LORENTZ

August 2008

Solar Water Pumps
in Namibia

A Comparison Between
Solar And Diesel

v080912

INTRODUCTION

Solar pumps offer a clean and simple alternative to fuel-burning engines and generators for domestic water, livestock and irrigation. They are most effective during dry and sunny seasons. They require no fuel deliveries, and very little maintenance. Solar pumps are powered by photovoltaic (solar-electric) panels and the flow rate is determined by the intensity of the sunlight.

Solar panels have no moving parts, and most have a warranty of at least 20 years. Most solar pumps operate without the use of storage batteries. A water tank provides a simple, economical means of storage. Solar pumps must be optimally selected for the task at hand, in order to minimize the power required, and thus the cost of the system.

A wide variety of solar pumps is available, to meet a wide variety of needs. The purpose of this booklet is to inform Namibia's farmers about the economic merits of solar water pumping technologies as a replacement for diesel water pumps. Against rapidly increasing diesel fuel prices, volatile livestock and crop markets and mounting threats to maintain agricultural productivity - can any farmer seriously afford not to consider solar water pumping?

This brochure aims at providing the basic information to decide whether a solar pump is suitable for your farm and whether it can economically replace a pump powered by a diesel engine or a wind mill.

DIESEL - CAN YOU BUILD A BUSINESS ON IT?

To decide whether solar or diesel pumping is more economical for your farm, everything comes down to the question: How much do you have to pay per litre of water pumped up?

This is expressed by the Unit Water Cost (UWC): the cost of a specific volume of water that one has to sell to recover the capital cost, maintenance cost and operating cost of a pump – over the full life cycle. The total cost for setting up and operating a pump must be earned back by the water pumped.

The two following tables show the UWC for solar and diesel pumps for a variety of common heads and daily flow rates. It is obvious that diesel pumps are very high in cost, i.e. low in efficiency, at small to medium daily flow rates. Solar pumps, in comparison, are up to 70-90% cheaper than diesel pumps.

All calculations are based on a diesel price of US$ 1.30 per litre (US$ 4.90 per Gallon).

UWC FOR DIESEL PUMPS IN US$/m³ IN US$/1,000 US-GAL.*

Head		Daily Flow Rate					
m	ft	**3** 0.8	**6** 1.6	**8** 2.1	**13** 3.4	**17** 4.4	**m³/day** 1,000 US-Gal./day
20	65	5.00 18.90	2.45 9.25	1.80 6.80	1.70 6.45	1.25 4.75	
40	130	4.90 18.55	2.45 9.25	1.85 7.00	1.70 6.45	1.25 4.75	
60	195	4.95 18.75	2.50 9.45	1.85 7.00	1.70 6.45	1.30 4.90	
80	260	5.00 18.90	2.50 9.45	1.90 7.20	1.75 6.60	1.30 4.90	
120	370	5.15 19.50	2.55 9.65	1.95 7.40	1.75 6.60	1.40 5.30	

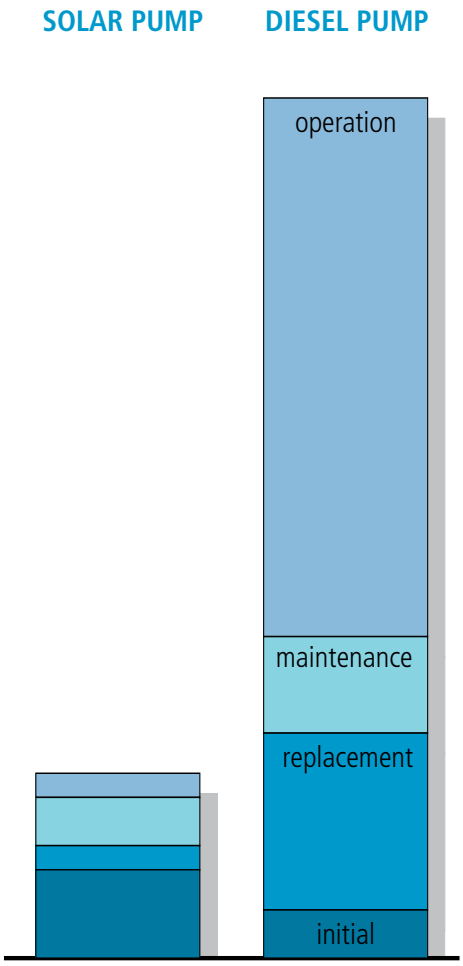
UWC FOR SOLAR PUMPS IN US$/m³ IN US$/1,000 US-GAL.

Head		Daily Flow Rate					
m	ft	**3** 0.8	**6** 1.6	**8** 2.1	**13** 3.4	**17** 4.4	**m³/day** 1,000 US-Gal./day
20	65	0.70 2.65	0.40 1.50	0.25 0.95	0.20 0.75	0.15 0.55	
40	130	0.65 2.45	0.35 1.30	0.30 1.15	0.20 0.75	0.20 0.75	
60	195	0.70 2.65	0.40 1.50	0.35 1.30	0.25 0.95	0.25 0.95	
80	260	0.75 2.85	0.45 1.70	0.40 1.50	0.35 1.30	0.35 1.30	
120	370	0.85 3.20	0.55 2.10	0.50 1.90	0.50 1.90		

* Taken from the Study: Feasibility Assessment for the Replacement of Diesel Water Pumps with Solar Water Pumps. September 2006. Prepared by EMCON Consulting Group, Windhoek. Commissioned by the Ministry of Mines and Energy of Namibia. For the increase of diesel prices since Sept. 2006 20% have been added to the UWC for diesel pumps.

COMPARING APPLES WITH APPLES

Very often investment decisions are based only on the cost for purchasing a technology, neglecting the operational, maintenance and replacement costs. For example: leaving aside the fuel costs when comparing solar to diesel water pumps. This skewed economic perspective sometimes results in the general perception that "solar is expensive".



When comparing solar and diesel water pumps in terms of total costs over the minimum 20-year life-span of the solar panels, one must add the cost of fuel that has to be delivered to the borehole for the next 20 years, to the cost of the diesel pump itself. This compares "apples with apples".

1. The **initial costs** for the diesel pump are lower. Not much, but every penny counts, doesn't it?
2. Next add **replacement costs**. This includes replacing the diesel pump every 5 years and the submersed solar pump unit every 7 years. When these costs are added to the initial costs, the cost for diesel already surpasses the solar pump.
3. Now add **maintenance costs**. For diesel pumps, as every farmer knows, these costs are significant. Already at this point the diesel pump is twice as expensive as the solar pump.
4. Adding **operational costs** reflects the true costs when choosing a diesel pump as a water supply technology on a farm. The actual all inclusive costs over 20 years now stand at US$ 12,750 for a solar pump and US$ 73,750 for a diesel pump (at today's diesel price).

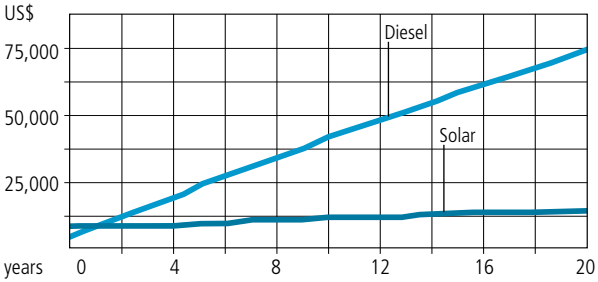
*Figures calculated for a pumping head of 50m and a daily pumping volume of 10,000 litres. Diesel fuel cost is US$ 1.30 per litre (US$ 4.90 per Gallon) and diesel pump operating time is 5 hours every day.

BREAKEVEN PERIOD

Solar pumps are cheaper than diesel pumps over their lifetime, but initial costs are usually higher. After how much time of operation will a solar pump be cheaper than a diesel pump? 5 years? Even longer? The moment when the costs of a solar pump and a diesel pump for pumping a given quantity of water every day are the same is known as the breakeven point. The breakeven point depends on pumping height and daily water pumped.

LIFE CYCLE COST OVER 20 YEARS IN US$

For 50m Lift, 20,000 Litres Flow



The **graph above** illustrates the breakeven points for a specific pumping configurations. Given that the breakeven point varies, the **table below** is useful for determining the breakeven point* for different pumping specifications.

BREAKEVEN POINT IN MONTHS

Depth		Flow						
m	ft	**5** 1.3	**7** 1.8	**10** 2.6	**12** 3.2	**15** 4.0	**20** 5.3	**m³/day** 1,000 US-Gal./day
10	33	0 **	0	0	1	2	4	
20	65	0	0	1	2	5	8	
30	100	0	0	3	5	7	11	
40	130	0	2	6	8	11	15	
50	165	1	4	8	11	14	20	
60	195	2	6	11	15	20	- ***	
80	260	4	9	15	19	-	-	
100	315	7	14	-	-	-	-	
120	370	8	16	-	-	-	-	
150	470	12	-	-	-	-	-	

* Figures calculated for a LORENTZ helical rotor pump at retail prices (including VAT) as of January 2008 and at a diesel fuel cost of US$ 1.30 per litre (US$ 4.90 per Gallon). Diesel pump operates for 5 hours each day.

** "0" indicates that the purchase cost of the solar pump is already less than the cost of the diesel pump. There is thus no breakeven point, because the solar pump already starts from a winning position from when it is put into operation.

*** Blanc cells are areas where larger centrifugal pumps or multiple HR pumps are recommended.

THE FUTURE OF DIESEL

The Namibia Agricultural Union estimates that diesel water pumping, together with lick and interest rates, contribute 35 to 40% of operational expenses of a farm. Naturally, as diesel fuel prices increase, so do overheads.

How stable is the diesel price? Well, reflecting on historical oil price data shows a steep upward trend. During the past 10 years diesel prices have increased by 20% in average. In 1999 a litre of diesel cost US$ 0.25. By 2008 prices are as high as US$ 1.30 per litre (US$ 4.90 per Gallon).

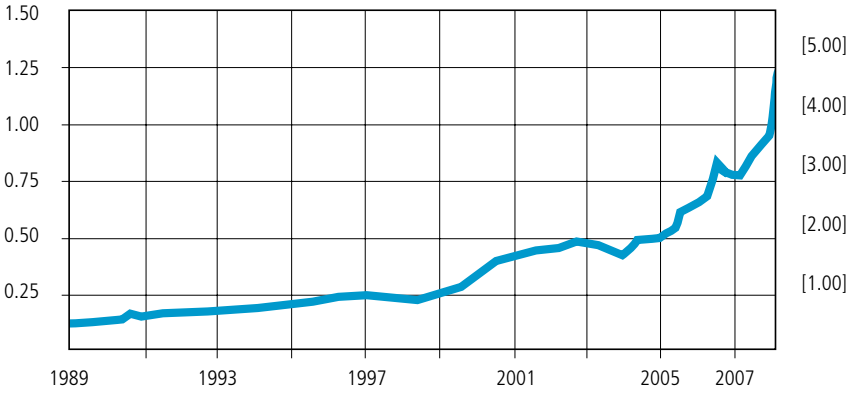
Experts say: Countries like China and India, home of about 50% of the world's population, are developing their industries and grow at fast pace. This is causing a additional demand for oil and will keep prices high or even increasing in future. It is expected that peak oil production will be reached around 2007-2010. Afterwards less and less oil will be available to refine, no matter where drillers look.

Unlike in the past, major world oil reserves are not in the hands of big oil companies anymore, but in the hands of countries and governments. That turns oil into a political commodity, with a growing risk that oil supply is used as political weapon. This makes the oil price even less predictable.

The price of diesel will rise and remain volatile. Solar pumps are the answer.

NAMIBIA DIESEL PRICE

US$/litre and [US$/US-Gal.], Windhoek, 1989 to May 2008



PUMP TYPES

There is a large variety of solar water pump types in the market. The most common types of mechanisms are

- helical rotor (mono)
- centrifugal
- piston or diaphragm

The most simple and robust pump ends are the **mono or helical rotor type pumps** with only one turning part: a rotor turning in a rubber stator. They are a good choice for daily flows of 6 to 20m³ for medium to high lifts (50 to 150m).

Centrifugal pumps are very economical for shallow to medium lifts (up to 80m) with large flow rates.

Piston or diaphragm pumps are much more complex with a lot of moving parts. Usually they require oil lubrication inside the pump which might be a potential risk in a water well. Typically they are used in low voltage (24-48V) applications with small daily flows (up to 5m³/day) for lifts up to 150m (max. 2m³/day).

centrifugal type pumps

SUBMERSIBLE MOTORS FOR SOLAR PUMPS

Solar Power is direct current power, also called DC. Hence DC motors are used most commonly. **DC motors can be up to 100% more efficient than AC motors of the same size.** Unlike AC motors, DC motors use permanent magnets which are responsible for the large efficiency advantage. Due to this advantage, solar pump systems below 4-5kW typically use DC motors.

Double efficiency means: **you need only half the power for the same performance**, accordingly you can work with a much smaller solar generator than you need for an AC system. The solar generator is the most expensive part of the system and usually accounts for 70-80% of the total system cost.

There are two different types of DC motors that differ a lot: Brushed and brushless DC motors.

- **Brushed DC motors** have small carbon blocks that are called brushes. They are needed to create the turning field to make the motor rotor spin. They wear out and must be replaced after some time. Brushed motors must be air-filled in order to make the carbon brushes work; otherwise a short circuit will occur. If the motor shaft seal or any other motor seal fails the motor will be damaged and cannot be repaired.

- **Brushless DC motors** do not use these brushes. The brushless motor concept is the answer to these problems and was developed about ten years ago. They do not need reliable seals – in most cases they are water filled anway! They where designed to be maintenance-free for many years and as reliable as AC motors are.

A COMPARISON OF THE ADVANTAGES OF THE DIFFERENT MOTOR CONCEPTS

Motor	Motor filling	Efficiency	Maintenance	Reliability
AC	water or oil	very low	low	very high
DC with brushes	air	high	very high	low
DC brushless	water	very high	low	very high

SUBMERSIBLE SOLAR PUMP

The pump is mounted on a submersible motor and is submerged below the water level in the borehole. Electricity is provided by a solar panel array installed within a close distance from the borehole.

Attached to the submersed pump unit are a plastic water pipe made of PE, an electric cable, an electric water sensor and a safety rope. Solid steel water pipes are not required. As a result, installation and extraction of the pump unit is simple and fast.

The pump's operations are regulated by an electronic controller, which initiates starting and stopping, and monitors the water level.

For the LORENTZ pump the controller is installed above ground, while for the Grundfos pump the controller is integrated with the pump unit and thus in the well located below the water level.

Solar pumps can be lowered down
to depth of up to 50m within minutes,
deeper installations can be made with a tripod

WINDPUMPS VS. SOLAR PUMPING

Wind pumps are the pioneering technology of water pumping. In the 1990s there were an estimated 30,000 wind pumps installed in Namibia. The technology has a well developed service infrastructure.

Wind pumps have a similar life span as solar pumps and are able to deliver water from depths of about 120m. Daily flows from depth greater than 50m are typically considerably less then 10m³ per day.

Although only basic technical skills are required, wind pumps are work-intensive to maintain. Typically a maintenance takes three days. One day alone is needed to pull the pump up and take it apart in order to know which type of cylinder is used. The variety is very large, so spare parts cannot be ordered in advance. A second day is needed to get the spares, a third to reassemble the pump. Maintenance of the rotor, e.g. exchange of blades, and of the gearbox is a dangerous job, as you have to climb and work on a 15m high tower.

Against that, a solar pump is easy and fast to maintain. It can be pulled up in 30 minutes. A spare pump end or motor is replaced in 15 minutes. 20 minutes later you have lowered the pump back into the well and get it started again.

Solar pumps are less expensive than windmills, are easier to install, and provide a more consistent supply of water. This is especially true in areas where wind may be seasonal and inconsistent.

A solar pump produces its highest volume of water when water is needed the most - when the weather is sunny and hot!

A transformed windmill installation with solar replacement pump

FINANCING A SOLAR PUMP

Whether you wish to purchase a single pump, or replace all of your diesel pumps in one determined swoop, the question of how to finance such a purchase is critical. The following institutions are geared towards providing loans for solar water pumps:

Before you approach a financial institution of your choice:

- **Know your borehole specifications** You need to know the water level and daily pumping volume for each borehole you want to convert in order to obtain quotations from the suppliers.
- **Have a chat with solar suppliers** Arrange an appointment with different suppliers. Take your time when consulting with them. Discuss general water and solar issues as well. Ask about warranties and after-sales service and negotiate for the best price. Obtain a written quotation when satisfied.
- **Consult with financial institutions** With your quotation at hand contact the financial institutions and request a loan. Compare loan criteria and negotiate for better conditions. Complete the loan application form when satisfied.

WHAT ABOUT CASH FLOW?

Securing a loan might be simple enough, but a loan must be repaid. Is the cash saving on diesel fuel sufficient for repaying the loan for the solar pump? The calculation below compares only the actual cash expenditure for diesel fuel.

The calculation presented here does **NOT** consider:

- purchasing the diesel pump
- collecting and transporting the diesel from the nearest depot
- travelling on farm roads to the borehole
- wear and tear on your pick-up
- time spent

DIESEL INSTALLATION

Diesel fuel consumption	0.8 litres per hour
Duration of pumping	5 hours per day, every day
Diesel consumption	120 litres per month
Diesel price	US$ 1.30 per litre
	US$ 4.90 per US-Gal.
Diesel cost per month	**about US$ 156**

SOLAR INSTALLATION

Total cost of solar installation	US$ 6,875*
Interest rate	10% per annum
Deposit	10%
Loan amount	US$ 6,187.50
Loan duration	5 years
Monthly repayment	**about US$ 130**

The diesel fuel savings alone, against a market-related loan facility, are sufficient to cover the loan repayment. And interest paid on loans is tax deductible from your income statement.

* Calculated for a LORENTZ PS series pump at retail prices (including 15% VAT) as of January 2008 for a pumping head of 50m and daily pumping volume of 10,000 litres.

SOLAR TRACKING FOR SOLAR WATER PUMPS

A solar tracker is a PV rack that rotates on an axis to face the sun as it crosses the sky. It is well known that solar tracking will increase energy yield by 25-50%. For solar pumping, tracking offers even greater gains and benefits that can greatly reduce system cost.

Optimum yield during the peak watering season Tracking offers more water out of smaller, less expensive system by increasing performance when the most water is needed - during long sunny days of the growing season. This is most appropriate for agricultural and seasonal summer uses.

Prevention of pump stalling Many solar pumps experience a disproportionate drop in performance when the sun is at a low angle (early morning and late afternoon). When the PV array output is less than 50%, a centrifugal pump may produce insufficient centrifugal force to achieve the required lift. By causing the pump to run at full speed through a whole sunny day, tracking can often **DOUBLE** the daily water yield.

Water distribution for PV-direct irrigation Solar irrigation can be practical without storage device, in some situations. The soil itself stores water during cloudy days! But sun-tracking may be necessary to achieve uniform water distribution. When water flow is reduced, a sprinkler just makes a puddle. A trench or drip line feeds only the first few plants, or the lowest ones. A tracking array minimizes the periods of reduced flow. It makes solar-direct water distribution an option for dry sunny regions.

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

When not to use a tracker Tracking is least effective during shorter winter days and cloudy weather. If the need for water is constant during the year or greatest in the winter, or if the climate is very cloudy, then it may be more economical to design the system with more solar watts and no tracker.

THEFT PREVENTION FOR SOLAR PANELS

The theft of solar PV panels is often cited as a reason for farmers' being reluctant to invest in this technology. Here are some suggestions for minimizing the risk of theft:

- **Try to establish a permanent presence** at the water point or pumping installation by erecting a labourer's home there. This will also help to control poaching and/or stock theft. By incorporating the installation's solar panels, this residence can in some instances be electrified too!

- **Mark the underside of the panels** with the farm name and contact details in non-removable paint. You can paint the entire underside in your favourite colours. This will be hard work for a thief to clean off.

Effective theft protection: Panel and tracker fenced in and protected by barbed wire

- **Keep records of serial numbers** of all panels. This is proof that the panels are yours when they are recovered, or when you place an insurance claim.

- **Put a fence around the PV installation!** Or plant a solid wall of cacti or sisal that can only be crossed with a removable arched ladder.

- **Install the panels on six meter steel poles** with a large concrete block as foundation, guy wires for anchorage, and fill the inside of the steel pole with cement. Fit razor wire underneath the panels. This also deters baboons from playing or tampering with your assets.

- But above all: make a plan! You would not leave your car parked in town with the key in the ignition; you would not let your stud bull roam freely on a public road. So, do not leave solar panels exposed in the field without at least making it hard for thieves.

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Enhancing decision making for sustainable development