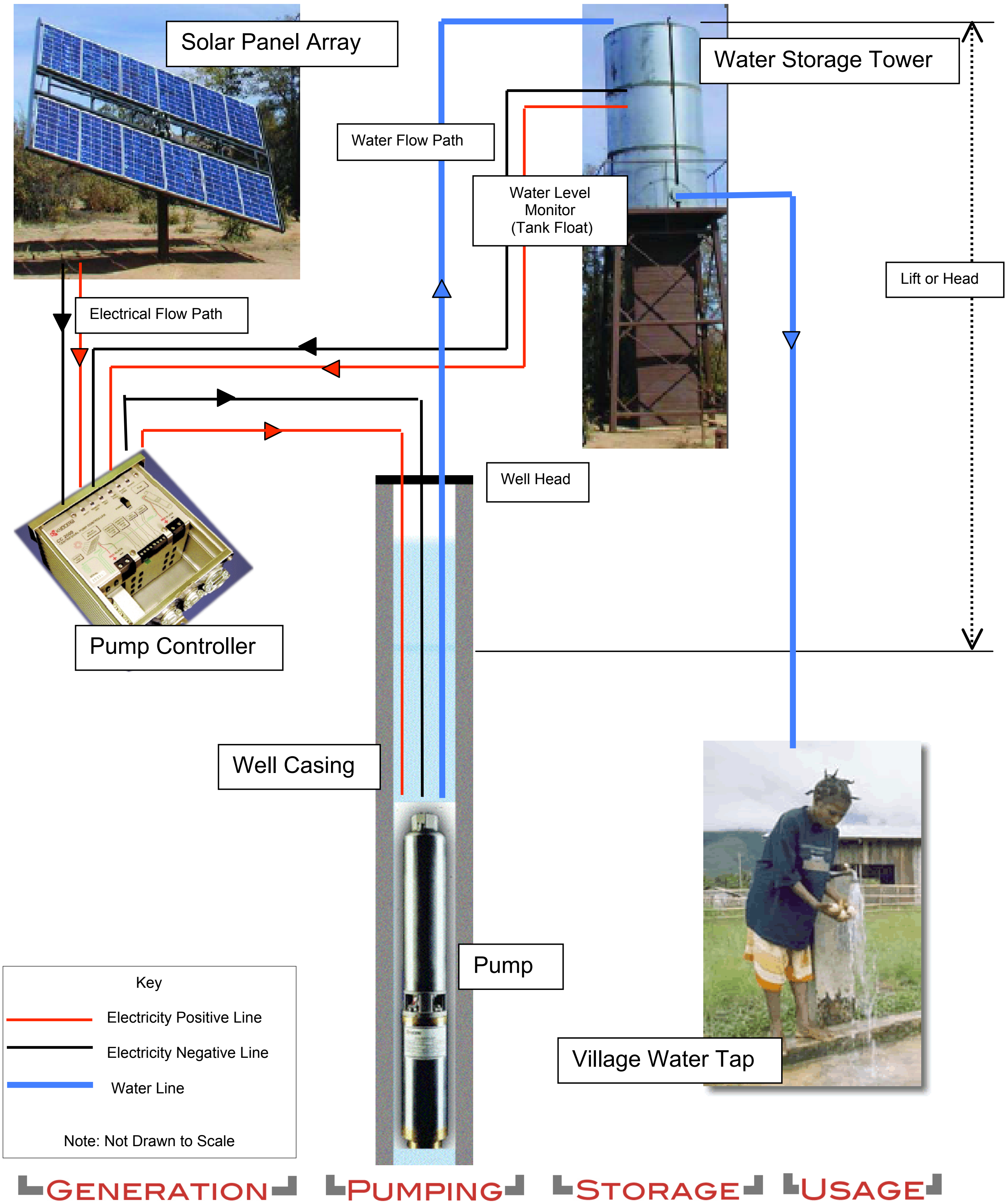
Pumping: If the sun is shining, the storage tank is not full, and the well is not empty, the pump runs. Water is pumped from the water level in the well to the top of the storage tank, a distance generally called the head or lift.

> DEFINTION
> **Lift or Head**
> The height that the water is raised by the pump. Usually from the water level in the well to the top inlet of the storage tank.

Water Storage: Water is stored in a large tank, usually set on a hill at a point that is high relative to other locations in the village. It is best if the well is located close to the location of the tank. Excess water is pumped to the tank to provide water when the pump is being serviced or cloud cover prevents electricity from being generated. Storage is generally provided for at least two to three days projected use.

Water Points: The water tap or taps are the places where the village residents come to gather water. Since we depend on gravity to carry the water from the tank through the piping system to the water points, the water points need to be at a lower elevation than the bottom of the storage tank. This way, no additional electricity is needed to distribute the water from the tank.

3.b System Diagram



3.c Description of Components

Solar (PV) Panels

Solar panels are electrical devices that generally use Silicon-an element made from sand-and most commonly used in the manufacturing of computer chips. When solar energy hits the top layer of Silicon, it frees electrons from the Silicon atoms. These free electrons are attracted to the bottom layer and flow towards it. **The flow of electrons IS electricity, and is captured for use.**

PV panels mounted on "tracking" arrays follow the sun like flowers.

Pump

Pumps for village water pumping are typically submersible low-volume, high-lift types. They often have brush-less DC motors for long life and little maintenance. There are two types: positive displacement, which include the higher lift helical coil (like a screw - shown at right dissected) and the less costly and lower flow rate diaphragm pump. The other type is a centrifugal pump (spins to create suction), which is used in higher lift applications.

A helical coil pump, casing, motor, and controller

Controller

The controller has two primary functions. First, it monitors the characteristics of the electricity being produced by the PV panels (volts and amps) and electronically modifies these values to enable the pump to run longer and more efficiently. Secondly, the controller is an electronic switch to control when the pump goes on and off. The controller monitors electricity from the PV panels, the water level in the well, and the water level in the tank to ensure efficient and safe pump operation.

Storage Tank

A tank to store water until it is ready to be consumed. Large enough to ensure backup in case low weather conditions do not allow for pumping.

PV panel rack — Racks are used to mount the solar panels. Either ground, roof, or top-of-pole mounted, many are user-adjustable to meet the sun at a more optimal angle. Some racks can passively or actively (using a motor) track the sun to maximize the efficiency of the PV panels.

Water Piping — A variety of water piping is needed. The piping from the pump to the top of the well is generally a 1.25" or 1" PE pipe. PE (Poly Ethylene) pipe is a thin plastic pipe, similar to PVC, but thinner and more flexible. PVC piping is then installed from the wellhead to the inlet at the top of the storage tank. If the water points are not at the tank, then piping needs to be installed from the tank to the watering points.

Electrical Wiring — Power wiring in conduit is installed from the solar array to the controller. Control wiring in conduit is installed from the controller to the float switch in the tank. Electrical Wiring is installed from the pump in the well up to the controller. This wiring is inside the well casing is generally special submersible pump wiring.

Safety disconnects — Mechanical switches (not shown on diagram) to manually shut off electricity in case of an emergency or maintenance. Usually installed between the solar panels and the controllers and between the controller and the pump.

Well Drilling and Casing — A large one-time expense, the well must be located, drilled, and lined. The lining is most often heavy-duty PVC pipe. It is usually 4" to 6" in diameter. The size of the casing needs to be coordinated with the requirements of the pump that is to be installed.

> DEFINTION
>
> **Centrifugal Pump**
>
> A pumping mechanism that spins water in order to push it out by means of centrifugal force.
>
> Definitions from Windy Dankoff, Lorentz

top-of-pole rack

> DEFINTION
>
> **Well Head**
>
> A cap on the top of the well to keep the water clean. Holes in the well head allow for wiring and water piping to pass though.

A common lockable disconnect switch

3.d Conversions and Units

Use the conversions below to help in understanding figures or doing calculations.

	Metric	U.S.
Distance	1 meter	3.28 feet
Volume	1 liter	0.264 gallons
Volume	3.785 liters	1 gallon
Volume	1 m^3 = 1000 liters	264.2 Gals.
Volume Rate	1 Liter Per Day (LPD)	0.264 Gallons Per Day (GPD)
Volume Rate	3.785 liters / day	1 Gallon per Day (GPD)

DEFINTION

GPD or LPD (gallons or liters per day)

A rate of water use. Amount of water used per day in gallons (GPD) or liters (LPD).

The following table can be used as a guide to compare lengths in feet versus meters.

Feet	10	20	50	100	150	200
Meters	3	6	15	30	46	61

DEFINTION

M^3

Volume measured in meters cubed
1m3 = 1000 liters
1000gal = 3.8m3

Similarly, the following table can be used as a guide to compare gallons per day, liters per day, and M^3 per day. This table assumes a family of 5 people, with each person requiring 10 gallons of water per day.

Families	10	20	50	75	100
People	50	100	250	375	500
Gallons per Day	500	1000	2500	3750	5000
Liters per Day	1893	3785	9463	14194	18925
M^3 per Day	1.9	3.8	9.5	14	19

4.0 Example Systems

Use these snapshots of successful SPS projects to become familiar with the relationship between cost, water supply, flow rate, and resources. Details on determining these factors will be covered in the design guide.

PROFILE: Village North of Managua, Nicaragua	
Number of people	100
Uses:	Drinking, Washing, Livestock Watering
Water requirement	1000 GPD / 3,785 LPD
Head height	150 ft. / 46 m.
Water storage	3000 Gal. / 11,355 L.
Solar resources	5 Peak Sun Hours
Solar array	376 W.
Project costs:	$25,000

PROFILE: Small village in central Nicaragua	
Number of people	240
Uses:	Drinking water, household water uses, some animal watering
Water requirement	3000 GPD/ 11,355 LPD
Head height	210 ft. / 64 m.
Water storage	6000 Gal. / 22,710 L.
Solar resources	5 Peak Sun Hours
Solar array	1100 W
Project costs:	$42,000

Feasibility Guide

5.0 Community Feasibility

- 5.a Checklist for Your Community

6.0 Technical Feasibility

- 6.a What Are Your Resources?
- 6.b What Are Your Needs?
- 6.c Summary of the Design Inputs
- 6.d Can a SPS Handle Your Flow and Lift Requirements
- 6.e What Size is the System?

Now that we have discussed where and when a SPS is typically used and how it functions, we should have a general idea if SPS technology might be a solution for this community.

This section on feasibility is meant to be an investigation of the project to determine if it is a good candidate for a solar pumping system, from both a technical and community standpoint. To be a good candidate, the needs of the community must be addressed and responded to, and the technical aspects of the project have to be appropriate.

5.0 Community Feasibility

Community concerns are perhaps the most overlooked, yet most important consideration for a SPS implementation. Designing and installing a SPS may take up to a year or two, but the system life should be over 25 years. During this initial period, the needs of the community must be surveyed, along with the characteristics of the community leadership and organization to assure that the project, if built, can be sustainable. Careful community planning and forethought is important now to ensure a smooth operation of the system throughout its lifetime.

Do not overlook community planning!

5.a Community Checklist

The checklist below can help you to think about the issue that are important in making sure that the community can accomplish what will be needed to use a SPS.

- [ ] Complete a survey of all community members regarding water uses. The purpose of this is to get a better idea of the requirements of a solar pumping system and the expectations of the community.

Survey Details section 7b →

- [ ] The community already has organizations or groups that meet regularly to solve problems or make decisions. Do you already have a group to handle water usage issues? Will you create one?
- [ ] The community leaders have worked with NGOs or other outside organizations. If not, how can you support them to do so?
- [ ] Individuals in the community can step forward to take the roles of: water steward, security, technical lead, maintenance supervisor, and perhaps more.

Suggested Community Roles section 7c →

- [ ] The community can agree to the equitable division of labor necessary for installing the system. All able members of the community should be willing to chip in with the required work.
- [ ] The community is agreeable to sharing the costs of operating and maintaining the system. It will be impotant to go through a proces to determine how much money needs to be charged to each individual or family for use of the water to pay for the long term maintenance, repair, and equipment replacement.

Rate Structure Determination section 7b →

- [ ] You have considered the possible population increase and other social changes that may occur from installing a SPS. Make a plan of action for several scenarios.
- [ ] You have considered how to fairly distribute the water resources both physically and socially.
- [ ] You have considered a long-term plan including procedure for emergencies and component repair and replacement (pumps last 10 years).
- [ ] You have considered how your SPS might interact with regional water authorities. Will they help?

Can your community meet the above criteria? If not, proceed with caution.

6.0 Technical Feasibility

If the community review done in the previous section indicates that a solar system could be right for the village, then some technical inputs need to be considered to determine if the project is technically feasible. To do so, we need to examine:

What are your resources?

What are the characteristics of the well?
What is the solar resource?

What do you need from the system?

How much water do you need per day?
How high do you have to lift it?
Can a SPS handle your water requirements and lift

6.a What are Your Resources?

Well Characteristics

At this stage in the project, it is often the case that the well has not yet been drilled, and therefore only projections can be made as to what will be found. The key items to know here are:

(a) How deep is the water?
(b) What is its recovery flow rate?
(c) What is the drawdown?

If the well has not been drilled, the next best solution is to talk to someone knowledgeable about the water depths in the area to get the best input as possible. If the recovery flow rate is not available, we can see what flow rate requirement comes from the preliminary calculations, and compare this with what might sound reasonable. The Recovery flow rate should not be too much less than the pumping flow rate, or the well may frequently run dry. Of course, all of these numbers would have to be verified with an actual well drilling and test procedure before proceeding with a final project.

DEFINTION

Drawdown

When the pump is running, the water level in the well goes down. This drop from the standing level is the drawdown.

DEFINTION

Well Recovery Flow Rate

How long it takes for a given amount of water to refill in the well after it has been pumped out. In GPM or LPM.

Water Quality

Once water is found, it will be important to test the water for potability. One advantage of a solar water pump is that it can pump water from deeper, purer water tables, inaccessible to manually pumped wells. If the water does contain impurities, a filtration system will be necessary.

> **DEFINTION**
>
> **PSH**
>
> Perfect Sun Hours. Number of equivalent daily hours that provide solar radiation energy equal to 1000W/m^2

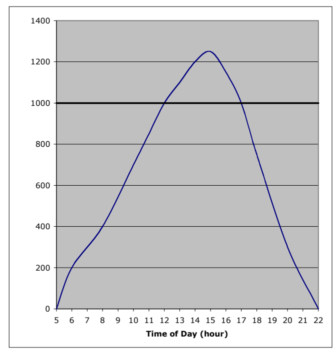
Solar Resource:

To determining the feasibility of the system, there are two considerations here:

a) What is the PSH where the project is located?

b) Is there a clear area to mount the solar array where it will not be shaded?

For systems tht will operate year-round, it is best to use worst-case (yearly low) sun hours. Maps of the worst-case PSH across the globe can be found in section A1. Charts for cities or specific countries can often be found on the internet. The PSH number will tell how many hours the pump you will expect to operate per day, or how many hours you have to pump the daily required amount of water. Also see RETScreen.org tools for data.



Sun Radiation vs. Hours of the Day

(Area under curve is integrated then divided by 1000 W/m^2. Result is PSH)

On this worst-case PSH map, Honduras has 5 PSH.

Shading:

The site that is chosen for the solar panels cannot be shaded from the sun. Even a small amount of shading (5% of the panel) seriously affects the amount of power that can be generated by a solar array (up to 90%). **If no site is available that is not shaded during the Peak Sun Hours, then solar pumping is not a possible solution.**

6.b What are Your Needs?

Water Requirements: (GPM or LPM).

In the community feasibility section, you considered the community's current and future water needs. It is very important to account for future population growth in your area, as it is much easier to plan for a larger system now, versus recognizing the need later, when it might be more expensive and difficult to include the expansion needs.

> DEFINTION
>
> **GPM or LPM**
> (Gallon/Liters per Minute)
>
> Daily amount of water used divided by hours. Divided again by 60 min. per hour to yield a rate per min.

In the Design Guide, we will present more detailed information on determining daily water requirements. For this feasibility study, we will use the following example to illustrate a quick first estimate of a community's water requirements.

General Water Requirements

Assume a family consists of 5 people, each person using 10 gallons (38 liters) per day. This requirement is typical of families used to carrying their own water. Many families with plumbing use 50 to 100 gallons per person per day. But, again, do not expect to be able to handle indoor plumbing with a SPS.

Human, Animal And Crop Watering needs section 8.a →

We will need to determine both Gallons or Liters Per Day (GPD or LPD) and Gallons or Liters per Minute (GPM or LPM). This is due to the way in which different manufacturers list their pump performance information.

The following chart assumes 5 people per family each using 10 GPD in an area of 5 PSH.

Families	10	20	50	75	100
People (5 per family)	50	100	250	375	500
GPD (10 per person)	500	1000	2500	3750	5000
GPH (5 PSH)	100	200	500	750	1000
LPD (37.8 per person)	1890	3780	9450	14175	18900
LPH (5 PSH)	378	756	1890	2835	3780
GPM	**1.66**	**3.33**	**8.33**	**12.5**	**16.66**
LPM	**6.3**	**12.6**	**31.5**	**47.25**	**63**

Use the above numbers for your estimate or increase for higher water uses like drip irrigation or higher consumption for drier climates.

Example: Calculating GPM

GPD: 1000 Gallons Per Day
PSH: 5 hours

GPD / pumping hours = gallons per hour. Since there are 60 minutes per hour, divide again by 60 to yield GPM.

1000 GPM / 5 PSH = 200 GPH.
200 GPH / 60 minutes = **3.33 GPM**

Lifting Requirements: Total Dynamic Head

The vertical distance water is pumped is called head. There are two varieties of head: Total Vertical Lift and Total Dynamic Head.

Total Vertical Lift (TVL) is the vertical height from the drawdown level in the well to the storage tank inlet, as shown on page 21.

(TDH) is similar, but increased for losses in the piping system due to friction and fittings. Calculating TDH will be explained in the Design Guide. For now, 10% will be added to the TVL number as an estimate.

For now, estimate the depth of your well to the water line using string and weight. If the well is not drilled, then use your best judgment as to how far down the water is from talking with people in the village. Then estimate the location of your water storage tank. How high above ground level will it be to the top of the tank? Use the example below and the diagram on the next page to calculate a rough TDH.

Example: Estimating TDH – quick method

Non-operating water line depth: 60 ft.
Drawdown: 10 ft.
Height of tank: 10 ft.
Height of tank above ground level: 10 ft.

TVL = 60 ft. + 10 ft. + 10 ft. + 10 ft. = 90 ft.
TDH = TVL x 1.10 = 99 ft.

DEFINTION

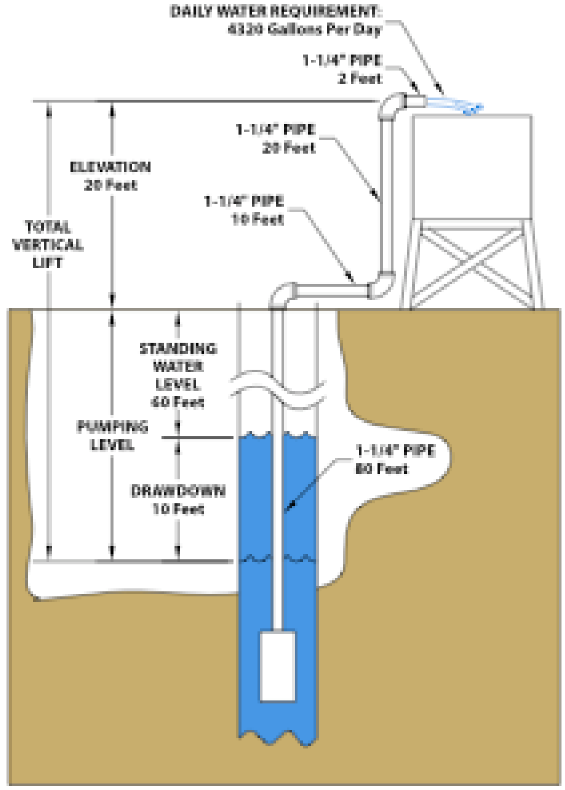
Total Dynamic Head (TDH)

Total Vertical Lift adjusted upwards by frictional losses in the piping and pressure losses to create a slightly (~5-10%) taller height.

LEARN MORE

Flow Rate Versus Head

The pump operating flow rate inversely related to TDH. A given pump can pump a lot of water at a small vertical lift, or a lot less water, at a higher vertical lift.



Kyocera total vertical lift diagram

6.c Summary of Inputs

At this point, we have rough estimates for our resources, and for our needs. With this information, we can determine if technically, this project is a candidate for solar pumping.

Summary of Initial Feasibility Inputs		
Resources:	Water Depth (ft. or m.):	_____
	Well Recovery Rate (gpm / lpm):	_____
	Solar PSH:	_____
Needs:	GPD / LPD:	_____
	GPM / LPM:	_____
	TDH: (est)	_____

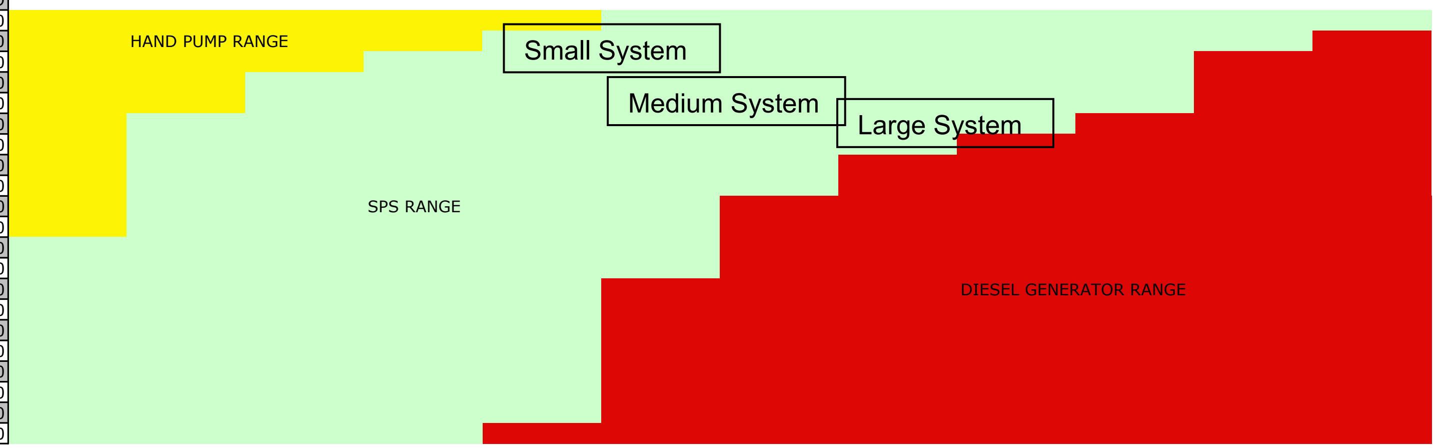
6.d Can a SPS Handle Your Flow and Lift Requirements?

Now that your community and water uses seem to be in line with typical SPS deployments, make certain that a SPS can handle the pumping requirements you need. Below is a chart comparing TDH to flow rate needs. As mentioned, solar-powered pumps can only pump so much water at a certain TDH. Use this to be sure that a hand-pump or a diesel generator may not be more cost effective for low/high flow rates OR low/high a TDH.

If your selection is on a borderline, SPS may or may not be the right solution. Consider long-term village growth rates, community structure complexities, and other issues that may be already pushing you one way or another. Use this chart data to aid in your decision about whether or not to use a SPS.

HEAD (ft)	3	7	17	33	66	99	165	198	248	330	660	1650
HEAD (m.)	1	2	5	10	20	30	50	60	75	100	200	500

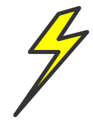
#of Families	GPD	LPD
10	528	2000
20	1057	4000
50	2642	10000
80	3963	15000
110	5284	20000
130	6605	25000
160	7926	30000
180	9247	35000
210	10568	40000
240	11889	45000
260	13210	50000
290	14531	55000
320	15852	60000
340	17173	65000
370	18494	70000
400	19815	75000
420	21136	80000
450	22457	85000
480	23778	90000
500	25099	95000
530	26420	100000



Instructions:
1) Locate your # of families, GPD, or LPD on the left side.
2) Find your required TDH in feet or meters along the top.
3) Locate the point on the chart where the two meet.

Is SPS recommended?

6.e What size is the system?



Cost Details section 10 →

Now that you know that your project project fits within the range of normal solar pumping systems, see if it would be considered a small, medium, or large system. This information can help you understand some of the limitations an issues with each general size category.

Small Systems:
-2 GPM (600 GPD)
-Up to 100 ft. TDH
Small systems could be generally accomplished with a diaphram pump. These pumps are not extremely expensive, and the solar array may be in the area of 100 to 300 watts.

Medium Systems:
-4 to 8 GPM (1200 to 2400 GPD)
-Up to 100 ft. TDH
The pumps for these medium – sized systems are more expensive than a small system and will often take a helical rotor positive displacement pump or a centrifugal pump. The array might be between 200 and 600 watts.

Large Systems
-over 8 GPM (over 2400 GPD)
-Up to 200 ft. TDH
Systems over 8 GPM at most lifts and systems over 4 GPM at lifts over 100 feet could be considered large systems. These would take the more expensive helical or centrifugal pumps, and could require arrays approaching 2000 watts.

Lifts exceeding 200 to 250 feet become extremely costly, if even practical, with anything but the smallest of flows. Flows exceeding 16 GPM (5000 GPD) with any appreciable head are generally not feasible, with today's solar pumping technology (except for some of the very new, very expensive systems). Options would be to install multiple wells and pumps, and/or go to standard AC pumps with inverter/controllers such as the Aerovironment Universal Pump Controller.

If you plan on expanding your system in the future, you may want to consider installing extra infrastructure (poles, footings) now to save money in the future. If you are installing a large system, it may not be possible to expand.

Design Guide

In the Feasibility Guide, we did a review of the main criteria, both in terms of the community and the technology, needed to determine if the proposed Solar Pumping System is feasible, and to determine its approximate size. Now that we have determined that the SPS system is a likely candidate for the community, a more detailed review can be done to arrive at better data for use in the design.

The refinements we will look at will include:

- 7.0 Community Development
  - 7.a Community Development: Goals
  - 7.b Community Development: Activities
  - 7.c Roles and Responsibilities
- 8.0 Technical Design
  - 8.a Refining Water Requirements
  - 8.b Mapping the System
    - 8.b.1 Community Aspects of Mapping
    - 8.b.2 Technical Aspects of Mapping
  - 8.c Refining Total Dynamic Head
  - 8.d Preliminary Array Sizing
- 9.0 Summary of Design Inputs

7.0 Community Development Aspects

In the feasibility section, we looked at several qualities of the community that need to be in place in order for the system to work over a long period of time. As stated earlier, these aspects are often overlooked because we tend to get wrapped up in the technical review and installation. It is one thing to install the system, but it is quite another to have a system that meets the specific needs and abilities of the community, and that will be sustainable. **But without the proper community-related planning efforts behind a project, it is doomed to failure, just as surely as if there was insufficient water in the well.**

7.a Community Development: Goals

Therefore, once it is decided in the feasibility review that a SPS is likely to be good for the community, a plan must be developed to address the following community development goals:

- Is the community ready for such a project? Does the community have the interest, organizational resources and determination necessary to complete the project and ensure its sustainability?
- What community surveys need to be done?
- How must the community be organized to own and manage the project?
- How will the project benefit the community members and local environment?
- What training will community members need to maintain their system?
- How will the community charge community members for services or otherwise raise money to maintain their system?
- What ongoing involvement of the NGO, if any, will be needed after completion of the project?
- Prepare a budget that adequately accounts for the community development aspects of a project.

7.b Community Development: Activities

All of the community development goals outlined above involve specific tasks that must be completed in order to determine if a project is viable and sustainable. The people best suited to performing these activities are the local leaders, and the local NGOs who are already involved heavily in the day-to-day activities and needs of the community. **The role of Green Empowerment, based on our experience with many NGOs in many countries, is to act as a facilitator and to ensure that the correct issues are addressed and answered as the project progresses from concept, through feasibility, to implementation.**

7.b.1 Is the community ready?

- What organization currently exists in the community: leadership groups, local government,churches, and women's groups?
- Who are the community leaders and how are they chosen? The real leaders are not necessarily those who hold the positions of leadership.
- What social projects, if any, has the community previously completed and what were the successes or failures in that effort?
- How much has the community worked with outside NGOs?
- How much in-kind work, money or other resources are the community members ready and able to contribute to the project? What is the monetary worth of such contribution and how is that determined?

7.b.2 Community Surveys

- How is the community currently obtaining its water? How far do people have to walk currently? What is the quality of water?
- What is the community demand for potable water for the home? To determine this, the organizers need to do a *community survey* interviewing all families and community members about their current water use habits. This community survey must also evaluate likely increases in population in the area.
- If the water is to be used for agriculture, the survey must also determine the typical family use of water for animals and for irrigation of family gardens.
- Who owns the land where the well and tank would be? Are the owners agreeable to putting the land into public ownership?
- Where will the water points be located? How will the community determine where they should be so that everyone has equal acess to the water?

7.b.3 Organization for the Project

- What community leadership structure is necessary to own, run, and maintain the project? Will an existing structure do this or will a new water committee need to be elected?
- How will this group function to mobilize community members at the survey, construction, and operational phases of the project?

- **What is the proposed legal ownership structure of the project? If this is not done right at the start, there can be serious problems later on.**
- What alliances can be formed with other local, national or international NGOs or government agencies? Each party's financial and in-kind contributions and responsibilities should be layed out clearly before the project starts.
- Are there individuals that can take on oversight of the technical, financial and construction aspects of the project?

7.b.4 Community Benefit

- What benefits do community members *expect* from the project? This should be covered in the community survey.
- What social and environmental benefits do the organizers think might be achieved from this project?
- As the needs and wishes of women and children in the community are often not adequately considered, the organizers must ensure that women and children are interviewed and their needs addressed so that they are full participants in the project.
- Who will benefit from the project? And who will not?
- If some community members will not benefit from the project, what kind of community problems might this cause?

7.b.5 Training

- What training will community members need to do the surveys, other preliminary work and construction of the system?
- What training in specific organizational skills will the community need to run and maintain their project?
- Who will provide this training, how will it be done, how

long will it take and how much will it cost?

7.b.6 Rate Structure & Project Income Generation

- **What is the community willing to charge itself for the service provided? This must be realistic and there must be firm commitment on the community's part to pay, or the project will not be sustainable!** The community can compare a reasonable rate structure to what community members pay for nonessential items commonly consumed in the community or what would be charged by a national water system.
- Are there any other methods of raising money from the project in addition to a tariff on individual users or families?
- Is the rate structure sufficient to cover pump replacement or other repairs and to ensure the sustainability of the project?

7.b.7 Involvement of the NGO After the Completion of the Project?

- How will the NGO evaluate the project upon its completion? Will the project results be evaluated against the goals and budget? How will this summary, if any, be provided to the community and other participants in the project?
- What possible needs might the community have for the NGO for technical or organizational help after completion of the project?
- Is the NGO prepared to provide such help?
- Can the NGO afford to provide such help?

7.b.8 Budget for Community Development

- How much should be budgeted for the community survey, organizational training, community benefits evaluation, training, rate structure, and post-completion work of the NGO?
- How should these costs be allocated within the budget?
- What potential sources of funding are there for the project?

7.c Roles and Responsibilities:

The following are several roles that are suggested to deal with the management of a SPS during installation and operation. Although these are merely possible issues, **it is important to seriously consider them as most systems that end in failure do so because of a lack of operational structure and planning.** These roles may all the responsibility of a single committee or distributed to different people.

Water Rights Committee: Decides who has access to water points and when, including orienting newcomers to the community. Is able to physically lock off access to taps. Has emergency plans accounting for times of drought, damaged equipment, or other region-specific issues.

Technical Supervisor: This person or committee oversees operations from a technical standpoint. Has a mechanical understanding or knows where to get resources and help. Understands operation of the system to be able to troubleshoot. In charge of troubleshooting and repairs, if not personally carrying out the work.

Construction Manager: This person manages village labor resources for systematical maintenance and in times of emergency. Works with the Water Right Committee and Technical Supervisor to ensure the equitable use of village labor resources. Also possibly manages labor during initial construction of SPS.

Financial Manager: This person or committee determines an equitable distribution of fees paid by community members to offset use, maintenance, and future expansion of the SPS. Possibly part of the Water Rights Committee.

8.0 Technical Design

8.a Refining Water Requirements

The previous section included the recommendation to perform a community survey. The results of this survey need to be compared against what has been shown to be the norm in other locations. In addition to the results of the survey, and the comparison with other locations, we need to plan for future growth. This occurs in two ways: First growth occurs because villages grow in population (partly due to improved infrastructure). Second, growth occurs because if water is more available, demand for it is likely to go up as well.

These growth issues need to be taken into account in order to provide for future sustainability. In the end, if the water resources are not great enough, or if the costs are too great, then we would proceed with caution, knowing that there is minimal allowance for growth.

IIn addition to growth in demand, which affects the daily water requirements, intensive use of the well and long term climatic trends may result in a drop of the water table. The pump intake needs to be placed at a sufficient depth to be under water in 20 years, and total head to be adjusted accordingly.

System Sizing
Recall Section 6.e

In addition to human consumption and use, you may want to consider the needs of animals and small home gardens or single-use crops. The following charts give some idea of water requirements of humans, animals, and crops based on previous data.

People

For villages currently using hand pumps, a daily usage of about 10 gallons per day (40 liters per day) is suggested. For a larger town, where indoor toilets and showers are common, consumption rates of up to 75 GPD (280 LPD) have been found.

The best data will be that gathered from the community survey to determine what amounts of water the residents are currently using. This information, along with the usual water usage, will help you choose an appropriate water consumption requirement.

Animals	*GPD*	*LPD*
Horses	13	50
Dairy Cattle	23	88
Steers	9	35
Pigs	4.5	17.5
Sheep	1.5	6.5
Goats	1.5	6.5
Chickens	0.04	0.15

Crop Irrigation

Major Crop irrigation is not recommended with SPS as multiple large systems would be required. Drip irrigation, however, may be possible.

(Per hectare)	*GPD*	*LPD*
Rural Village Farms	16,000	60,000
Rice	26,000	100,000
Cereals	12,000	45,000
Sugar Cane	17,000	66,000
Cotton	15,000	55,000
Drip Irrigation	Varies	Varies

Two conclusions can be drawn from this review of water consumptions.

1. There are different ideas published on the daily water requirements of people and animals. We have to use our best judgment in reaching a design number. It is best to overestimate the daily water requirement.

2. Crop irrigation is NOT something that lends itself to normal solar pumping. This requires far more water than providing potable water for people, and would require far more money. Drip irrigation is possible, but local methods, appropriate crops, etc. must be investigated.

8.b Map the System

At this stage, the layout of the system should be mapped. Mapping will help you determine how the system will be integrated in the community physically and logistically.

8.b.1 Community Aspects of Mapping:

Each solar pumping system needs a physical location for the well, the storage tank, the water points, and the piping that runs between them.

It is best that the tank and the well be located at the high point of the village, which would ideally be situated centrally to the proposed water points. But, rarely are things this ideal. The higher the tank is, and the closer the well is to the tank, the better, because this lowers the total head that the pump has to push the water. Recall that with a smaller head, a given pump can pump more water.

But, when you locate the ideal locations of the tank, well, and water points, close attention has to be made to the ownership of the property, as well the ownership of the paths for the piping from tanks to the water points. Many times the equipment has to be designed in non-ideal locations due these property ownership issues, or geographical issues like ravines, rocks, and streams.

The location of water points can be a delicate issue and it is important that the taps are placed roughly equadistant to each household if geographically possible. The community and NGO will have to weigh the costs and benefits of putting water points at each house or in several central locations. At the water point, you may want to construct a concrete “apron”, areas to wash pots, clothes and even to bathe. It is important for all community members to have a voice in determining where the end use points will be.

8.b.2 Technical Aspects of Mapping:

Once you have decided where the well, tank, and water points are to be located, and have them drawn roughly on the map, it is important to get relative elevations between each point, and distances. Both of these tasks can be accomplished with a GPS system with altimeter functions.

8.b.2.1 Altitudes:

At each point, record the altitude using surveyor's equipment, a pressure gauge, an altimeter or a GPS. Sometimes you will need to take several values and take the average. The values of altitude read by an altimeter change with changing atmospheric pressures so it is best to try to do this when the weather is stable, and to do it quickly. If the distances are close and you have more accurate means of measuring the elevation differences, such as surveying equipment, this would even be better,.

8.b.2.2 Distances:

The distance can be measured with a rope, a tape measure or a GPS. If using GPS, the x-y co-ordinates should be marked as well. Then, using the "distance" function of the GPS device, you can determine the lateral distances - even after you have left the site. You need to keep in mind that the x-y distances given by the GPS do not account for changes in terrain, so you will have to make adjustments for that.

With accurate distance and altitude data between the well and the tank, you can determine the height difference between the ground at the well, and the ground at the tank. Then, by adding in the height of the tank and the depth of the water in the well, you can get the Total Vertical Lift. A section below will go through the steps needed to calculate the Total Dynamic Height, which takes into account the friction losses in the piping system.

The distance and altitude data between the tank and the water points are used to determine how much trenching and piping will be required for the water distribution system. It also helps to check and be sure that the elevations of the water points are lower than the elevation of the tank.

This is usually straightforward, but sometimes, with a lot of hills and distances, it is difficult to tell for sure if the water points are below the tank level. This is important, because we depend on gravity to distribute the water from the tank.

8.c Refining Total Dynamic Head

TVL, Total Vertical Lift, was introduced earlier in the guide as the vertical distance from the drawdown level in the well to the top of the storage tank. Previously it had been estimated using knowledge of the site and the well. Now that we have done a GPS survey and a map, we can get a more accurate measurement for the Total Vertical Lift. The only guess, if the well has not been drilled and tested, will be the drawdown depth of the water in the well, in which case, it will need to be estimated.

TDH, Total Dynamic Head, is a similar quantity, but takes into account real-world losses that will take place as the water travels from the pump to the tank. Mostly this is due to friction of the water traveling through the pipes and the pressure losses as water goes through pipe fittings. The process of determining the TDH involves determining the length of the pipe from the well head to the tank, sizing this pipe, and selecting its material.
The routing of the pipe must be approximated as well to be able to make a determination of the number of fittings (elbows primarily.) Tables usually provided take the length of a given size pipe, and the numbers of fittings and convert them into equivalent additional height that must be added to the Total Vertical Lift to obtain the Total Dynamic Height.

Pipe
Friction
Charts
See references →

TDH
Worksheet
See references

Complete friction losses calculations are also found in

mechanical engineering handbooks

8.d Preliminary Array Sizing.

The size of the solar array is ultimately determined by the specific pump manufacturer as the wattage output must be closely matched to the pump requirements. However, it is a good idea to do a preliminary calculation to see approximately what the solar array size might be, in order to estimate costs of the project.

The power needed to move water is = Flow rate x Pressure
or = FLow rate x Head x g x fluid gravity
The formula for sizing pump power requirement is:

U.S. Units

$$\text{Watts} = \frac{\text{(Required flow in GPM) x (TDH in feet) x .188}}{\text{Efficiency of Pump (\%)}}$$

Metric Units

$$\text{Watts} = \frac{\text{(Required flow in LPM) x (TDH in meters) x .163}}{\text{Efficiency of Pump (\%)}}$$

(The numeric value of the constant comes from combining water density x gravity g x flow rate unit conversions)

Example: Estimating Array Size

Assume that we have a 20 families, with 5 people each for a total of 100 people, each needing 10 gallons per day. There are no needs for watering crops or animals. This would result in 1000 GPD requirement.

If the PSH of the area is 5 (5 hours of Perfect Sun), then the Gallons per Minute that we need to pump during this time is 1000 gallons / 300 minutes = 3.33 GPM. A conservative estimate of the pump efficiency would be 30%. (Many pumps are as high as 50% efficient or more).

If the calculated Total Dynamic Head is then 150 feet, the resulting equation becomes:

$$\frac{3.33\text{ GPM} \times 150\text{ feet} \times .188}{30\%} = 313\text{ watts}$$

This would be the theoretical quantity of PV Panels (measured in watts) required by the pump to pump the amount of water through the head chosen.

Since there are additional losses associated with the solar array, we need to include an efficiency factor. These losses come from several areas, such as dirt, performance degradation, temperature, and wiring. For these calculations, it is common practice to divide the resulting watts required by the pump by 80% to obtain the watts required for the installed solar array.

Calculating for losses:

313 watts / 80% = 391 watts.
Round to 400 W

It must be emphasized again that this number is very approximate. Sometimes it is very close to what the manufacturer recommends, but other times, due to differences in the pump efficiencies, there can be significant differences.

It is best to use the wattage derived in this fashion as a first estimate to get an initial budget. As soon as possible, use the vendor published data to determine the actual array size needed to produce the output you need.

Note: The major source of variability among pump models is the following. Pumps are usually designed for a 'nominal' constant speed for which efficiency will be optimal. During the day, as the power & current available from the panels vary, the motor/pump speed varies all the time, and the efficiency itself changes accordingly. Therefore, using an average efficiency doesn't reflect actual dynamic performance.

For positive displacement pumps, the efficiency is much more stable over a wide range of speeds, so the overall efficiency over the day is better and a smaller array can be used.

9.0 Summary of Design Inputs:

At this point, we are ready to summarize the pertinent information regarding both the needs of the community and its pumping system, as well as the resources. With this information we can:

1. Perform a Preliminary Cost Budget
2. Start reviewing vendor data for specific equipment

Project Information

Village Name: ______________________________
Location: ______________________________
Altitude: ______________________________

Describe how people currently get their water and why a SPS is being considered. ____
____
____
____

Solar Resources

PSH: Best Month ________ Hours
PSH: Worst Month ________ Hours
PSH: Use for Design ________ Hours

Water Requirements

Describe Current Water Uses: __________________________________
____
____

Describe Projected SPS Water Uses: ____________________________
____
____

People

Number of Families: _________
Total People: _________
GPD/LPD per person: _________

Total GPD/LPD for people: _________

Animals

Type	Total #		GPD/LPD per animal		Total GPD/LPD
____________	_________	x	_________	=	_________
____________	_________	x	_________	=	_________
____________	_________	x	_________	=	_________
____________	_________	x	_________	=	_________
____________	_________	x	_________	=	_________

Total Animal GPD/LPD = _________

Drip Irrigation or Additional Water Uses: _______________________
____

Additional Water Use GPD/LPD: _________

Total Design GPD/LPD (Add all above): _________
Divide by PSH for GPH/LPH: _________
Divide by 60 min/hr for GPM/LPM: _________

Water Resources

General Description of Water Resource (location, quality, supply, seasonal variances): ____
____
____

Where would a SPS be located? Is a new well required? Can it provide the flow rate you have determined above?: _______________________
____
____

Water Storage

How many days' usage should be stored for bad weather or other unusual demand days?	________ Days
Backup Days x Required GPD/LPD:	________ G or L
Estimated Size of Tank (Add one more day of water supply)	________ G or L

Total Dynamic Head (TDH)

Total Vertical Lift:

Depth of Standing Water in Well.	______ Ft. or M
Est. Drawdown Amount:	+______ Ft. or M.
Height of Tank Inlet above Ground	+______ Ft. or M.
Elevation Difference – Well to tank	+______ Ft. or M.
Add for Total Vertical Lift: (refer to page XX for drawing)	**=______ Ft. or M**
Design TDH as Calculated on Page XX.	**=______ Ft. or M**
OR	**OR**
If it is a short run with few bends, multiply TVL by 1.05:	
	=______ Ft. or M
For longer runs and/or ones with many bends, multiply TVL by 1.10	

Array Sizing

Pump Efficiency %: ________ %
Elec. Loss Factor (temperature variations, dirt, wiring losses) Usually 10-20%, i.e. 80-90% efficiency ________ %

Array Wattage Estimate:

U.S.

$$\frac{(GPM) \times (TDH) \times .188}{\text{Pump Efficiency (\%)} \times \text{Elec Efficiency (\%)}}$$ ________ W

Metric

$$\frac{(GPM) \times (TDH) \times .163}{\text{Pump Efficiency (\%)} \times \text{Elec Efficiency (\%)}}$$ ________ W

Only use as an estimate.
Compare to Manufacturer's Sizing for actual numbers.

Design Summary

PSH: ________
Daily volume (GPD/ LPD): ________
Total Dynamic Head: ________
Estimated Array Size (Wp): ________

Budget Guide

With the system summarized to this point, we can now prepare a preliminary cost estimate. The system costs will consist of community development costs and project installation costs.

10.0 Community Development Costs

The community development costs will include time, travel (food and lodging), and transportation costs required by the local NGO and the community to meet and develop the information needed for the initial discussions and data gathering. This is likely to require several visits to the site.

In the previous sections, we discussed the need for a community structure to be able to manage and administer the water system. In many cases this does not cost any money. But in some larger projects, it may be necessary to include in the budget a part-time paid manager to oversee that the community appropriately utilizes the water system. You may also need to pay someone to be responsible to collect the fees and perform routine maintenance.

It is important to estimate and record in-kind costs. In-kind means that the community or the NGO plans to donate the labor or materials and does not expect to be paid for these activities. For example, to calculate the communities in-kind contribution, estimate the number of people, the days of labor and the average wage for daylabor. Most funders like to see how much the community and NGO are contributing.

We have to separate the cost items into those spent to get the project started, and those cost items that are required to assure that the project is sustainable. The costs associated with establishing the community structure, staff, and responsibilities, need to be estimated, and included as **project costs**.

The continuing costs of maintaining the staff are very important as well, but need to be summarized as part of those costs that have to be supported through the collection of usage fees.

When the map was prepared for the system, it would have pointed out any property issues that might exist with the preferred location of the tank, well, and water points. Will these require any expenditure of funds to either purchase property rights or lease equipment? It is hopeful that any property rights issues can be worked out in the interest of the community, but you may need to include some costs for a properly drawn up and legally recorded document to indicate what agreements were reached.

All of the community development costs should be tabulated and summarized and carried forward to the final cost recap sheet.

11.0 Project Installation Costs:

The following paragraphs discuss the general areas of cost. Ballpark cost estimates are included to get you started on arriving at an overall cost estimate. As you get closer and closer to this being a definite project, each of the cost estimates needs to be confirmed with local pricing and quotations.

Well:
This includes a price for drilling the well and installing the casing. $20/foot is a rough estimate for the drilling an $5 a foot for the casing. If rock is encountered, the drilling costs could increase to $50/foot. You'll need to make a judgment regarding the probable depth and likelihood of hitting rock. As in all of these estimates, it always best to get some local input as to the costs in your area. The cost of well drilling varies widely from location to location.

Pumps:
Small Systems: Diaphragm pumps for very small systems are about $700. Larger diaphragm pumps could run $1000.

System Sizing
Recall Section 6.e

Medium Systems: Helical or centrifugal pumps will run $1000 to $2000.

Large Systems: The largest pumps for a SPS will cost $2000 to $2500

Controllers:
Controllers cost between $400 and $1500. A controller for a small system would be close to $400. A controller for a medium or large system would normally be closer to $1000.

Solar Panels
Solar Panels cost approximately $6/Watt without wiring or installation. (Check current market prices!)

Racks
A rack for solar panels can be simple or complicated.

Non-tracking racks can be fixed at one angle or be manually adjustable. As mentioned, the PV panel captures the most energy when perpendicular to the sun, which changes with season. Far north or south latitudes see a dramatic seasonal change in sun position in the sky, so a rack that is adjustable would be most beneficial here. Near the equator, this effect of sun position is minimized, so tracking or moveable racks are not recommended.

Tracking racks will automatically follow the sun's path either from East-West, North to South, or both. They use either passive methods or active (requiring an electric motor). The more complicated, the more to repair and maintain. See manufacturer's data in the appendix for specifics on efficiencies to be gained with a tracking rack, specific to your location. You can then make a judgment if the extra cost and complexity is worth the benefit.

In most cases, a non-tracking, manually adjustable rack is the most efficient, cost and otherwise.

Non-Tracking: $50-100 per solar panel.

Rack support: If the solar array is to be ground mounted, you will need footers and some supporting mechanism. If it is to be pole mounted, you will need to allow a budget for the furnishing and installation of poles and foundations.

Piping and Wiring:

The wiring can be budgeted at $1 per linear foot for small and medium systems and $1.50 per foot for large systems.

Piping is sized by the pump and is usually 1" O.D. or 1.25" O.D. (outer diameter). While cost varies widely, $1 or $1.5/l.f. for water pipe is a rough estimate.

Switches, disconnects, misc.
An amount should be included for manual safety disconnects, float witches, breakers, etc. $500 should be enough.

Water Storage:
From the number of gallons of storage you need, include a budget for constructing a tank from locally available materials. Inquire locally, but some estimates have shown $1 to $2 a gallon.

12.0 Budget Worksheet

Project Information
Village Name: ______________________________
Location: ______________________________
Altitude: ______________________________

Costs Items			Funded	In Kind
Community Development Costs				
	Site Investigation Surveys			
	System Mgmt Costs			
	Collection Costs			
	Property Rights Issues			
	Local NGO Devel. Costs			
	Other			
	Total Community Dev.			
Equipment Costs (normally quoted by Pump Supplier as a package)				
	Pump Cost			
	Controller			
	Solar Array			
	Rack for Solar Array			
	Float Switch for Tank			
	Other			

	Total Costs Normally Quoted by Pump Manufacturer:		

Other Equipment Costs				
	Well Drilling			
	Well Casing			
	Storage Tank			
	Water Piping – Well to Tank			
	Water Points			
	Piping – Tank to Water Points			
	Foundations for Solar Array			
	Auxiliary Structures			
	Electrical Wiring			
	Electrical Disconnect Switches			
	Spare Parts			
	Total Other Equipment Costs:			

Installation Labor and Tools			
	Labor for Installation of Solar System		
	Labor for Installation of Piping and Trench		
	Trucks for transportation		
	Other		

Summary of Project Cost Items			
	Community Development Costs		
	Equipment Costs (pump package)		
	Other Equipment Costs		
	Installation Labor and Tools		
	Taxes and Customs Charges		
	Consultancy and Technical Support		
	Travel		
	Total Project Costs		

13.0 Sustainability Costs

Based on the Total Project Costs, funds will usually be sought to cover a portion, sometimes even up to 100%, of the project's initial costs. In some cases the community will be able to raise some or all of the funds needed for a project, but it is not unusual that funding will have to be sought for at least a portion of the initial costs as defined above.

But, this is only part of the picture. No project maintains itself. A project that is not maintained and supported by the community will fail. There are, sadly, too many examples of this throughout the world – where initial project concepts and installations were well thought through, but the continuing sustainability aspects of the project were not.

13.a Examples of Sustainability Costs

There are costs that are directly related to the community aspects of the project. For example, do we need to pay any money to whoever is assigned the various responsibilities that go along with maintaining a community water system? These responsibilities have been discussed previously, but include things such as:

- Assuring that the facilities are utilized properly, and within the guidelines voted on by the community.
- Making regular checks on the equipment to determine whether any preventative maintenance repairs are needed.
- Performing regularly scheduled maintenance on the system, outlined in the manufacturers manuals.
- Collecting fees from the users of the system.
- Taking care of the banking and paperwork associated with the proper collection and tracking of the individuals' payments.
- Enforcement of the rules in regards to non – payment, discontinuing of services, and re-instatement of services.

There are other costs that are directly related to the equipment itself, including:

- Keeping on hand appropriate spare parts.
- Maintaining a good supply of tools and miscellaneous wiring and piping items for when they will be needed.
- Regular upgrades to the physical sites around the well, tank, and water points to prevent deterioration, and damage from animals.

* Shipping and re-importing costs and delays if any part of the system needs to be snet overseas for repair.

All of the costs associated with the above items are on-going, and are not included in the initial budget. Although a starter supply of spare parts and equipment should be included in the initial purchase, most of these items will be continuing.

The community may already have a co-op system in place, which can absorb many of the responsibilities at little or no cost. But this should not be assumed. The discussions should be engaged early on in the project and agreements reached as to how these services will be provided.

Therefore, unless provisions are made to pay for these items outside the initial funding, the project will not be able to be sustained.

All of these items need to be reviewed and the annual amount that each item will costs needs to be tallied. Then, this annual amount, converted to a monthly figure and divided by the number of users, would represent the amount of money each user would need to pay per month to keep the system maintained and sustainable

13.b Determination of Service Fee

Knowing the amount that must be collected to render the project self-sustaining, we need to see if the residents of the community are able and willing to pay this amount for the service.

When making this assessment for projects providing electricity, we would often use as a starting point, the amount of money a family would save from having electricity - say from a micro hydro plant. The expenses on kerosene for lighting, and batteries for radios might be a large cost that can be replaced with the introduction of electricity.

However, with solar pumping, it is not as clear cut. We must point out that the savings, although not easily put into trade-offs with current expenses, can be quite important. These benefits would be in the form of cleaner water – resulting in less sickness. The reduced sickness would mean less time away from work, more time in school, less money spent on medicine, and a generally improved way of life. The reduced time spent in fetching water by the women and children needs to be given a value.

After this review of both the ongoing expenses and the ability to collect this amount in fees, we will get an idea of whether or not the project can be sustained. If we learn that the community can not afford the payments that would be required to sustain the project, then the project should not be pursued further.

It is important that all through this procedure, the community remain involved in the surveys, the discussions of the benefits of the system, and the discussion of the costs. It is often the community members who come up with solutions as to how a project can be affordable and sustained, even when the first-pass calculations would make it seem otherwise.

In the end, as in the beginning, it has to be the community

and their needs that not only originate such a project, but determine whether or not it is sustainable.

Worked Examples

The following three sections include worked examples involved in the process of considering and designing a solar pumping system.

Included are the following:

14.0 Design Example– This section is a step-by-step, spreadsheet-based procedure covering the Village Input Information, Establishing the Water Requirement, determining the Total Dynamic Head, and calculating a preliminary size for the Solar Array.

15.0 Example Systems – In this section we have included information for what type of system might result in 5 different village sizes, each with 6 different heads. These village sizes and head ranges are chosen so that it would be likely that your village requirements might fall close to one of these categories.

16.0 Budget – This template is presented as a way to record the cost information developed in sections 10 through 12 on Budgeting.

14.0 Preliminary Design

Below are templates that follow the guidelines of the preliminary design information.

This section includes four parts:

Village Input Information:

The basic information about the village including its location, number of families, PSH, and information about an existing well is recorded here.

Water Requirement

This template helps to calculate a total daily water requirement in Gallons per Day, or Liters per Day for the village. It takes into account the number of people, and special allowances for minimal animal watering and small crop irrigation needs.

Total Dynamic Head

This template helps to calculate the total dynamic head for the installation. You will need friction loss charts in order to look up the values of equivalent inputs for head loss due to pipe and fittings.

Solar Array Sizing

Using the required flow in GPD or LPD, the PSH, the Total Dynamic Head, and the pump efficiency, this page shows how to calculate the initial size for the array that may be required. It is noted that the size of the array quoted by a given manufacturer could be quite different from the value calculated here, because the efficiency of the various pumps varies a lot. However, this will give a good starting place for arriving at a preliminary budget.

Units:

These calcualtions can be done either in English or Metric units. But, it is crucial to utilize the same units throughout. (i.e. either use feet and gallons, or meters and liters.)

The following pages include a sample of the completed templates. The example used is a village of 100 families, requiring 5000 GPD with a Total Dynamic Head of 100 Feet.

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VILLAGE INFORMATION

Village Name:	Hypothetical Village
Altitude:	
Number of Families	100

PSH:	
Summer	6
Winter	5
Use	5

Description of Existing Well.

Is there an existing Well?

If yes - Record:

Size of Casing:		
Depth of Water	Static	
	Dynamic	
Flow Recovery Rate		

If no - record:

Estimated Water Depth:	
Estimated Recovery Rate:	

For Storage Tank Purposes:
Days' of Water Storage Needed: 3 (usually 2 to 4 - depends on weather experience.)

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Daily Water Requirement Hypothetical Village

People:

Number of Families	100
Residents per Family	5
Total People in Village	500
Assumed daily Water Consumption	10
Total Daily Water Requiement - People	5000

Animals:

Animal Type	Qty	Daily per Animal	Total GPD/LPD
			0
			0
			0
			0
			0
			0
Total Daily Water Requirem't - Animals			0

List Other Water Requirements:

Description			Total GPD/LPD
Total Other Water Requirements			0

Total Water Requirements:	Total GPD/LPD
People	5000
Animals	0
Other	0
Total Daily Water Needed	5000

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Determination of Head: Hypothetical Village

Total Vertical Lift:	
Depth to Static Water Level	60
Drawdown	10
Ground Elevation Difference: Well to Tank Base	10
Height of Tank Water Inlet above Ground:	10
Total Vertical Lift:	90

For an Initial Approximation of Total Dynamic Head (TDH)

If Well to tank is short	94.5	(1.05 x TVL)
If Well to tank is long	99	(1.10 x TVL)

OR - Use Calculation of Total Dynamic Head:

Calculate Friction Loss:

Sum of Pipe Lengths:	200	(in Feet / meters)
Equivalent Fitting Lengths:	12	(in Feet / meters)
Total Equivalent Length of Pipe:	212	(Lenghth plus Equivalent Fitting Length)
Total Daily Output - GPM	17	(GPD or LPD / (PSH*60))
Friction Loss Factor	0.04	(From Table)
Total Friction Loss	8.48	

Summary of Total Dynamic Head Calculation:	
Total Vertical Lift	90
Total Friction Loss	8.48
Tank Pressure (see note)	0
TOTAL DYNAMIC HEAD	98.48

The tank pressure input only applies if there is a pressurized tank. When water is allowed to flow freely into an open or vented tank, the tank pressure is zero.

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Preliminary Array Sizing Hypothetical Village

This calculation is for prelinary budget information. The actual array required may be quite different from what is arrived at with these calculations, because a given manufacturer's pump is designed to operate at different efficiencies.

The array size is based on the power required to run the pump. The power required to run the pump is related to the required flow and the required head.

The formula for determining required power in watts to run the pump is:

$$\text{Watts} = \frac{\text{(Required flow in GPM) x (TDH in feet) x 18.8}}{\text{Efficiency of Pump \%}}$$

(If the pump efficiency is 30 percent, the denominator is 30)

The result of this calculation is the quantity of power that must be delivered to the pump. So, the losses inherent in the production of power with a solar array must be taken into account. These losses include temperature variations, dirt losses, and wiring losses.

A good rule of thumb to use here is 20%, so the size of the array as determined above could be multiplied by 1.2.

If the units being used are liters per minute, and meters head, then the factor of 18.8 can be changed to 16.3.

From previous worksheets, enter the variables below:

Total Dynamic Head	96.48	(Feet or Meters)
Daily Water Requirement	5000	(GPD or LPD)
System Design PSH	5	
Resulting flow per minute	17	(GPM or LPM)
Pump System Efficiency	30	(between 20 and 50 - use 30)
Constant Factor	18.8	(18.8 if English, 16.3 if metric)
Depreciation Factor	1.2	(usually 1.2)
Resulting Array Size Needed	1234	Watts (peak) of solar array

15.0 Example Systems

The following three pages show examples of system sizes for villages with 10, 20, 50, 75, and 100 families.

In each example, we assume that there are 5 people per family, with each person requiring 10 gallons per day. There are no allowances for animals or crops.

System applications are then illustrated for heads ranging from 20 feet to 250 feet.

The array wattage, determined by the formula presented earlier is calculated for each resulting system.

Then, we have used the manufacturer's data from several of the major vendors to record what pump and array they would recommend.

These examples are useful to compare a projected solar pumping system to one of these applications to give an idea of where your system fits in.

You can see that that are some small pump lines that are not applicable as the systems get larger.

These charts also list the size of the solar array that the manufacturer recommends, as compared to the calculated solar array. This gives an idea of the relative efficiencies of the various pump systems, and what your overall system might look like based on whose equipment you would use.

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Green Empowerment
Comparison of Pump Applications 01-Jul-03
Based on Area with 5.0 PSH

For Array Wattage Multiplier	
Array Multiplier	1.2
Assumed Eff. %	30

10 Families		10	Families =	50	People =	500	GPD
		500 GPD 1.67 GPM			1893 LPD 6.31 LPM		
Manufacturer	Feet Meters	20 6	50 15	100 30	150 46	200 61	250 76
Array Wattage by Formula		25	83	125	188	251	313
Sun Pumps	Cat No	SCS-18-45	SCS-14-70	SCS-9-100	SCS-4.5-160	SCS-2-280	SCS-2-280
	Array Size	240	240	640	600	600	600
Grundfoss	Cat No	11-SQF-2	11-SQF-2	11-SQF-2	3-SQF-2	3-SQF-2	3-SQF-2
	Array Size	100	100	200	200	250	250
Dankoff	Cat No	ETA-04-090	ETA-04-120	ETA-04-180	ETA-04-240	ETA-04-300	ETA-04-480
	Array Size	90	120	180	240	300	480
Kyocera	Cat No	SD-12-30	SD-12-30	SD-12-30	SC-500-15-60	SC-1000-15-105	SC-1000-15-105
	Array Size	40	80	160	640	960	1280
Shurflo Sub Pump	Cat No						
	Array Size	58	78	100	120	141	n/a

20 Families		20	Families =	100	People =	1000	GPD
		1000 GPD 3.33 GPM			3785 LPD 12.62 LPM		
Manufacturer	Feet Meters	20 6	50 15	100 30	150 46	200 61	250 76
Array Wattage by Formula		50	125	251	376	501	627
Sun Pumps	Cat No	SCS-18-45	SCS-14-70	SCS-9-100	SCS-4.5-160	SCS-2-280	SCS-10-230
	Array Size	240	480	640	600	600	840
Grundfoss	Cat No	11-SQF-2	11-SQF-2	11-SQF-2	6-SQF-2	6-SQF-2	6-SQF-2
	Array Size	100	150	250	350	400	500
Dankoff	Cat No	ETA-04-120	ETA-04-180	ETA-04-240	ETA-07-480	ETA-04-480	ETA-07-600
	Array Size	120	180	240	480	480	600
Kyocera	Cat No	SD-12-30	SD-12-30	SD-12-30	SC-1000-25-85	SC-1000-15-105	SC-1000-15-105
	Array Size	100	150	275	960	1280	1280
Shurflo Sub Pump	Cat No	Beyond the Flow Capabilities of Shur Flow					
	Array Size						

P

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Green Empowerment
Comparison of Pump Applications 01-Jul-03
Based on Area with 5.0 PSH

For Array Wattage Multiplier:	
Array Multiplier	1.2
Assumed Eff. %	30

50 Families		50	Families =	250	People =	2500	GPD
		2500 GPD 8.33 GPM			9463 LPD 31.54 LPM		
	Feet	20	50	100	150	200	250
Manufacturer	Meters	6	15	30	46	61	76
Array Wattage by Formula		125	313	627	940	1253	1567
Sun Pumps	Cat No	18-45	14-70	9-100	18-160	10-230	16-300
	Array Size	200	480	640	840	1200	1600
Grundfoss	Cat No	25-SQF-3	11-SQF-2	11-SQF-2	11-SQF-2	11-SQF-2	3A-10
	Array Size	200	250	400	600	800	1920
Dankoff	Cat No	ETA-14-240	ETA-14-300	ETA-14-600	ETA-14-900	ETA-07-900	out of range
	Array Size	240	300	600	900	900	
Kyocera	Cat No	SC-500-40-25	SC-500-40-25	SC-1000-45-60	SC-1000-35-70	SC-1000-25-85	SC-1000-25-85
	Array Size	480	480	960	1280	1920	1920
Shurflo Sub Pump	Cat No	Beyond the Flow Capabilities of Shur Flow					
	Array Size						

75 Families		75	Families =	375	People =	3750	GPD
		3750 GPD 12.50 GPM			14194 LPD 47.31 LPM		
	Feet	20	50	100	150	200	250
Manufacturer	Meters	6	15	30	46	61	76
Array Wattage by Formula		188	470	940	1410	1880	2350
Sun Pumps	Cat No	18-45	14-70	30-115	18-160	16-300	16-300
	Array Size	200	540	???	1320	1600	1600
Grundfoss	Cat No	11-SQF-2	11-SQF-2	11-SQF-2	11-SQF-2	3A-10	2A-15
	Array Size	250	350	600	850	1920	1920
Dankoff	Cat No	ETA-14-300	ETA-14-480	ETA-14-720	ETA-14-900	out of range	out of range
	Array Size	300	480	720	900		
Kyocera	Cat No	SC-500-40-25	SC-500-40-25	SC-1000-45-60	SC-1000-45-60	out of range	out of range
	Array Size	480	640	1280	1920		
Shurflo Sub Pump	Cat No	Beyond the Flow Capabilities of Shur Flow					
	Array Size						

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Comparison of Pump Applications 01-Jul-03
Based on Area with 5.0 PSH

For Array Wattage Multiplier	
Array Multiplier	1.2
Assumed Eff. %	30

100 Families		100	Families =	500	People =	5000	GPD
		5000 GPD 16.67 GPM			18925 LPD 63.08 LPM		
	Feet	20	50	100	150	200	250
Manufacturer	Meters	6	15	30	46	61	76
Array Wattage by Formula		251	627	1253	1880	2507	3133
Sun Pumps	Cat No	18-45	18-45	14-160	14-160	20-200	16-300
	Array Size	240 F	480 T	900 F	1120 T	1540 T	2160 T
Grundfoss	Cat No	25-SQF-3	11-SQF-2	11-SQF-2	3A-10	3A-10	out of range
	Array Size	250	500	900	1800	1920	
Dankoff	Cat No	ETA-75C-480	ETA-75C-720	ETA-14-900	out of range	out of range	out of range
	Array Size	480	720	900			
Kyocera	Cat No	SC-500-40-25	SC-1000-105-30	SC-1000-60-45	out of range	out of range	out of range
	Array Size	480	960	1920			
Shurflo Sub Pump	Cat No	Beyond the Flow Capabilities of Shur Flow					
	Array Size						

Letter after array watts indicates the following:T = Tracking Array and F = Fixed Array

16.0 Sample Budget

This section includes a worked example of a project budget, using the preliminary design developed for the hypothetical village in section 13.0 as an example.

Initial Budgeting - Community Development

	Total Costs	In-Kind by Comm.	In-Kind Other	Funding Required
Site Investigation Surveys	600			600
Property Rights Issues				
Local NGO Development Costs	1200			1200
Other				
Total	1800	0	0	1800

Initial Budgeting - Equipment

	Total Costs	In-Kind by Comm.	In-Kind Other	Funding Required
Equipment Costs - Normally Quoted by Pump Vendor, in Package				
Pump	2000			2000
Controller	500			500
Solar Array	7500			7500
Rack for Solary Array	800			800
Float Switch for Tank	50			50
Other				
Total Package System Cost	10850	0	0	10850
Other Equipment Costs				
Well Drilling	3000			3000
Well Casing (often included in drilling estimate)	0			0
Storage Tank	10000			10000
Water Piping - Well to Tank	250			250
Water Points	800			800
Water Piping - Tank to Water Points	1500			1500
Foundations for Solar Array	400			400
Auxiliary Structures (water points, etc.)	200			200
Electrical - in Well wiring	150			150
Electrical - controls wiring to tank	50			50
Electrical - Disconnect Switches				
Total:	16350	0	0	16350

Initial Budgeting - Labor, Tools, Summary

	Total Costs	In-Kind by Comm.	In-Kind Other	Funding Required
Labor and Tools				
Labor - Install Solar System and Pump	400	400		
Labor - Install Tank	1000	1000		
Labor - Install Water Points	600	600		
Labor - Install Water Distribution System	2500	2500		
Labor - Other				
Truck and Equipment	500		500	
Total Labor and Tools	5000	4500	500	0

	Total Costs	In-Kind by Comm.	In-Kind Other	Funding Required
Summary of Project Costs				
Community Development Costs	1800	0	[illegible]	[illegible]
Equipment Costs - Pump and Package	10850	0	[illegible]	[illegible]
Equipment Costs - Other Equipment	16350	0	[illegible]	[illegible]
Installation Labor and Tools	5000	4500	[illegible]	[illegible]
Sub-Total	34000	4500	500	[illegible]
Other Local NGO Costs				
Customs and Freight and Taxes	1500			1500
Consultancy and Technical Support	2000			2000
Travel	2000			2000
Project Total:	39500	4500	500	[illegible]

What's Next?

Now that you have determined that SPS is a viable solution by completing a survey of the community, established that the community is well prepared to manage such a project, and to keep it operationally sustainable, and you have worked through the preliminary sizing of the system, and have a ball-park idea of the costs involved, it's time to take the next step.

As stated earlier, this is not a complete design manual, and further technical and financial assistance will probably be required. The next two sections will discuss those steps necessary to carry forward with turning this concept into a project. These steps are:

17.0 Review Vendor Information.

18.0 Proceeding with the Project

17.0 Review Vendor Information

The actual pumping equipment that the individual pumping manufacturers produce are all quite specialized. In many cases, a particular pump manufacturer concentrates most of their engineering and development on a particular style and design of pump, which is most suited to a given range of flow and head requirements.

In our preliminary array sizing examples, we used a default of 30% for the efficiency rating of the pumps. In many cases, this is very close to the actual efficiency. But, more and more systems are coming out with much better efficiencies, and therefore require a smaller solar array than what our initial calculations indicated.

At this point, you need to review the literature of several pump manufacturers, to see what pumping system they would recommend for the given flow and head of your community. You may find that some manufacturers don't even address the particular range you need. All manufacturers approach the sizing of their systems differently, although they are all ultimately based on flow, head, and available sunshine. If you have access to the internet, there are generally details available there.

When the time comes to discuss the project with a pump manufacturer or supplier, we cant assume that we have chosen the proper pump. Manufacturers are testing their pumps and developing new technologies all of the time. As before, the information that the vendor will ultimately need is the flow required, the Total Dynamic Head, and the geographical location for PSH.

The pump manufacturers will produce a chart that will tell us how much water a chosen pump will produce at each month of the year, illustrating any problem months. This will be based on their choice of optimum solar array size.

18.0 Proceeding with the Project

Generally, what is required most at this point, in order to proceed with the project is funding.

In order to obtain funding, a grant proposal needs to be prepared. While the preparation of this grant request is beyond the scope of this manual, Green Empowerment can assist in this effort, and every foundation has separate guidelines, timeframes and applications.

Funding is difficult and time consuming to obtain. It will generally come from different sources, with no one source funding the majority of the project. It will often take foundations 6 months to a year between submitting a grant application and receiving funding. This timeframe will be important to relay to the community.

It is important to show the value of the services that the community is providing “in kind”. This is the reason behind keeping track of these items separately on the budget worksheets. The efforts that the community is willing to expend go a long way in contributing to the project viability.

As the project concept is being developed, other sources of funding should be kept in mind as well. These sources would include those groups more closely related to the project – such as local governments, or local branches of large NGO’s working to promote potable water in the area. For example, a municipality or an NGO might be able to fund (or perform) the drilling of the well, and other portions of the civil work required in the project.

If the well is not already drilled, which is often the case, an early step in the process needs to be the completion of the well, and the testing required to determine that it will, in fact, provide the water supply we assumed throughout the process.

Conclusion

We hope that the information contained in this manual has helped you to determine if a Solar Pumping System is an appropriate solution to the needs of your community.

And if you feel that a SPS is an appropriate solution, we hope that we have provided you with some tools to move forward to determine:

- Whether or not a Solar Pumping System is feasible
- What a system's approximate costs would be.
- Where to go from here.

More importantly, we hope we have stressed enough the ideals that Green Empowerment embodies – those of Local Leadership, Social Justice, and Sustainability.

Any project such as this must always first be viewed from the aspect of whether or not it addresses the real needs of the community, and provides a solution that the community wants.

From there, we must determine if the project can be sustained.
Only then should we looking at the details of the design and installation of the technology. In the long run – these are the easiest issues to deal with successfully. Yet it is the concerns of the community development and sustainability that are far more complicated and important to the success of a project.

Appendices & References

For Solar Resource Maps, see Kyocera Solar Pumping Guide, p 12 - 18
For Site specific month by month data, see RETscreen.org downloadable PV3 software
For Friction losses and TDH calculation, see Kyocera SP Guide, p.9-10
For other Manufaturer's information, see Grundfos product guide, and sample data sheets from Shurflo, SunPumps, Dankoff, etc.
Manufacturers web sites:
http://www.global.kyocera.com
http://net.grundfos.com
http://www.sunpumps.com
http://www.mono-pumps.com etc.
also see local vendors websites in relevant countries.