

## **MAIN REPORT**

### **Diesel and Solar Powered Water Pumping Technologies**



November 1994

Jonna van der Krift  
Irene Visser

Delft University of Technology

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FOR COMMUNITY WATER SUPPLY AND  
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## CONTENTS

Preface	1
AMREF and ASAL	2
The diesel engine	3
The four stroke cycle	3
Maintenance	4
Pumps	6
The monopump	6
The submersible pump	7
The reciprocating pump	8
Solar energy	9
Solar water pumping	9
History of solar water pumping	9
Kenya	10
Technical description	11
Village water supply system	11
The photovoltaic process	13
The array	14
Performance	14
Useful hydraulic energy	14
The head	15
The Wattpeak	15
Operation and maintenance	15
PV pump types	16
Choosing your water supply system	18
Costs	19
Cultural aspects	20
Investigation questions diesel sites	20
Investigation questions solar sites	21
Results of diesel site visits	23
Results of solar site visits	26
The operator's training course	26
The Isinya course	27
Results	27
Recommendations	28
Workshop	28
Water sources in Kajiado District	29
Shallow wells	29
Nooltresh water pipeline	30
Environmental aspects	31
Solar companies- Total Solar	32
Solar companies- Davis & Shirliff	34



Enclosure I	Report diesel site visits	36
Site 1-	Ngatataek	36
Site 2-	Meto-Olmakau	37
Site 3-	Kumpa	38
Site 4-	Ngatataek- Ole Birisha	40
Site 5-	Olgulului- Ole Mangi	41
Site 6-	Lenkism	43
Site 7-	Imaroro	44
Site 8-	Bissel- Nkoile	46
Site 9-	Bissel- MOWD	47
Site 10-	Isinya	48
Site 11-	Kisaju	49
Site 12-	Kiserian	49
Site 13-	Esaikeri	51
Enclosure II	Report solar site visits	53
Site 1-	Kititwa Well	53
Site 2-	Embaringoi	54
Site 3-	Olgulglui- Primary School	55
Site 4-	Ipartimaro	57
Site 5-	Olooloitikoshi	58
Site 6-	Enkusero	59
Site 7-	Iltial	60
Site 8-	Enkii	61
Enclosure III	Literature	62
Enclosure IV	Explanation of abbreviations and Swahili words	63



## PREFACE

This report is part of the results of the study 'A Comparative Research of Diesel and Solar Powered Water Pumping Technologies in Kajiado, Kenya', that was carried out during the summer of 1994. The study was done by Jonna van der Krift and Irene Visser, both students Industrial Design Engineering at Delft University of Technology. Their task was to give an advice concerning the choice between diesel and solar powered water pumping systems. They gave this advice by means of a Decision Guide. The Decision Guide is a helping hand in making the choice.

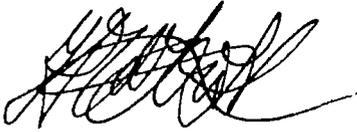
This report is complementary to the Decision Guide and contains background information. Used abbreviations and Swahili words are explained in enclosure IV.

The project has been carried out at AMREF, African Medical and Research Foundation, Nairobi, Kenya. This project has been realized thanks to the cooperation between CICAT, Centre for International Cooperation and Appropriate Technology, Delft, the Netherlands and AMREF, Kenya.

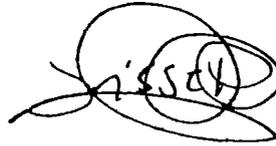
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Jonna van der Krift



Irene Visser



## **AMREF AND ASAL**

### **AMREF**

The African Medical and Research Foundation was started in 1965 as a one man organization providing curative services to remote areas in East Africa. Over the years AMREF has grown and evolved. Headquarters are situated in Nairobi but the organisation has dependences worldwide.

The main objective of AMREF is to contribute to the improvement of health care in East Africa by medical help, education and research. In the AMREF programme education, preventive and active health care, food, sanitation, birth restriction and research are emphasized, especially in Kenya and Tanzania.

### **ASAL**

ASAL, short for Arid and Semi Arid Lands, is a national project started by the Kenyan government and funded by foreign governments like The Netherlands, Sweden, Denmark and Great Britain. ASAL works together with line ministries as MOWD and MOAC and NGO's. The ASAL personnel is paid by the Kenyan government, projects are all funded.

The projects ASAL carries out are on a basis of cooperation with the community. Especially when water projects are concerned, the community has to collect a considerable amount of money herself. In principle, the community contributes 50 percent of the total costs. When the community is not capable of raising this amount or when it's really an emergency case, ASAL will pay more. To make people aware of the possibility to start projects with the help of ASAL, there is a special person who is supposed to travel around and provide information about this.

### **AMREF and ASAL**

In short: ASAL pays and AMREF does the job.

Concerning the borehole rehabilitation: This was initially an idea of ASAL. Melvin Woodhouse from AMREF raised a lot of money for the project so AMREF was able to buy a car and build the compound. Now ASAL is paying for materials (together with the communities) and AMREF provides the people with the knowledge. Diesel for the car is paid by AMREF, but in the future ASAL will contribute to these costs.

## THE DIESEL ENGINE

### The four stroke cycle

The diesel engine is an internal combustion engine. It produces power with four different up and down strokes of the piston, which is called a four stroke cycle.

1	'Suck'	Inlet stroke
2	'Squeeze'	Compression stroke
3	'Bang'	Power stroke
4	'Blow'	Exhaust stroke

The output of the engine is a rotating crankshaft, which can have a varying speed. This speed depends on the type of engine.

Diesel engines can be divided into water cooled and air cooled types. Other differences between the engines are mainly based on the difference in the number of delivered horsepowers.

In this research the diesel engines are usually Lister engines.

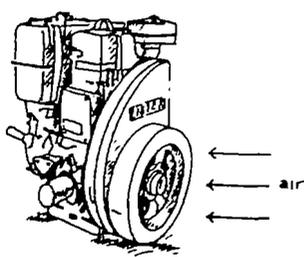
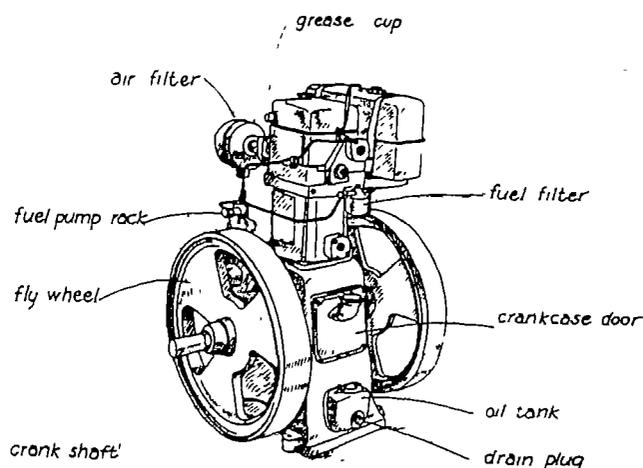
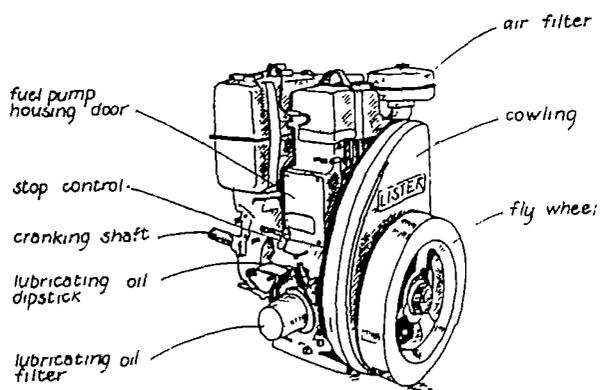


Figure 1- Air-cooled engine

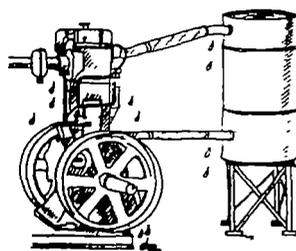


Figure 2- Water-cooled engine

### *Before starting the engine*

- 1 Check fuel level
- 2 Check oil level
- 3 Greasing parts, if necessary
- 4 If water cooled, check water level

### **Maintenance**

#### **Servicing the aircsystem**

Air is needed for combustion and in water cooled engines also for cooling. The servicing of the aircsystem consists mainly of cleaning and changing the airfilter. There are two different types of airfilters:

A Dry paper air filter: This one should be taken out every now and then and shaken to get rid of loose sand and dust. Every 250 hours it has to be replaced by a new one.

B Oil bath filter: This one should be washed with paraffin and refilled with oil to the proper level.

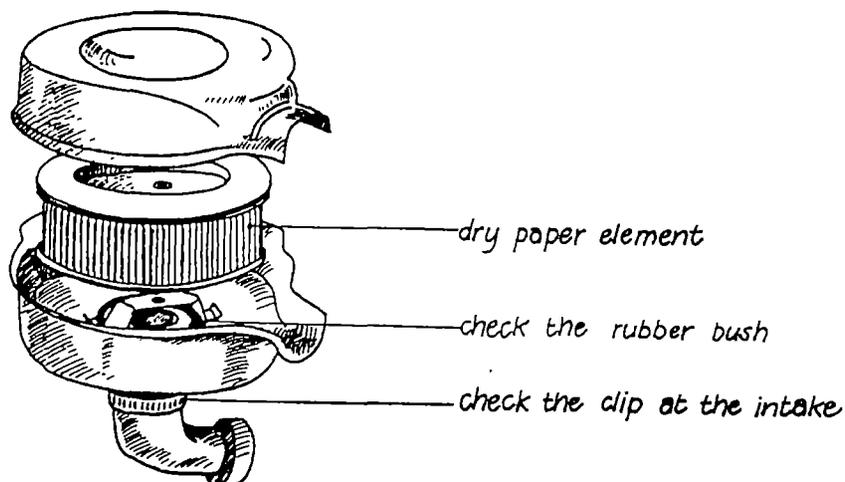


Figure 3- Dry paper air filter

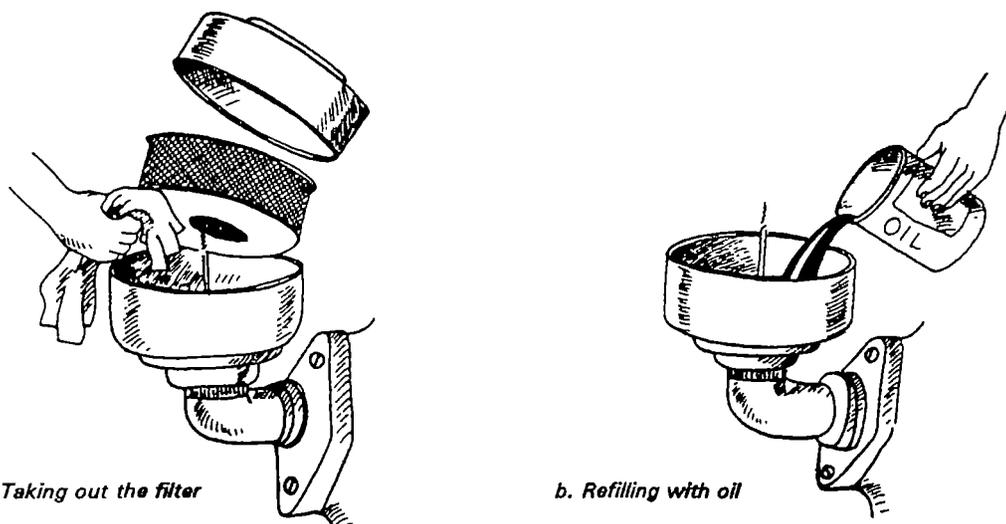


Figure 4- Servicing the oil bath filter

### Servicing the fuelsystem

Every 1000 hours of running, the fueltank has to be drained and the fuelfilter has to be changed. Check for fuel leaks and tighten if necessary.

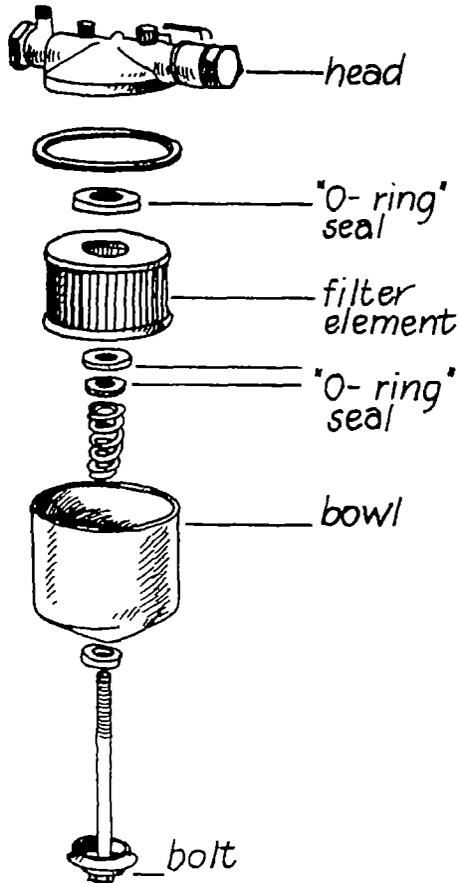


Figure 5- Changing the fuel filter

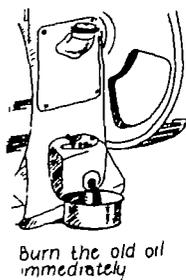
### Servicing the oilsystem

After every 250 hours of running the oil should be drained from the engine into a container and burned. This should be done shortly after the engine has stopped, when the oil is still hot and fluid.

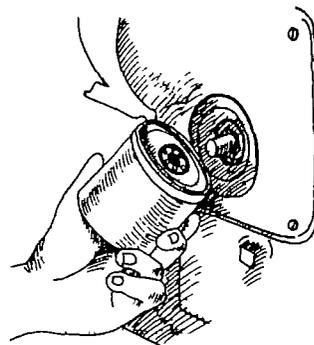
Water cooled engine: The oil strainer has to be cleaned with fuel.

Air cooled engine: The oil filter has to be changed.

The engine has to be filled with new oil.



The mesh oil strainer



Change the old oil filter

### *Other maintenance*

- \* Check nuts and bolts, especially those that fit the engine to the foundation block.
- \* Check the exhaust pipe, keep it clean. This can be done by tapping it to shake out dust and smoke particles or, when it is very dirty, heat it in a fire to burn out the residue.
- \* Check exhaust smoke, this should not be too dark or white.
- \* Keep the engine thoroughly clean.
- \* On water cooled engines, refill the grease cup. The waterhoses should also be checked, they should not be hard and cracked.
- \* If there is a clutch, grease it every 50 hours of running.

In order to pump water, the movement of the engine crankshaft can be used in two ways. It can be used to drive a generator, which produces electricity. It can also be connected to a mechanical pump. When the engine is driving a generator, the pump will either be a multistage submersible pump or a monopump. When the crankshaft of the engine is directly connected to a pump, the pump will be of the reciprocating type or a monopump. In the following these different types of pumps will be further explained.

## **PUMPS**

A distinction can be made between mechanical pumps and electric pumps. In this research two types of mechanical pumps and two types of electric pumps are found:

### *Electric pumps:*

- 1 Monopump
- 2 Multistage submersible pump

### *Mechanical pumps:*

- 1 Monopump
- 2 Reciprocating pump

An electric pump is driven by an electric motor. Possible energy sources are:

- A Electricity grid
- B Diesel driven generator
- C Solar energy

A mechanical pump is driven by the rotating movement of the crankshaft via a belt.

### **The monopump**

The rotary monopump (figure 6) can be powered both mechanically and electrically, so it can respectively be driven by a diesel engine or an electric motor.

The pump has three main parts:

- \* Discharge head
- \* Rising main
- \* Pump element

The discharge head is located immediately above the borehole. This is where the rotating movement, which makes the water come up, is generated. When a diesel engine is used as energy source, the discharge head is connected to the engine with a belt.

The water is lifted inside the rising main. Rubber stabilizers hold the raising main firmly in the borehole casting.

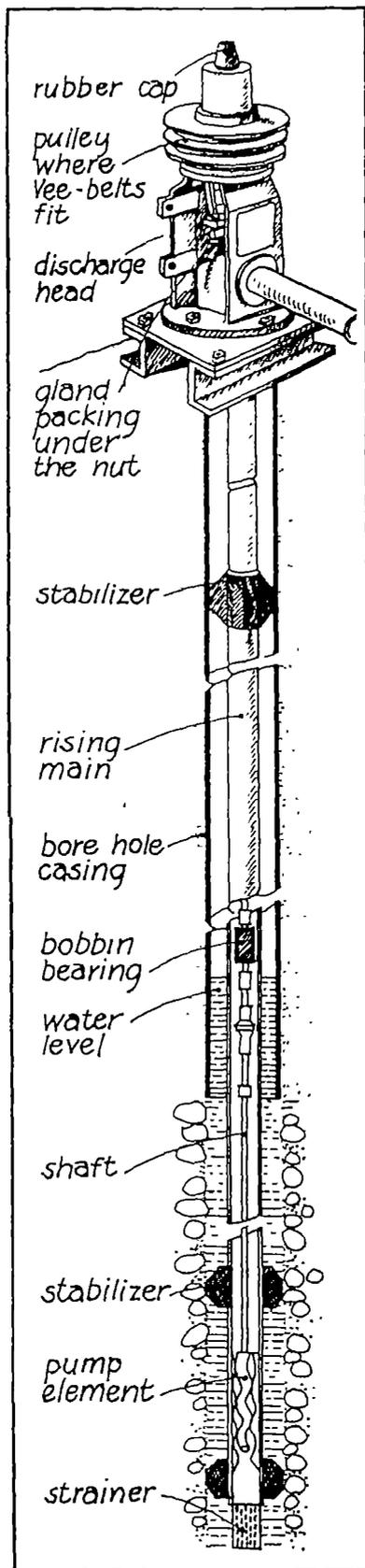


Figure 6- Mono pump

A turning movement generated by the pulley drives the pump element at the bottom end of the rising main. The pump element looks like a big screw, which turns up the water. A rotating axis is leading the turning movement down the borehole, of which the depth can exceed 100 meter. When electricity is used, the pump is driven by a DC electric motor. The electricity is generated by solar panels. When electricity is generated by a generator, it will be AC and usually used for a multistage submersible pump.

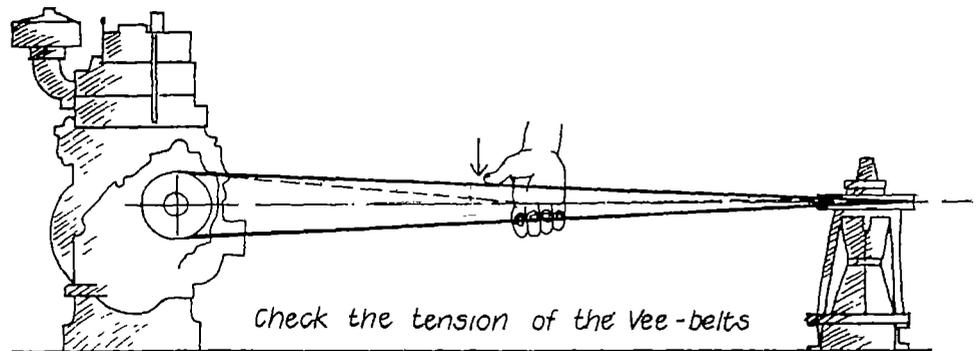


Figure 7- Connection engine and mono pump

### The submersible pump

Submersible pumps are centrifugal pumps. The principle of operation is that water enters at the center of the pump and a rotating impeller throws water outwards due to centrifugal force. The water outlet is on the outside of the impeller gravity and thus a pressure difference is created between the inlet and the outlet of the pump, which pushes up the water. All submersible pumps are multistage, which means that a number of impellers are connected. The outlet from one impeller feeds the centre of another, each one adding a further pressure difference. The capacity of the pump is determined by the number of stages.

A submersible pump is fed by a submersible AC motor, with which the pump is integrated. Electricity generated by solar panels is DC, so a DC-AC inverter is needed. This inverter also includes a piece of electronics which seeks the maximum power point, the MPP-tracker. When the pump works on DC, there is no inverter, so a MPP-tracker has to be built in. Another extra from the inverter is that it also provides the system with some control checks to prevent it from e.g. overload, underload, running dry and short circuit. The electricity has to be transferred to the motor through wires.

electricity has to be transferred to the motor through wires. This wiring is very expensive because of the high waterresistent requirements.

#### Reciprocating pump

The motor is placed on the ground and the pump is submersed in the borehole. The rotating movement of the crankshaft is turned into a reciprocating movement of the pump. These pumps are usually Lee Howls. The reciprocating pump is an old kind of pump and is not installed anymore.

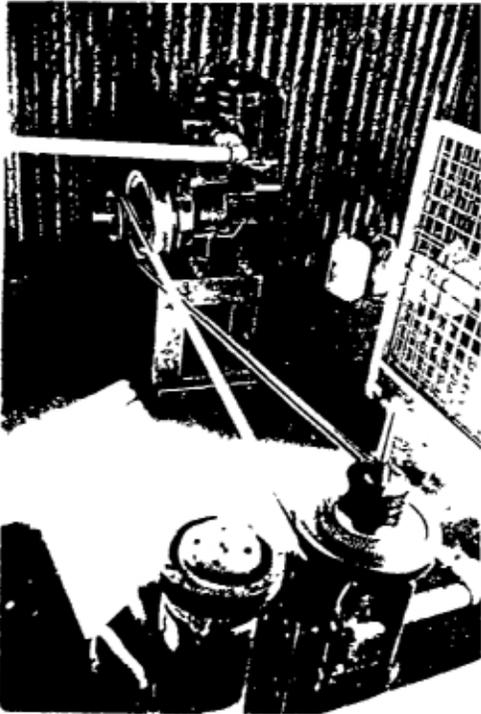


Photo 1- Mono pump

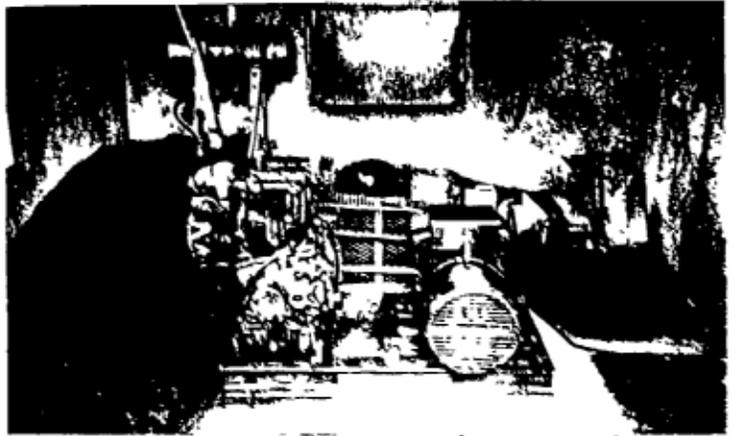


Photo 2- Diesel engine and generator for submersible electric pump

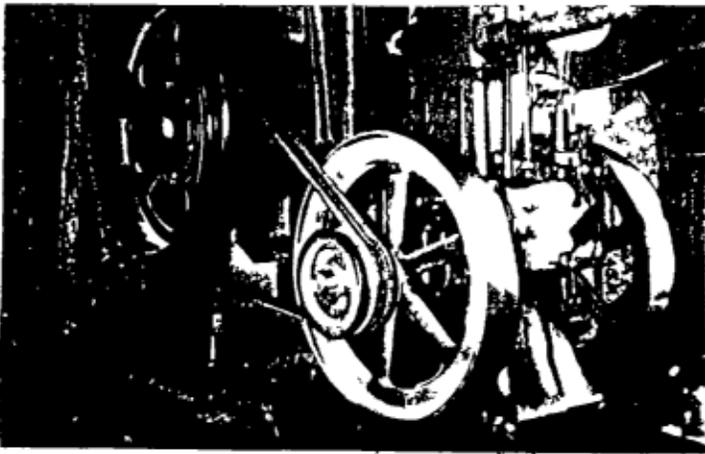


Photo 3- Lee Howl pump with diesel engine

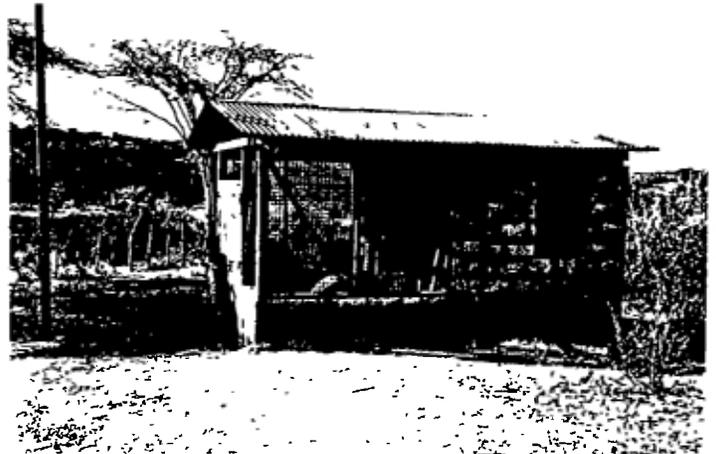


Photo 4- Borehole house- Imaroro

## SOLAR ENERGY

Solar energy is a so called renewable energy. This means that it doesn't harm the environment or waste valuable sources. There is no toxic waste, actually there is no waste at all. Other sources of renewable energies are wind and water.

Solar energy can be used in two ways. Mentioned applications are all relevant for (health care in) developing countries.

- |              |   |
|--------------|---|
| 1            | <i>The warmth of the sunrays</i> is used. This is also called 'solar thermal energy'  |
| Applications | refrigeration/freezing<br>water heating (e.g. warming houses)<br>steam sterilisation  |
| 2            | Photovoltaics or PV. This is based on the <i>generation of a difference in voltage</i> , which creates the possibility of connecting electric equipment. These systems work on the light produced by the sun. |
| Applications | lighting systems/portable lamps<br>refrigeration/freezing<br>radio and communications<br>water pumping<br>battery charging  |

A common misunderstanding about solar energy is the idea that a lot of sunshine is needed to make the connected equipment work. This is not true. For example: the energy of the amount of sunshine that, during one hour, reaches the earth surface of Kenya at noon, is equivalent to the energy being supplied by the country's electricity grid.

## SOLAR WATER PUMPING

The application of solar energy for water pumping is one that gets a lot of attention. The World Health Organisation has recently done a lot of research on the subject and plans are developed to install PV pumps all around the world in developing countries, in order to provide as many people as possible with drinking water.

### History of solar water pumping

A significant part of the early development of solar technology was concerned with water pumping. It actually started with a solar steam engine in 1878. In the 1970's many solar pumps were installed around the world. In 1978 the first PV pumps were installed and in the same year a team at the World Bank presented a programme to apply small PV pumps for irrigation on a huge scale. It was considered appropriate as having a severe impact on world food production.

As a result of these developments, the United Nations Development Programme (UNDP) provided funding for the Global Solar Pumping Project, to be executed by the World Bank. From then on, solar pumps were developed, tested and improved. Results of field testing indicated that there was indeed considerable potential for solar pumps. The UNDP and the World Bank

decided to continue the work to the point where really widespread demonstration could be contemplated. The final outcome is that PV pumps have evolved to be simple and reliable. A total of 10,000 has been installed, of which 30-40% are in developing countries.

It is estimated that there are over 1 million remote areas in the world (population over 200 persons) that need to pump water to sustain their existence. Most of them are located in hot, dry areas where the PV water pump can be an ideal solution.

## **Kenya**

The 1981 Nairobi UN Conference on New and Renewable Sources of Energy catalyzed interest in photovoltaic power amongst donors, the Kenyan Government and the private sector. Since then the solar market has grown rapidly. Initially it concerned mostly donor funded projects in telecommunication, water pumping and refrigeration. The private market has grown substantially since 1984. At present the market for 'domestic lighting systems' (which powers also television, radio, etc.) has grown to an approximately 60 % of the entire photovoltaic market in Kenya.

### *Markets*

The solar market consists of two main categories. First there are donors, NGO's and the government herself. Second there is the overall private sector, dominated by rural households. The local photovoltaic industry can also be divided into two sectors, both serving one of the main markets.

#### The donor market

Since the early 1980s solar has been used for a variety of development assistance purposes. This market is mainly served by companies with close relations to 'parent' solar companies. Contacts are in foreign currency and, because the projects are donor financed, equipment is not subject to sales tax or import duties. These companies are the suppliers of photovoltaic equipment for other companies operating on the private market.

#### The commercial market

Since 1984 more than 20,000 home units have been sold and installed in Kenya. The rapid growth of the private photovoltaic market occurred due to the following factors.

1. Rural customers choose photovoltaics because these systems are easier to access than grid power. Less than 3% of the power supplied by the Kenya Power and Lighting Company (KPLC) is consumed by rural customers whereas more than 90% of the Kenyans live in rural areas.
2. Competitive costs. Photovoltaics are often less expensive than grid connections or systems driven by generators.
3. Effective marketing and promotions. People learn about the systems through newspapers, radio, and see them at country trade fairs and in their neighbours' homes.
4. A strong desire for television in rural areas is one of the major driving forces behind photovoltaic sales.
5. The removal of taxes in 1986. This reduced the prices of PV products with 30-45%, and sales increased enormously. Unfortunately, the Government reintroduced taxes in 1991 and value added tax (VAT) on photovoltaic equipment. This, together with the recent devaluations of the Kenyan shilling have decreased the PV sales in the last three years. The present tax level on PV panels is 53 %.

Table 1- Estimated number of photovoltaic systems installed in Kenya- 1993

Application	No Installed	Estimated kWp	Customer
Vaccine refrigeration systems	450	90	Donors/NGOs
Home Lighting Systems	> 20,000	> 480	Private
Water Pumping systems	30-50	50	Donors/NGOs
	> 20	20	Private
2-way radio power supply	> 200	n/a	Government
Cathodic protection	> 3	n/a	Government
School/mission power and lighting systems	> 100	n/a	Donors/NGOs
Repeater stations	> 40	40-60	Government
Electric fencing	> 200	7	Government, private

Between 30 and 50 photovoltaic pumps have been installed in Kenya by donors and government since 1983. These supply water for villages, refugee camps and livestock watering points. To a lesser extent they are used to meet irrigation needs.

Four of the international PV companies located in Nairobi are:

- 1- Animatics Ltd
- 2- BP Solar East Africa Ltd
- 3- Kensid
- 4- Kenital Solar Electricity

## TECHNICAL DESCRIPTION

### Village water supply system

During the last ten years, solar water pumping systems have become a more or less industrially standardized configuration. This consists of (see figure 8):

- \* PV-array: an ensemble of PV-modules with their electric wires, together forming a generator. This converts sunlight directly into DC-electricity.
- \* Power regulator A three-phase transformer which transforms DC into AC.

- \* Electrical submersible centrifugal pump, connected to a threephase asynchrone motor.
- \* Storage tank in which water is pumped to be used on cloudy days or when the sun isn't shining at all.
- \* Tap, the actual distribution point.
- \* Distribution system, if any. Concerning our project, there is no further distribution of water.

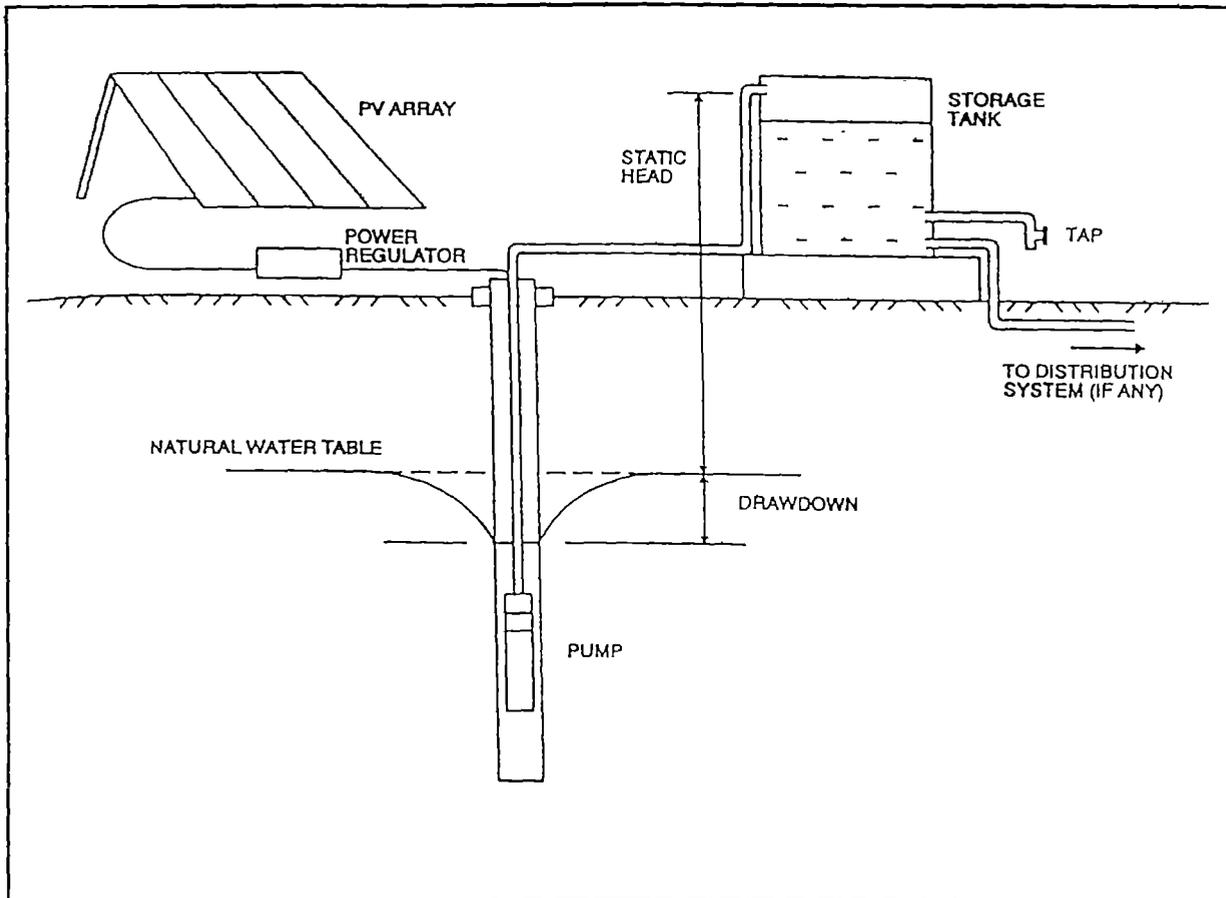


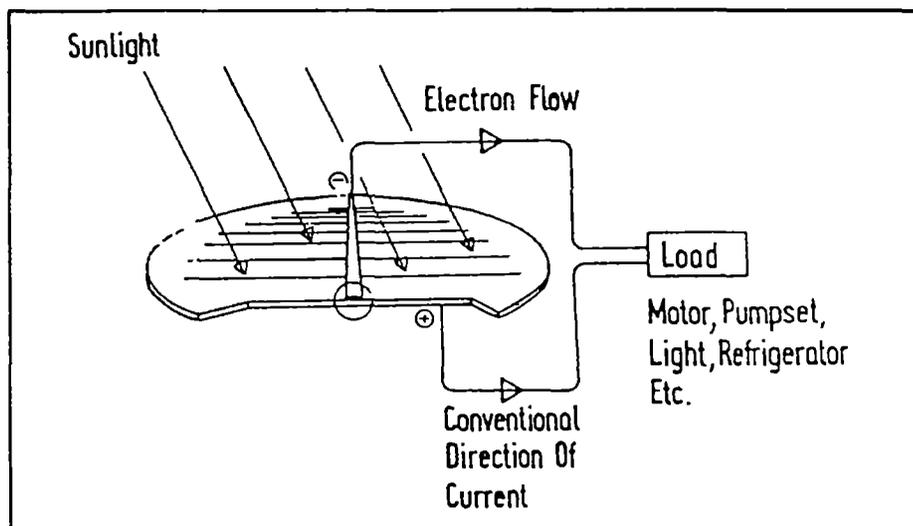
Figure 8- Components of a PV water supply system

The system functions very simple: The PV-modules deliver direct electric current to the transformator. This current is almost proportional to the insolation. The transformator transforms the direct current into alternating current and delivers this to the pump. This initiates the rotation of the motor, with a variable velocity, depending on the insolation and the manometric height. Finally, the PV-pump delivers an amount of water which is a direct function of the insolation and almost proportional to it. So the amount of water delivered is less in the morning, maximum at noon and diminishes to become zero in the afternoon.

With solar energy water is not available on demand. A storage tank is needed to build up some reserves on the sunny days for the more cloudy days.

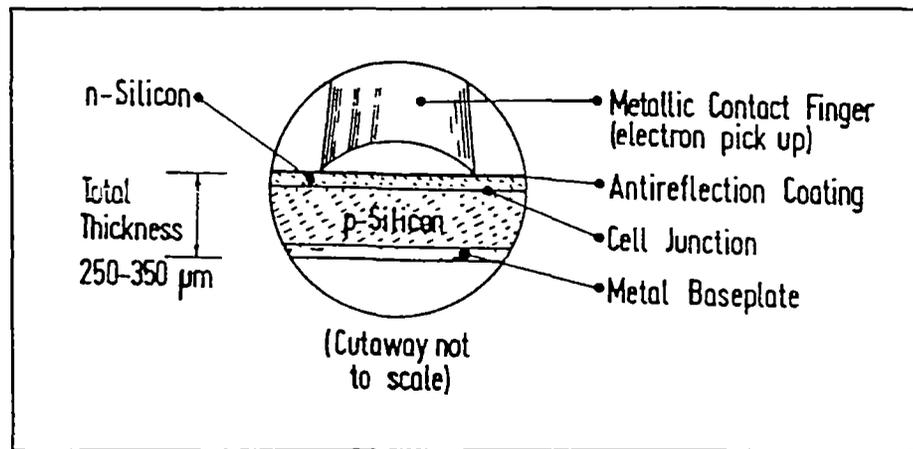
The photovoltaic process

The photovoltaic effect was first observed by the French scientist Becquerel in 1839. He noticed that when light was directed onto one side of a simple battery cell, the generated current could be increased. The first practical photovoltaic devices were selenium and cuprous oxide cells, used for photographic exposure meters and light sensors. Efficiencies, in light to electricity, of about 1 percent were achieved in the early 1940. It took until the late 1950s until crystalline silicon cells were developed with high enough efficiencies to be used for power generators.



When light falls on the surface of a PV array, the photons in a solar cell become energized, in proportion to the intensity and spectral distribution of the light. Solar cells are interconnected in series and parallel to achieve the desired operating voltage and current. When their energy level exceeds a certain point, a potential difference or open circuit voltage (Voc), is established across the cell. When an external load is connected to this circuit, produced by the total amount of solar cells in the PV array, a current will be driven through the circuit. This process is illustrated in figure 9.

Figure 9- The circuit generated by the sunlight



Most PV systems use silicon, mainly as monocrystalline or multi-crystalline cells, as the base material. The

Figure 10- Construction of a mono-crystalline PV module

different components of a mono-crystalline silicon cell are shown in figure 10. The most essential part is a thin wafer of a high purity silicon crystal, coated on a metal baseplate. Phosphorus is diffused into the active surface of the wafer. The front electrical contact is made by a metallic grid and the back contact usually covers the whole surface. An anti-reflective coating is applied to the front surface.

## The array

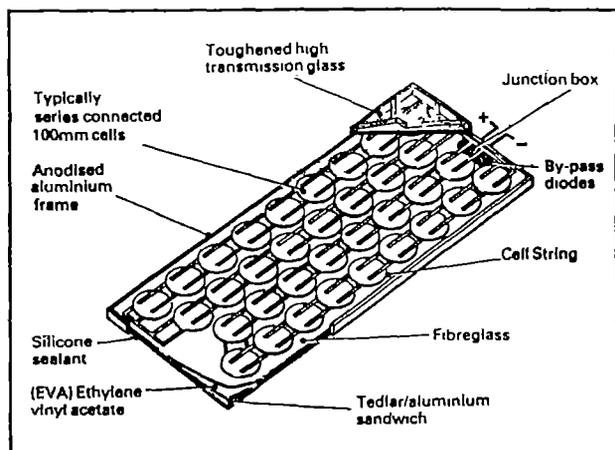


Figure 11- Construction of mono-crystalline PV-module

The required number of solar cells is encapsulated between glass and a tough resin back. This is all hold together by a stainless or aluminium frame to form a module. These modules form the basic building blocks of a solar array. Modules can be connected in series or parallel to achieve the required solar array characteristics. The number of modules required depends on the quantity of water demanded.

## PERFORMANCE

### Useful hydraulic energy

The performance or capacity of a solar pump is defined as useful hydraulic energy. It is expressed in  $m^4/day$ , for a given daily insolation. The insolation is a measure for the amount of sunshine expressed in  $Watt\text{hour}/m^2/day$ . This is the total solar energy received by one square meter, on the horizontal surface, in one day. The  $m^4$  is the volume ( $m^3$ ) which is to be pumped, multiplied by the height (m) over which the water is to be pumped. The volume of water to be pumped can be determined globally from table 2. An important factor that should be taken into account is the generally known fact that better water supply systems consequently lead to a higher water demand. The less effort it takes to get water, the more water is used.

Table 2 - Water requirements for various purposes

Use	Daily requirement
<b>Domestic</b>	
minimum for survival	5 l/person
water carried home from distant communal supply	10 l/person
water carried home from nearby communal supply	30 l/person
one tap in each house	50 l/person
multiple tap connections	200 l/person
<b>Livestock</b>	
cattle	35 l/head
horses, mules and donkeys	20 l/head
sheep and goats	5 l/head
poultry	25 l/100
pigs	15 l/head
<b>Irrigation</b>	
including conveyance and field application losses	5 to 10 mm or 50 to 100m <sup>3</sup> ha

### The head

The term 'head' is a common one when dealing with solar energy. The height over which the water is pumped is called the static head. Besides the static head, which is easy to measure, there is the dynamic head. The dynamic head is due to the increased pressure caused by friction of the water through the pipework. It is expressed as an equivalent height of water and can be calculated from the flow rate, pipe size and pipe materials. Smaller pipes and higher flow rates produce a greater dynamic head. The total head is the sum of the static and dynamic head. This head is necessary to calculate the hydraulic energy requirement, to which it is proportional. It is cheaper to pump through lower heads.

### The Wattpeak

Every module is able to supply, under standard conditions concerning insolation and temperature, with an electric power, by which it is characterized. This is the power-peak, expressed in Wattpeak (Wp). The capacity of the entire generator is equal to the sum of the capacities of the modules of which it consists. The useful hydraulic energy depends on the power-peak (Wp) of the solar pump and climate conditions. As a first approximation, one can consider the hydraulic energy proportional to the insolation and the number of Wp.

To calculate the dimensions of a system to build, one can, besides the required amount of water, handle the following general rules:

- \* 1 Wp is enough to deliver 0,55 m<sup>4</sup>/day for an insolation standard of 6000 Wh/m<sup>2</sup>/day (=6 kWh/m<sup>2</sup>/day).
- \* With solar pumping, a daily demand varying from 300 till 2000 m<sup>4</sup> can be satisfied.

#### *Example:*

- \* 1 solar pump, consisting of 32 modules van 50 Wp has a total of 1600 Wp.
- \* This pump is capable of delivering 0,55 \* 1600 = 880 m<sup>4</sup>/day.
- \* This can be a daily volume of 44 m<sup>3</sup> from a depth of 20 m or 22 m<sup>3</sup> from a depth of 40 m.

### OPERATION AND MAINTENANCE

Solar systems need very little maintenance. The PV arrays should be kept clean by wiping them with a wet cloth. Once a week will do, but once a day would be ideal. When the arrays are dirty, it effects the capacity of the system. Bolts and electrical components should be checked for tightness periodically and lubricate moving parts as required.

When a PV pump breaks down, however, there is a big chance that a specialist is needed to repair it. This is contradictory to diesel pumps. These usually can be repaired in the local workshop by local people. The PV technology requires more detailed knowledge and a greater accuracy, simply because the system is more complex. It consists of more and smaller parts, which have to be assembled exactly.

## PV PUMP TYPES

Solar pumping systems are broadly configured into five types as described below.

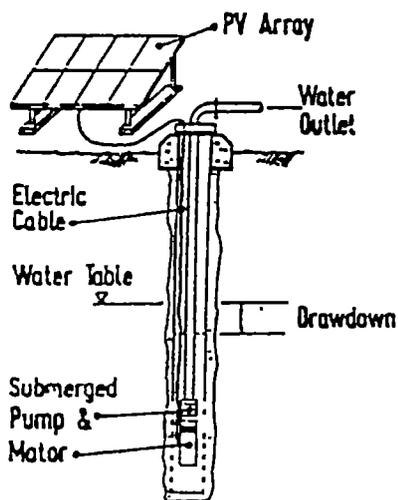


Figure 12- submerged centrifugal pumpset

### 1 Submersed multistage centrifugal motor pumpset

The pumpset consists of an integrated submersible pump and motor. This type is probably the most common type of solar pump used for village water supply. The advantages are that it is easy to install, often with lay-flat pipework and the motor pumpset is submerged away from potential damage. Either AC or DC motors can be incorporated into the set, although an inverter is needed for AC systems. In the case of a brushed DC motor the equipment will need to be pulled up from the well to replace the brushes. This would have to be once every two years. When brushless DC motors are used electric commutation will be necessary. The most commonly employed system consists of an AC pump and an inverter with a PV array of less than 1500 Wp. Submersible pumps are very common in the field, since they are also widely used in combination with a diesel driven generator. With both diesel and solar electricity needs to be transferred from the surface powersource

(generator or PV array) to the submersible motor through wires. This wiring is extremely expensive because of the high waterresistant requirements.

Submersible pumps are centrifugal pumps. The principle of operation is that water enters at the center of the pump and a rotating impeller throws water outwards due to centrifugal force. The water outlet is on the outside of the impeller gravity and thus a pressure difference is created between the inlet and the outlet of the pump, which pushes up the water. All submersible pumps are multistage, which means that a number of impellers are connected. The outlet from one impeller feeds into the centre of another, each one adding a further pressure difference. The capacity of the pump is determined by the number of stages.

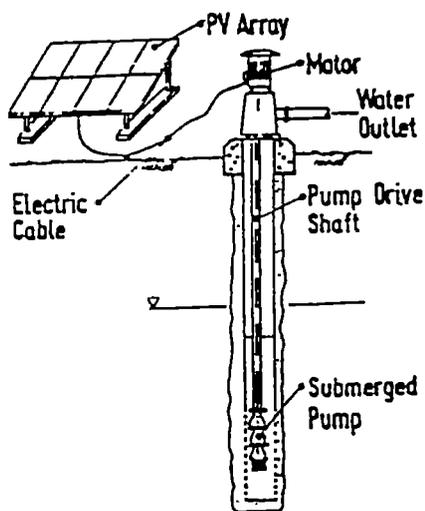


Figure 13- surface motor - submerged pump

### 2 Submerged pump with surface mounted motor

This configuration gives easy access to the motor for the change of brushes and other maintenance. Disadvantages are the low efficiency caused by power losses from the shaft bearings due to fibration and friction, and the high costs of installation. A very common type of these pump is the rotary mono pump. The rotary mono pump can be driven by a diesel engine or an electric motor (fed by a PV array). The pump can be powered both mechanical and electrical. When diesel is used, the pump is driven mechanically, the rotating movement of the diesel engine is direct used to empower the pump. When solar is used as energy source, the pump is driven by a DC electric motor. An inverter is not needed since the electricity produced by PV panels is DC. The pump has three main parts: the discharge head, rising main part and the pump element.

The discharge head is located immediately above the borehole. Here the rotating movement, which makes coming up the water, is generated. The water is lifted inside a rising main. Rubber stabilizers hold the rising main firmly in the borehole

casting. A turning movement generated by the pulley drives the pump element, at the bottom end of the raising main. The pump element looks like a big screw, which turns up the water. A rotating axis is leading the turning movement through the whole depth of the borehole, which can exceed 100 meter.

### 3 Reciprocating positive displacement pump

This type is also known as the jack pump or nodding donkey. It is very suitable for high head, low flow applications. The output is proportional to the speed of the pump. At high heads the frictional forces are low compared to the hydrostatic forces, often making positive displacement pumps more efficient than centrifugal pumps. This pump creates a cyclic load on the motor which, for efficient operation, needs to be balanced. Hence the components of the pumps which are above the ground often are heavy and robust and power controllers are often used for impedance matching.

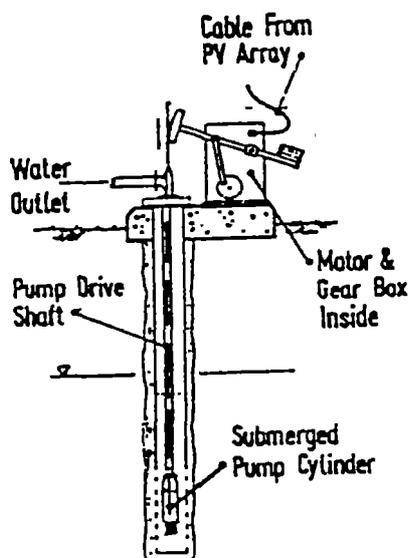


Figure 14- positive displacement pump

### 4 Floating motor-pump sets

This type is ideal for irrigation pumping from canals and open wells because of the versatility of the floating unit set. The pumpset is portable and there is a negligible chance of the pump running dry. Most of these pumpsets use a single stage submersed centrifugal pump. The most common type is provided with a brushless (electronically commutated) DC motor. The solar arrays are often mounted on wheels to allow easy movement. This design is not suitable for borehole pumping.

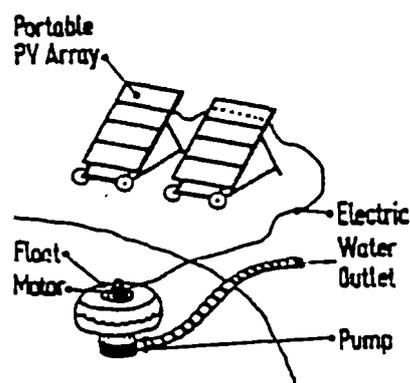
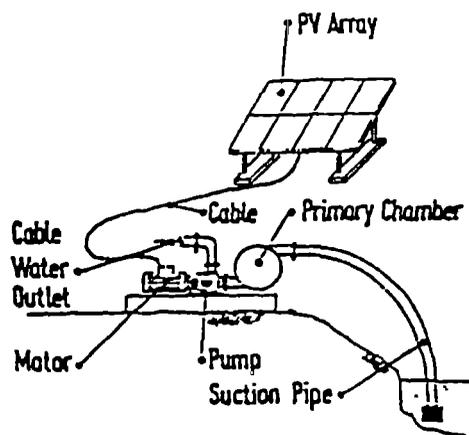


Figure 15- floating motor-pump

### 5 Surface suction pumpsets

Only when an attendant is present all the time, this type of pump is recommended. Although the use of priming chambers and non-return valves can prevent loss of prime, self start and priming problems are experienced in practice. It is impractical to have static heads of more than 8 metres.



When you are dealing with very high heads and volumes only the first two types of pumps can be used. The Kajiado circumstances makes only these types of pumpsets suitable.

### CHOOSING YOUR WATER SUPPLY SYSTEM

It is technically possible to use a solar pump in all applications where an electric pump can be used. Therefore, the assessment of viability centres on the question of costs. When deciding on a power source for a water pumping system there are several basic factors that should be taken into account.

Figure 16- Surface suction configuration

- 1 What is the minimum average monthly solar radiation in kWh/m<sup>2</sup>/day (H).<sup>\*)</sup>
- 2 Daily average water requirement by month in cubic metres per day (V). See table 1, page 9.
- 3 Water table depth in metres (d). This should be specified per month, when there is a seasonal variation.
- 4 The total lift (h) which is the sum of water table depth, tank height and the expected lowering of the well water due to pumping (well draw-down). This is the *head* (page 9).
- 5 The average volume-head product in m<sup>4</sup>/day, which is h\*V. (Useful hydraulic energy, page 8).

<sup>\*)</sup> This is called the design month. It is the month during which the insolation is the lowest.

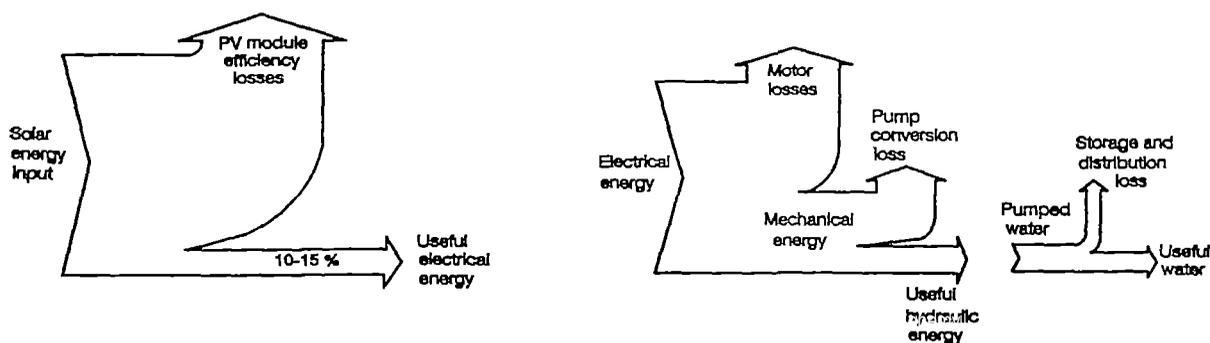


Figure 17- Scheme of energy flows in a PV pumping system

When the above questions are answered, the system can be dimensioned. A very important point that should be considered is the fact that the efficiency of the system is not very high. Figure 5 shows the schematic energy flows in a solar pumping system. The final efficiency of the entire system is about 4 to 6%.

## COSTS

The calculation of the costs of a solar pumping system is not a very easy thing to do. There are two reasons for this. First, the specification for each pumping system depends very much on the characteristics of the site, so it is not possible to perform a life-cycle costing for a general case and definitely say that solar pumping will be the most effective alternative in a certain situation. Second, the calculation does not only include the costs of purchasing and installation of pump, well and tank. It also includes all future maintenance and components replacements costs. These future costs should be multiplied by discount factors to account for the expected changes in the value of the money.

There is also a difference in who's paying. For most developing projects much of the capital costs have to be provided in the form of grants or other financial assistance. This will usually cover the purchase and installation of the system. The remaining costs, such as maintenance operating costs, must be paid by the community and they will almost certainly have to take out a loan. Therefore, the crucial factor to the users is not the lifetime economics, but the cash flow from year to year.

Because there can not be given any standard prices for pumping systems, we'll only give some rough indications. A separation can be made between system costs and PV modules costs. As one can see in the examples, the system costs can vary quite a bit. The costs of PV modules have been steadily falling the past two decades, as can be seen in figure 11.

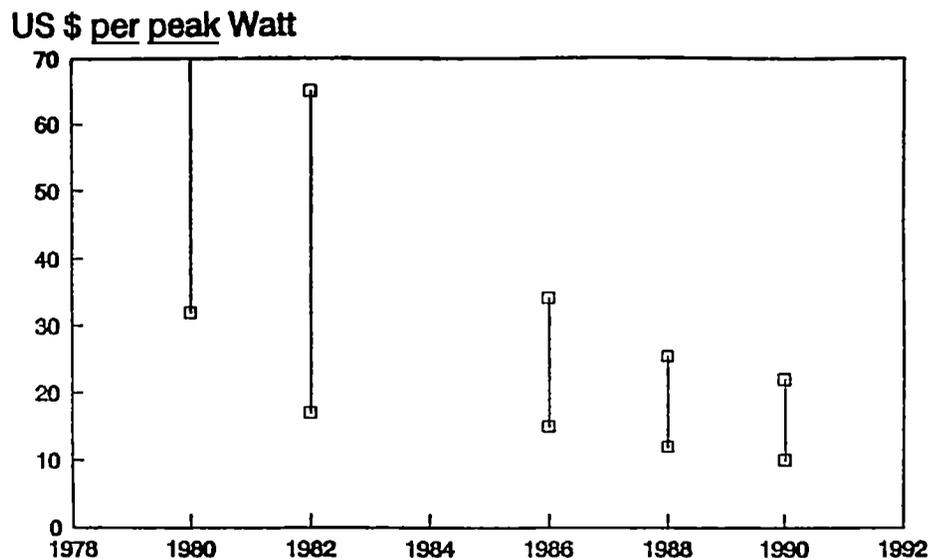


Figure 18- PV modules price history

The total life-cycle costs are expressed as costs per year or as costs per m<sup>3</sup>.

## CULTURAL ASPECTS

Many NGO's, governments and donor organizations are interested in the application of solar energy in developing countries. They are attracted by the facts that after installation the use is free, there is no pollution and little maintenance is required. But there are some aspects that should be taken into consideration. The choice for solar energy can not only be made on technical grounds. One has to take into account that not all people think in the same way and western theories and uses can not be implemented in developing communities without certain preparations.

The most important thing is the participation of the community in the decision to purchase, in the actual purchase and in the installation of a system. When the members of the community take part in these activities, they will feel concerned with the system and will show responsibility towards it. This means that they will take care of it and when it breaks down, they will make sure that the system will be repaired. When a donor finances a system without participation of the people, it is very likely that the people won't feel responsible for the system. When it breaks down or when parts of it are stolen, nothing will be undertaken to have it repaired or replaced.

Another important factor is information. Solar energy is not a common technology. Diesel engines, for example, are often used for various purposes like cars and posho mills. This means that there are workshops and a lot of people who know how to repair a diesel engine. It is sometimes assumed that people in developing countries are afraid of solar energy or that they cannot trust it because it is very different from what they know. This is not true. The fact is that they don't understand the technical principle, but they do trust it. Because it is an unknown technology it is hard to find a mechanic who knows how to repair it. When the people that are provided with water from a solar powered borehole are well informed on how to get along with it, there don't have to be any cultural problems with the use.

## INVESTIGATION QUESTIONS DIESEL SITES

- 1 SITE
  - 1.1 Description of the natural surroundings.
  - 1.2 Is the pump in working order. If not, why.
  - 1.3 What type of motor, pump, equipment is used.
- 2 PURCHASE
  - 2.1 Who has paid the pumping system.
  - 2.2 Who's initiative was it to buy a pump.
  - 2.3 Was there any involvement of the local people in the decision to and actual purchase of a pump.
  - 2.4 Who has specified the pumping system.
  - 2.5 Who was the supplier.
  - 2.6 How is equipment distributed and from where is it distributed.
- 3 INSTALLATION
  - 3.1 Who has been in charge of installing the pump.
  - 3.2 Who actually installed the pump.
  - 3.3 Did anybody check to see if the installation had been

- done properly.
- 3.4 Are necessary tools available at the site or nearby.
- 4 USE
- 4.1 How many people are authorized to operate the pump.
- 4.2 How many people/heads of cattle/smallstock are depending on this water source.
- 4.3 Are these people paying for the water they take.
- 4.4 Are these people paying for the diesel used by the engine or do they take it with them.
- 4.5 Where do people or where does the operator get the diesel. For which price.
- 4.6 Which actions are necessary before water is obtained.
- 4.7 Are there any difficulties in understanding these actions.
- 4.8 Is there any relation between these actions and damage or breakdown of the equipment.
- 4.9 Are there any facilities for water distributions, like storage tanks, drinking troughs for cattle or a distribution system.
- 5 MAINTENANCE AND REPAIR
- 5.1 Which are the necessary actions regarding maintenance.
- 5.2 Who is responsible for these actions.
- 5.3 Did this person/these persons get any training.
- 5.4 Which actions are performed by this responsible person and for which kind of maintenance or breakdowns is a mechanic required.
- 5.5 Are there any common spareparts available at the site or nearby.
- 5.6 Who is paying for spareparts and maintenance.
- 6 OUT OF ORDER
- 6.1 Who decides that the pump cannot be repaired and should be taken to the workshop.
- 6.2 What happens if a pump or engine breaks down.

## INVESTIGATION QUESTIONS SOLAR SITES

To make a thorough choice between the described systems, we should find an answer to the following questions:

- 1 SITE
- 1.1 Description of the natural surroundings.
- 1.2 Description of pump and further present equipment.
- 1.3 Is the pump in working order.
- 1.4 If not in working order, why.
- 1.5 What is the level of the groundwater.
- 1.6 What type of pump/motor/equipment is used, any special data.

## 2 PURCHASE

- 2.1 Who is paying for the pumping system.
- 2.2 On who's initiative is new equipment bought.
- 2.3 What's the involvement of the local people in the decision and purchase process.
- 2.4 Who is deciding which type of pump/equipment is purchased.
- 2.5 Who's the supplier.
- 2.6 How is equipment distributed and from where is it distributed.
- 2.7 Is there any knowledge about pumping available, is there anybody who can be considered a specialist.
- 2.8 If any knowledge is available, how recent are these data.

## 3 INSTALLATION

- 3.1 Who is in charge of installing the pump.
- 3.2 Who actually installs the equipment.
- 3.3 Does anybody check whether the installation has been done properly.
- 3.4 Are necessary tools available at the site or nearby.

## 4 USE

- 4.1 How many people are authorized to operate the pump.
- 4.2 How many water is pumped per hour and per day.
- 4.3 How many people are depending on the water supplied by the pump.
- 4.4 Are these people paying for the water used.  
Are they paying for the purchase and installation of the pump, or for the water used.
- 4.5 If water is used for cattle also, for how many cattle.
- 4.6 Which actions are necessary before the water is obtained.
- 4.7 Are there any difficulties in understanding these actions.
- 4.8 Is there any relation between these necessary actions and damage or breakdown of the equipment.
- 4.9 Are there any facilities for water distributions, like storage tanks, water distribution systems, or drinking throughs for cattle.

## 5 MAINTENANCE AND REPAIR

- 5.1 Which are the necessary actions regarding maintenance.
- 5.2 Who is responsible for these actions.
- 5.3 Is there any training given to people in charge of the system.
- 5.4 Which actions are performed by the local responsible person and for which kind of maintenance or breakdowns a mechanic is required.
- 5.5 Are there any necessary spare parts available.
- 5.6 Who is paying for spareparts and maintenance.
- 5.7 Are there any local workshops where parts can be repaired or made.
- 5.8 Which parts can be repaired or replaced locally.

- 5.9 If this can't be done locally, where is it done or where does a mechanic come from.
- 6 OUT OF ORDER
- 6.1 Who decides that a broken pump is not suitable anymore for repair.
- 6.2 What happens usually when a pump breaks down.
- 6.3 Are broken pumps disassembled and are parts used again.
- 7 SOLAR ENERGY
- 7.1 For which applications solar energy is used.
- 7.2 Are there any local persons who are familiar with solar energy.
- 7.3 Are they involved in the installation of PV pumping systems in Kajiado District or other parts of Kenya.
- 7.4 Are there any PV systems used for water pumping in other districts.
- 7.5 How are other solar pumping projects organized and what are the specifications of these systems.
- 7.6 If solar energy is used for any purpose, which are the known (dis)advantages.

## RESULTS OF DIESEL SITE VISITS

Of the ten sites that have been visited, 7 are community owned and 3 are owned by the County Council, the Ministry of Water Development, the National Water Conservation or a combination of these. All boreholes are communally used. At all the sites the borehole operator was interviewed, using the list of questions that is included elsewhere in this report.

The following results were found.

### Community owned boreholes

*Fuel:* At three sites the members of the community contribute money, so the operator or someone from the committee can buy diesel. At four sites the community members take their own diesel to the borehole.

*Money for maintenance, repairs and operator's salary:* At six sites the people from the bomas have to pay a monthly amount, usually based on their number of cows. When the money is not sufficient, a harambee is organized. This is a collecting of money. At one site there were no monthly payments. Everytime money was needed, a harambee was organized.

*Operator's salary:* This varies between Ksh 1000,- and Ksh 1500,-.

*Organization:* All communities have a borehole committee.

### CC/MOWD/NCW owned boreholes

*Fuel:* At one site the people contribute diesel, at the two other sites they pay money to the organization that owns the borehole.

*Money for maintenance, repairs and operator's salary:* At one site, the same site as where the people contribute their own diesel, monthly amounts are paid to the borehole committee. At the other sites, there is no committee and the money is provided by the owner.

*Operator's salary:* Varying from Ksh 2400,- to Ksh 2500,-.

**Organization:** At the site with the committee, the committee takes care of the organizational matters of the borehole. At the other sites, the owners arrange everything. There is no input from the community.

Basically it can be concluded that the community owned boreholes are performing average to good. The CC/MOWD/NCW owned boreholes are in a bad to average condition.

#### **Characteristics of a well run diesel borehole**

- \* Community owned
- \* Borehole committee
- \* Contribution of money instead of diesel
- \* Monthly contributions per boma and based on number of cows
- \* Administration kept by operator and by committee

#### **Characterisitcs of a badly run borehole**

- \* CC/MOWD/NCW owned
- \* people pay monthly and everything is arranged
- \* a lot of outstanding maintenance

## Summary of data collected at diesel sites

Site	bh depth	eng	pump	owner	contrib. Diesel	Ksh/cow/mth	salary operator Ksh
1 Ngatataek		ST2	SP	comm	yes, depending on amount of cattle	100 / boma / mth	1000.-
2 Meto-Olmakau	96	TS3	SP	comm	no	? / cow / mth	1500.- + 800.- watchm
3 Kumba		TS2	SP	comm	no	20 / cow / month	1000.-
4 Ole Birisha		SR2	LH	chief	yes, per boma	in case of repairs	-(sons chief
5 Olgulului Ole Mangi			MP	comm	no	per boma, not fixed	?
6 Lenkism	77	6/1	LH	CC	yes, dep. amount of cattle	2 / cow / month	2500.-
7 Imaroro	100	TS2	SP	comm	no	6 / cow / month + periodical extras	1000.-
8 Nkoile		YAN	MP	comm	4 l for every boma	50 / boma / month + extra for repairs	1200.-
9 Bissel		HR2	SP	MOWD	no	100 / boma / mth to mowd	?
10 Isinya			MP	NWC			2400.-

Site	bomas fam.	cows	small stock	V required m <sup>3</sup>	V pumped m <sup>3</sup> l/u	oper. hours	l diesel used
1	12b	6000	12000?	171	7 m <sup>3</sup> /u		
2	60f	2000	4000	64	72 9.0	8	18.5
3	20f	3000	6000	86	5.8	15	23
4	5b	3000	6000	85	4.8	18	25
5	14b	2100	4200	65	?	11	10
6	20f	1260	2500	38	33 37	9	9
7	10b	1400	2800	44	58 5.8	10	15
8	24f	3000	6000	86	?	14	10
9	pipe-lines				130 10.9	12	25
10	pipe-lines					8	

## RESULTS OF SOLAR SITE VISITS

Eight solar sites have been visited. Five of these were communally used, three by an institution. The financiers were:

- \* MOWD - 4 times, in some cases in cooperation with RDF or GTZ
- \* Friends of Amboseli - 2 times
- \* Kenya Wildlife Service - 1 time
- \* ASAL-programme - 1 time

The decision to install solar instead of diesel was always made by the donor, never by the community. In the cases of institutional use the water pumped by the system was always sufficient, in case of communal use never.

For the cleaning of the panels was found:

- \* At one site the panels were never cleaned.
- \* At two sites the users found out themselves that it was necessary to clean the panels.
- \* At the other five sites they cleaned the panels averagely 3 times a week.

At half of the sites a watchman was employed. Four of the eight systems were not in working order. This was caused once by a breakdown of the pump and three times by the fact that the panels were stolen.

Characteristics of sites with stolen panels:

- \* Financed by MOWD or MOWD/RDF.
- \* There was no watchman.
- \* Two times community, one time a school.
- \* No action was undertaken to have the panels replaced.

## THE OPERATOR'S TRAINING COURSE

For good functioning boreholes it is important that the operators know how to handle and maintain the engine and pump. Four years ago ASAL noticed the lack of trained operators in Kajiado District and came with the idea to organize an operator training course.

The first course was organized in 1992 in Isinya by Moses Mwangi from ASAL, in collaboration with AMREF. ASAL organized 3 courses, the last one was mainly organized by AMREF.

The first three courses were very successful. They took place in Isinya. People were selected and personally invited to attend the course. This 'selection' was rather random, Moses Mwangi, ASAL, travelled through the district talking to operators and committees to convince them to join the course. Every course was attended by about 20 participants. About 80 % of the invited persons showed up, so more people had to be invited. The course was free for the participants. Food, accommodation and transport were arranged for and paid. Mr Mwangi talked only once to the selected operators. He informed them about the start date, time and place and they came to the course by themselves. At the last course in Ngong, people were not personally invited. A letter was spread among the operators. Very few operators replied to this letter and even less showed up at the course. A misunderstanding was that in the letter was asked for two participants per borehole to attend the course. Some communities had only one suitable candidate, but they thought they had to send two, so they decided not to send anyone at all (this happened at Olgulului- Ole Mangi borehole). Another problem with written invitations is that a lot of operators are not able to read.

### **The Isinya course**

The course took 5 days. The participants were accommodated in Isinya. For three days they attended 'classes' in Kajiado in the mornings and they visited 'sites' in the afternoons. All operators got a brief introduction on all types of pumping technologies. They were told how a borehole house had to look and were taught some basic administration skills. Two days were spent in the GTZ workshop, Nairobi. Here, all types of pumps and engines are present. The operators were taught using working models and pictures of how to operate and maintain the engine and the pump.

To give the course an official look, the course was finalized by an exam. The candidates had to enter a room where the 'examinators' asked them some questions and told them to perform some operating or maintaining tasks. All the participants were given a certificate.

The courses were organized both in the dry and the rainy season. The difference was that during the rainy season the participants were less in a hurry to go back to their engines. This made them more motivated to follow the course. The course took one more day in the rainy season.

The participants were mainly operators. The borehole administration and management is mainly done by the borehole committee. We think it is important that they are aware of the importance of a good maintained borehole for a longer life since they are the ones who control the money. This committee members are respected 'wazee' and an other wayhas to be found to train them.

There has not been an official evaluation of the performing tasks of the operators after the course. Mr Mwangi was very content with the concept and thinks that the operators' skills have improved a lot.

Remarks: CC and MOWD owned boreholes are considerably worse organized than the community owned boreholes. With the first the course didn't make a big difference. Higher salaries will not improve their skills either, since the CC will pay them anyway no matter in which condition the borehole is.

After the first course a report has been written by Melvin Woodhouse, AMREF. This report contains the initial goals, results and some recommendations.

Operator knowledge and performing goals after the course:

- \* Basic knowledge of all types of engines and pumps, used in Kajiado District.
- \* Knowledge of the requirements of a good borehole house.
- \* To understand the diesel four stroke engine.
- \* To be able to perform basic maintenance tasks.
- \* To be able to record and schedule maintenance tasks and keep administration of used amounts of materials and fuel.
- \* To make up some ideas according to the borehole management.

### **Results**

- \* It is not good to let people bring their own diesel, because you get a mixed quality of diesel in the engine and the chance exists that the engine runs dry, because people want to see their own diesel finished. Every time the engine runs dry, it has to be bled, which causes unnecessary wearing out of parts.
- \* The job of an operator is a full job. During the rainy season the operator must perform maintenance tasks on the engine and the site.

- \* The motivation of the *committee* is much bigger during the dry season. During the wet season they are acting as if they are on leave.
- \* Some dissatisfaction exists among the communities about the difference between the estimated costs and the real costs companies charge for repair.
- \* The course must be lengthened to come to better results.

### Recommendations

- \* A borehole operator handbook has to be written.
- \* A maintenance chart suitable to hang in the borehole house, like a wall poster, on which the operator can note maintenance tasks, running hours etc.
- \* A training methodology for borehole committee members must be designed.
- \* A shop in Kajiado where spare parts and oil will be sold.
- \* Supply the operators with all the necessary tools for maintenance and operating.
- \* The encouragement of local electrical and mechanical repair facilities.
- \* Monopumps appear to be very reliable. A suggestion for future replacements.

### WORKSHOP

The workshop where broken engines and pumps from Kajiado District are taken to is located in Nairobi. We visited this workshop on Tuesday, 26th of July. There are no workshops in the District, so all equipment broken down has to be taken to Nairobi. The workshop has three functions. First of all it is the place where equipment is repaired. Second, it is a place where handpumps are manufactured and third, it is a centre for training the Maasai diesel engine operators.

#### The repair function

The workshop dispose of the following machinery/tools:

- \* Turning machine - 2
- \* Column drilling machine - 2
- \* Welding apparatus
- \* Shaving by hand
- \* General hand tools, like saws, drilling machines, file

#### The handpump manufacturing

Right now, the workshop has started the manufacturing of ten handpumps for shallow wells in Kajiado District. These handpumps are designed by the workshop in cooperation with Melvin Woodhouse. Other handpumps that are made are SWN, Afridev, South-African pumps. The self-designed handpump is much cheaper to make than the other ones mentioned. A construction has been built to test these pumps.

#### The operator's training

This training consists of a week in the District and two days in the workshop in Nairobi. The Maasai operators are trained to perform the principal maintaining tasks. Afterwards they are supposed to be capable of operating a diesel pump. When the pump or engine breaks down, the skill needed to repair is much more complex, so it still has to be taken to Nairobi. The results of the training are considered satisfactory.

## **WATER SOURCES IN KAJIADO DISTRICT**

In Kajiado District several water sources can be found. They can be divided into permanent and temporary sources. Permanent sources are boreholes, shallow wells and some permanent rivers. Temporary sources are small dams, pans and seasonal rivers. There is also a pipeline for Kilimanjaro mountainwater. Boreholes, shallow wells and the Kilimanjaro pipeline are the most important sources.

In the District are 378 boreholes. Of these boreholes 150 are owned by individuals and 228 by 'others'. Others are MOWD, CC, Group Ranches, institutions and other departments. Not all of these are in operating order: 100 are written off, 136 are functional and 145 are not operational.

Mr Moses Mwangi of ASAL has written the following piece about shallow wells and the Kilimanjaro pipeline.

### **Shallow wells**

#### **Introduction**

The geology of Kajiado favours the development of ground water mainly. Rainwater harvesting could rival but the existing situation on the choice has put the sources as secondary to other sources. The situation is made worse on the latter by the high evaporation rates and non conformity to preferred design requirements. The distribution of the perennial surface flow leaves one with less options as they are to be found only in the District west and south east fringes, and thus giving an insignificant coverage. The biggest part of the district is dry with no easily found water for both human, livestock and agricultural use.

The economic mainstay of the district is livestock production that can easily be done albeit with some hardships due to water, forage and some sociological reasons. Agriculture is mainly of the irrigational nature and is only possible in some patches of the district as indicated above. The area that needs development of groundwater is large and has necessitated the development of so many boreholes and wells to support the lifestyle of the people and their economy.

The boreholes number over 400 and less than half are in operation. Development of these sources is again not possible for every part of the district as geology varies.

Shallow wells have the biggest percentage of users.

#### **The sources**

The shallow wells as sources of water supply number about 1400 and are to be found mainly along the dry river beds of most rivers. These rivers are known to store a lot of sand that assists in the formation of aquifers that store water which in essence flows to the wells constructed. Equally, there are other wells that are dug away from the dry river valleys and are more close to the dwellings than the traditional ones. There is also a marked difference in use as apart from the designs the wells are mainly used for domestic water consumption. This notwithstanding, there is a clamour at the moment to develop many water sources this nature due to especially the land tenure system in the District.

Most of the wells are perennial. One important aspect of the wells is their nature in construction as all the traditional ones are not lined. Along with this is the operational procedure

of the sources which is very traditional. This coupled with the existing ownership arrangement and user rights make these sources very unique in the lifestyle of the people.

The operational aspects of these sources is such that the manual procedure of forming human ladders is the order of the day. Introduction of the modern systems of pumping have not penetrated into the minds of people and the idea is to take root. But this is a gamble at the moment as it demands some aspects to be considered. This is a subject of an ongoing research on the sources.

There is only one well in the district run on solar energy. This is Kitirwa Gate and is owned by Kenya Wildlife Service. Another worth mentioning is the Amboseli Lodge Well that is run on a Kijito Windpump and delivering to raised tanks. It has a capacity of 50 m head.

The lack of lining makes the sources somewhat expensive as after every rainy season the sources have to be scooped of the silt that is brought by the floods. The same scenario exposes the sources to much pollution both by human activities around the sources, wildlife and livestock. But even with all these, there is a total dedication to stick to the sources and it is seen the people struggle to keep the points in operation at whatever cost, the quality of the water being very secondary.

The depth of the wells defer with locations and method of digging with construction. The depth may go from as low as one metre to as deep as thirty metres. The diameters also vary and could be as narrow as one metre to six metres. The water rest level again depends on the seasons. The wells could flood or have water levels that could be as low as half a metre in the very dry season.

Properly put up wells have been seen to store better quality water and volumes have always been good. Some that are existing have water volumes that are impossible to deplete with the existing abstraction parameters.

#### Source ownership and development

The land tenure system has undergone big transformation and is still experiencing the process. This has meant a number of things to the water supply systems in the district of all kinds. Traditional shallow wells have been developed 'at random' with every pastoralism struggling to have his well. This has resulted in having many wells by the riversides. Areas next to the dry river valleys are a communal property and access is still free, but the situation may change with the ongoing land subdivision in the district. Access may be a problem in the future and the small paths left will be gullies with time. This may very likely lead to the development of shallow wells in the interior near the homesteads which in any case will be of a higher quality. The only big implication will be the demand to make tangible geophysical surveys.

The wells in the District have been dug by individuals and the ownership can be categorized as family, clan, individual and community. The usage and maintenance is largely communal as in the rural set up there is no single well that is used by a single individual - it is by the surrounding community and friends who by way of the current demands make the use of the well a requirement to live. But as noted above the payments are met mainly by the initiator(s).

#### Noolturesh Water Pipeline

##### Introduction

This is the system commonly referred to as Kilimanjaro pipeline. The system was put up completed about two years ago with an objective of meeting the water demands for livestock and people. The situation exists although with some yet to meet requirements.

This water pipeline has its source as the Noolturesh spring down in Loitokitok and runs for a better part of it alongside the old railway pipeline. Its water serves Kajiado town and its environments, Mashuru town, Athi River and Machakos. The undertaker for this pipeline is the National Water Conservation and Pipeline Cooperation.

The project was sponsored by the Italian government at a cost of about Ksh 1.0 billion.

#### Water supply

In the initial design of the water reticulation system there were to be communal watering facilities along the pipeline. At certain points watering livestock was to be made possible with some points going into the interior. This did not happen for the considerable part of the system. Only did the Mashuru line get some connections. The number of the so far given connections has been a bit difficult to correctly identify for this writing at least for the moment.

#### Line condition

The existing network of the system is characterized with a lot of leakages and from the look of things the repairs are not taken very seriously by the concerned parties.

#### Recurrent expenditures

The pipeline and its appertances are maintained through a revenue to sustain. Payments are collected from the metered and the not metered connections, the latter likely making the majority.

Monthly bills are circulated to registered consumers who are to meet payments as required.

### **ENVIRONMENTAL ASPECTS**

Diesel engines produce fumes, noise and pollution. The fumes are not filtered, most of the engines don't have a silencer and the sites are often polluted with oil and diesel.

With solar driven systems no fumes, noises or pollution is produced. There are no dangerous waste products and there is no contribution to the release rate of carbon dioxide. But the production of a solar panel requires a lot of energy. Only after four to five years of intensive use, the panel has produced the same amount of energy as was needed to manufacture it. And the panels contain industrial materials and chemicals that are not necessarily better than those in non-sustainable energy sources. However, solar power is infinitely renewable and inexhaustible.

Considering this information and the small scale of the applications, the environmental aspects are not considered to play an important role in the choice between diesel and solar.

## SOLAR COMPANIES- TOTAL SOLAR

Total Solar is a company selling solar powered equipment. Until now they have sold six solar powered water pumping installations. We spoke with Mr Vincent Loh.

1 From which countries and companies do you import?

Submersible pumps are from Grundfos and the panels from Solarex, although once from Siemens. All equipment is bought from the same dealer, usually one from Australia. The brands TS sells are the brands this dealer sells.

2 Who are your buyers?

Buyers are mainly NGO's. For example Unicef and GTZ.

3 For which purposes do you sell solar?

Lighting, cooling, water heating, pumping, office machines, computers.

4 Do you check orders to be sure that the dimensioning of the system is all right?

Yes, orders are checked.

5 Do you visit the site before making up the final order?

No, they don't.

6 Who does the dimensioning of the system?

Sometimes the NGO has her own engineers who are capable of designing a proper system. If they don't have their own people, TS will design it for them. For this, they use the data from the borehole's drillers report.

7 Who does the installation of the system?

The installation is done by people from TS. They always go to the site personally to make sure the installation is done properly.

8 Do you deliver complete systems or just components?

TS delivers components as well as complete systems.

9 When installing a system, is there any information, advice or training given to a person or persons at the site?

Together with the community a watchman is selected. He gets a one-day training and an operators' manual. He is shown how to switch on or off the system in case of a breakdown, how the system works and how to clean the panels.

10 What kind of guarantee is given?

The guarantee that is given by the suppliers of the components. So for the pump it will be the Grundfos guarantee and for the panels Solarex' guarantee which is twenty years.

11 Are installed systems checked later?

TS only visits installations when a problem has been reported, because they are all in very remote, far away areas.

12 Are there any particular problems occurring to components?

Not really. Once there was a problem with an inverter. It was taken care of by Grundfos, since it was a manufacturing mistake. The inverter can stay for about ten years, the entire system should be a constant energy source for about 25 years.

13 Experiences with submersibles and monopumps?

Of the six systems sold, five were equipped with submersibles and one with a monopump. Especially when a lot of water is required, submersibles are the best, although they are more expensive.

**Remarks - by Vincent Loh**

People here can't afford a double (diesel and solar) system. "Solar energy is better for mankind as such, but not yet for Kenya because of the costs".

Donated systems can cause problems in communities. For example: a school gets a water pumping installation and the people from the community have to walk very far for their water or they draw it from dirty wells. These people also want to draw water from the borehole, but there is not enough. Another, very important problem with donations is people's mentality: they don't consider the pump as theirs. So when a breakdown occurs or maintenance is needed, they don't feel responsible at all. Or, something that really happened at a borehole near a school, the headmaster sent the watchman to Namanga for a day and when he came back, two panels were broken.

Regarding the feeling of responsibility, the actual need should be defined. What do they need and do they really need it? If not, they will probably not feel very concerned about it.

*About diesel versus solar*

Solar has some unpayable advantages:

No noise, no fuel, no fumes, no pollution and no maintenance. The difference in initial costs is mainly caused by the high prices of the wiring, the inverter and the switchbox needed for solar. The difference in operating costs proceeds mainly from costs for maintenance, service and fuel needed for diesel engines. Over a twenty year period the overhaul costs for diesel and solar should be about the same.

*About tracking system*

It is better to use fixed panels, because the tracking system are too vulnerable and might cause more problems than that they increase the energy output with 40 percent.

"Rather than look for boreholes, look for shallow wells unless there is an NGO or technical team around. People are used to be self-providing, so when a pump breaks down, they will find water somewhere else."

## **SOLAR COMPANIES- DAVIS & SHIRTLIFF**

D&S is a company dealing in waterpumping equipment, especially pumps. Their main product is the Grundfos multistage centrifugal pump. We spoke with Mr David Gatende, the commercial manager. D&S. have sold solar equipment, panels together with pump, wiring, inverter to several NGO's and donor-organizations working in Kenya. However, their last order was more than one year ago.

The numbers refer to the questions as asked Mr Vincent Loh from Total Solar.

1

All solar equipment is sold together with the Grundfos, centrifugal pump. The panels used, were the panels delivered by Grundfos. D&S had no preference or influence on the panels used. Grundfos delivered some years ago Siemens panels, now BP panels are used. All equipment is imported from Denmark via Grundfos.

2

Buyers are NGO's and donor-organizations.

3

D&S sell waterpumps. The selling of solarpanels was a consequence of this. They only sold panels together with the pumps. Solar has never been part of the core business.

4

If the NGO has their own engineers, the orders are not checked. When they don't have, D&S makes up the design, including the number of panels and the pump type. They don't check the site for this purpose. All necessary information is in the driller's report, which is made up by the drilling company.

5

Buyers are NGO's and donor-organizations, like FINIDA, DANIDA, BEGECA, KEFINCO, the Ministry of Works, ASAL, and EEC.

6

No.

7

The engineers of the NGO's. When they don't have their own engineers, D&S does the dimensioning. All information for this purpose can be found in the driller's report. Information needed is the level of the groundwater, the condition of the borehole and the desired volume of water.

8

It depends on what the buyer wants. In some cases D&S does the whole installation. Sometimes, when equipment is bought elsewhere, they only get an order for installation. Some NGO's do their own installation.

9

Pumping equipment is sold separately. Until now, panels have been sold only together with pumping equipment.

10

When equipment is installed, some instructions are given. It seems to be that D&S don't care very much if the information is reaching the community. In some cases manuals etc. are taken

by ministry's or donors since they think the community can't handle these. D&S hasn't a concerned attitude, they sell, install, hand it over to 'someone' and leave.

11

The standard Grundfos guarantee is given, this is a one year manufacturers warranty against defects caused by faulty materials or design.

12

Unless somebody reports a problem, sites are never checked.

13

Most problems occurring to solar equipment are concerning the inverter.

14

They don't have experience with monopumps. They are not interested in these pumps, because of concurrential position.

#### Remarks

Most panels installed by D&S are placed on a very high frame. They do this from the viewpoint of theft. In Kajiado district Ololooitikoshi borehole and Ilpartimaro borehole were installed by D&S. At both sites the panels have been stolen. D&S was not aware of this, and very surprised to hear.

D&S is thinking that they are the main sellers of solar equipment for waterpumping in Nairobi. They think that the small number of solar systems sold, is because of the high costs. The panels are making up 80 % of the total system costs.

There are two workshops next to the office where pumps can be fixed. One of these is especially meant for the repair of submersible Grundfos pumps. Here are three trained people working. The main activities are the replacements of sealing rings and propellers in the stages. Problems in the field are solved by other D&S people.

D&S has never advised solar to buyers. All solars sold were on request of the donors and NGO's.

## ENCLOSURE 1 - Report diesel site visits

### Site 1 Ngatataek borehole - Community owned

The engine and the pump were donated by ASAL/MOWD, about 15 years ago. The borehole and the shortage tank were constructed a long time before.

#### 1. Site

Engine: Lister no. 05188ST229, RPM 1840  
 Generator: Markon type LG280  
 Pump: submersible

The inside of the borehole-house is completely black. At night they 'lock' the bh-house with a stone before the door.

There is a combined storage tank/cattle-trough. Water flows directly from a pipeline on top of the storage-tank in the cattle-trough. So the storage tank stays unused. There are no domestic water supplies. There used to be one, but it broke down a long time ago. People climb up to draw water.

#### 2. Operator

The operator works since 2 years on this borehole. He didn't attend any courses. There have been a lot of operators before him and knowledge is handled over from operator to operator. Also some knowledge has been transferred by engineers who came for repairs. The operator gets a salary from Ksh. 1000,- a month. He is not able to read or write and he does not speak Kiswahili. He does not understand the meters in the bh-house.

#### 3. Users

bomas: 12  
 Heads of cattle: 6000

#### 4. Maintenance

The operator knows how to check oil, to change filters and oil and to fill the fuel tank. He can't carry out repairs. There are some spare filters in the bh-house. They were bought by the committee and given to the operator.

#### 5. Diesel

People bring diesel to the site. The committee determines how much diesel everybody has to contribute.

People go to Namanga or Kajiado to buy diesel. The normal price of a 5 litres barrel is Ksh. 120,-.

#### 6. Breakdowns

There are many breakdowns, about 1 every 1 or 2 months. People have to donate money after a breakdown to raise money for the repair. Sometimes this takes a long time. Meanwhile they go to Ole Kanyoro or other bh's around to collect water. They bring their own diesel to these bh's.

Last year the pump needed replacement. The community had to raise half of the costs, the other half was paid by ASAL. It took them more than 2 months to raise the money.

## 7. Committee

There is a committee consisting of a chairman, secretary, and a treasurer. In case of a breakdown the committee collects money from the community and goes to Kajiado to arrange the repair.

## 8. Finances

Besides diesel every boma donates money for the operator-salary (Ksh. 1000,- a month). They don't have an account.

### *Remarks*

The operator is happy with his job, although he is not content with his low salary.

## Site 2 Meto - Olmakau - Community owned

The community self asked for the borehole. They went to ASAL, who gave them instructions and assistance in arranging all necessary things. The community paid half of all the costs (including the borehole, pump, engine, storage-tank etc.). Sixteen big bomas had to contribute Ksh. 12.500,- each. The other community members paid between Ksh. 500,- and Ksh. 1000,- each. It took them 6 months to raise the money. ASAL paid the other half of the costs. Before the bh was there, they went to a place 7 km. away to collect Tanzanian surface water.

### 1. Site

Engine: Lister no. 4103587TS3A 008, RPM 1500  
Generator: Unamec, UK

The bh-house looks very clean and well organized. There is a solid door with a lock. Around the bh-house is a fence. When the operator leaves the site he locks both the door and the fence. A pipeline (43 \* 20 feet) goes from the bh to a very well constructed covered storage-tank. There are 2 cattle troughs and a cattle dip. Next to the new storage-tank is an old tank, used to be filled with pipeline water from Tanzania.

### 2. Operator

The operator has been on the job since the construction of the bh (2 years ago). He went to the AMREF/ASAL Isinya course in 1992. There is an unpaid assistant operator. During the night there is a watchman.

### 3. Users

families: 60  
heads of cattle: ± 2000  
small stock: uncounted

The engine runs from 7 pm until 3 am if necessary the operator runs the engine also during the day.

### 4. Maintenance

The operator knows how to check oil, to change filters and oil and to fill the fuel tank. He can recognize problems by the sound of the engine and a decreased water output. He acquired this knowledge at the Isinya course. He is not able to carry out repairs by him self. There are no spare filters around, because they are just replaced (according to the operator). Filters are bought in Nairobi.

#### 5. Diesel

Diesel is bought by the operator. He buys it in Kajiado in very big barrels of 25 litres for Ksh. 650,- or 70 litres for Ksh. 2040,- .

People are paying Ksh 15,- a cow a month. For goats is paid by the 'herd', Ksh. 50 for a small herd and Ksh. 150 for a big herd.

#### 6. Breakdowns

Last breakdown: something with the electricity, repair costs: Ksh 2200,-.

#### 7. Committee

There is a committee. Together with the operator they manage the borehole.

They keep 2 administration books : 1 for cattle in which monthly cattle and goat payments are registered and 1 for all the other expenses.

#### 8. Finances

The collected money is used for : buying diesel, paying the salaries of the operator ( Ksh. 1500,-) and the watchman (Ksh. 800,-). This money is not sufficient to finance repairs. In case of breakdowns the community has to raise money, which is usually not easy.

#### 9. Rainy season

During the rainy season the pump is not operational. The operator is paid. People get water from small dams around.

Only people living very near to the bh draw water from the bh. They don't pay for it.

#### *Remarks*

This borehole looks remarkably well organized. Especially the administration books are kept very accurately and completely.

#### **Site 3 Kumpa borehole - Community owned**

This borehole has been in the ASAL programme. In 1991, the community raised Ksh 500,000,- and ASAL completed the amount so a new engine, a new storage tank and new cattle-troughs could be built. The money raising was done by letting every family pay Ksh 15,- per cow per month.

#### 1. Site

Pump: Submersible  
 Engine: Lister 3402867TS2A01 - a blue one  
 Generator: Markon

There is no tap for the drawing of water for domestic use. The women take water from the cattle troughs and it looks quite

## 2. Operator

The operator was employed for this borehole five years ago. He earns Ksh 1000,- a month. Two years ago he attended the operator course in Isinya. He is at the site day and night.

## 3. Maintenance

Although the operator has followed the special course, the replacements of filters is done by a mechanic from Kajiado. He knows how to check oil and fuel and to renew the oil. He says he can tell that something is wrong by the sound of the engine, the lights on the control panel or the fact that the amount of pumped water is not enough. There are no spareparts available at the site, they are bought by someone from the bh-committee on request of the operator.

## 4. Breakdowns

Since 1991 there haven't been any problems. When a problem might occur, the operator will report it to the committee and they will report it to MOWD.

## 5. Users

Number of cattle:	3000, 1500 daily
Bomas (families):	over 20

The operator says the amount of water is always sufficient. For the drawing for domestic water there is no special tap. People take water from the drinking trough, which doesn't look too clean.

## 6. Diesel supply

The diesel is bought by the committee from a petrolstation in Kajiado.

## 7. Committee

The committee consists of 7 members and keeps the administration of the number of cattle of each boma and the money that is being paid and spent. The financial administration is done by the treasurer. They also buy spareparts when the operator asks them. The operator is not a member of the committee. When we first arrived at the site, the operator was not present, so we spoke to a committee member. He said he was the one responsible for the running of the engine, the counting of the cattle and the book keeping.

## 8. Finances

The bomas pay every month Ksh 20,- per head of cattle. Water for goats and domestic use is free. In the administration books the numbers of cattle are written down each month, together with the amount to pay. This money is used for diesel, oil, spareparts, the salary of the operator and savings for repairs. The book keeping looks organised.

## 9. Rainy season

During the rainy season the borehole is not operative. The operator doesn't get his money and the people don't pay anything. For domestic use and watering their cattle they go to small dams, shallow wells and other boreholes.

**Remarks**

The operator remarks that the engine runs much better since he has been to the course. The son of the treasurer, present at the site, says that the engine could still perform better, when the maintenance would be done more properly.

**Site 4 Ngatataek - Ole Birisha boreholes**

The boreholes are situated next to each other. They are both owned by the chief. The first bh is very old, more than 30 years. The initial financier is unknown. The second bh is constructed 3 years ago and totally paid by the committee. It is initially constructed for irrigation purposes.

**1. Site****First borehole**

pump: Lee Howl reciprocating pump, serial no. 346,  
1500 rpm, 250 FTSD  
engine: Lister, no. 3424SR2 22, MP 10, RPM 1500

Pump and engine are located in a very shabby hut, without a lock. The borehole was out of operation since 6 months.

They were using at the moment the second borehole.

**Second borehole**

pump: submersible  
engine: Lister, no. 3506850TS2A01

Both boreholes are filling the same tank, an combined storage tank/cattle-through.

**2. Operator**

Both boreholes are operated by 3 sons of the chiefs. They are not paid. They haven't got any training.

**3. Users**

bomas: 5  
heads of cattle: 3000  
small stock: unknown

These 5 bomas possess all the cattle. People of these bomas are forming a borehole-committee. Besides these big bomas some people and cattle of the smaller bomas around are also allowed to take here water. How much people this are is not known. They don't pay to the committee.

**4. Maintenance**

The operators know how to turn the machine on/off, how to check and renew oil, to fill the tank and how the change the filters. There are no spareparts around.

**5. Diesel**

People bring diesel to the bh from Namanga. They don't count cattle, all the 5 bomas bring the same amount of diesel. Money is only raised in special occasions, like the recent breakdown.

**6. Breakdowns**

Six months ago the first bh broke down. The community raised Ksh 550.000,- for the repair. This amount is also for the construction of a new bh-house and a new storage tank and cattle-trough. They went to ASAL to ask for assistance. ASAL told them to raise the mentioned amount. Now they are waiting for ASAL for further action.

#### 7. Committee

There is a 5 member committee including a chairman, secretary and a treasurer. All members are from the five big bomas.

#### 8. Finances

There are no regular monthly payments. When money is required for repairs or spareparts, all the five bomas have to contribute the same amount. Normally they sell then a few cattle to raise the money. At the moment they have an account, with the KSH 550.000,- on it. In the future they want to keep an account for eventually repairs.

#### 9. Rainy season

They always use the bh also in the rainy season.

#### *Remarks*

They are very happy with the old Lee Howl pump and the engine. They don't want a new type of pump. They are less happy with the second borehole, equipped with a submersible pump, because the capacity is too little.

### Site 5 Olgulului- Ole Mangi borehole - Community owned (previously CC)

#### 1. Site

Pump: Monopump Davis and Shirtliff  
Engine: Lister

The Monopump is also connected to a solar system.

In september 1993 a new diesel engine was installed, together with the solar panels. The monopump is of earlier date. Before the engine and the panels were installed, the system had been out of order for half a year. The installations were paid by GTZ. The community didn't ask for solar, it was the donor's idea.

The people used solar after it was installed. The water delivered appeared not to be enough, so they turned to using the diesel engine most of the time. The operator says he is using solar sometimes, but after a lot of questioning they don't seem to use solar at all.

#### 2. Operator

The operator, who can't read and write, has been on the borehole for one year. He didn't get any training, some constructors who once came to repair the engine showed him how to change the filters and check oil and fuel. The operator has got an invitation for the borehole operator training course, but this letter asked for two persons to come and there is only one operator. They don't know who else to send, so nobody went. The engine is run from 7 am until 6 pm.

### 3. Maintenance

#### *Diesel*

Although the operator says to know how to perform the several maintenance tasks, the only maintenance he seems to do is dusting the engine, renewing the oil and filling the fuel tank. There are no spare parts available at the site, they are bought when needed. During the last year the filters have not been changed. The operator washed them a few times and put them back.

#### *Solar*

The operator knows he has to clean the panels. He used to clean them by climbing on a barrel, because the panels are installed in a way that makes it hardly possible to reach them. The operator told us he still cleans the panels once in a while in case they might want to use solar one day. The panels looked very dusty though.

### 4. Breakdowns

There have been two breakdowns during the last year. Both times it was reported to the committee, who reported it to 'Kajiado' (probably ASAL). The community paid both times for the repairs.

### 5. Users

The borehole is used for livestock and domestic use. There are cattle-troughs and a storage tank. There is no special facility to draw water for domestic use. The number of cattle is not known, but there are twelve herds of large stock. Each day six herds come to the borehole to drink. They also do not know the number of bomas depending on this borehole.

### 6. Diesel supply

People bring their own diesel. The operator estimates the number of large cattle and tells them how much diesel they have to bring. He doesn't write this down. People come with their cattle every two days. The engine uses 10 litres of diesel a day. The diesel is bought at the petrol station in Namanga.

### 7. Committee

The committee consists of a chairman, a treasurer, a secretary and some elders. The chairman of the bh-committee is also the chairman of the Group Ranch committee. The members are 'responsible persons', they don't represent every boma. The committee keeps the administration.

### 8. Finances

Every boma has to donate money to the committee. This is not a monthly amount, just a certain amount and when the money is finished, they have to donate again. There are two amounts every family has to pay. One is used for repairs and the operator's salary, the other is used for oil and filters. The committee keeps administration of the finances.

### 9. Rainy season

The borehole is not used during the rainy season. People go to seasonal rivers. The operator still gets his salary. The seasonal rivers do not provide enough water, so people take their cattle also to wells 20 km further or to other boreholes.

*Remarks*

A nice example of wasted donor money.

**Site 6 Lenkism borehole - CC owned****1. Site**

Pump: Lee Howl - looks very old  
 Engine: Lister - two years old  
 736121 / HP 6 / RPM 650

The borehole and operator houses are very shabby. The storage tank is a combined cattle-through/storage tank. There is no specific domestic water supply, people draw water from the pipeline on top of the storage tank.

**2. Operator**

The operator has been on this borehole for three years. He didn't get any training. He runs the engine from 5 am until 2 pm.

**3. Maintenance**

The operator knows how to renew the oil and how to open the filters for exchange. Necessary maintenance is probably performed by mechanics who happen to be there for repairs. During the last three years, the oil and diesel filters have been replaced once. There are no spareparts kept around. When something is needed it is reported to CC.

**4. Users**

Heads of cattle: 1260  
 Bomas (families): 20

The water is enough, according to the operator, although he says that the pump is not powerful enough.

**5. Breakdowns**

There have been five breakdowns. One was a broken nut, one was a broken injector, once the flywheel was blocked and two times there were problems with the pump cylinder. When a breakdown occurred it was reported to the CC or to the MOWD. The repairs were paid by the CC. Also a new V-belt, which was placed by the operator, was paid by the CC.

**6. Diesel supply**

People bring diesel to the borehole. The amount they bring is not fixed, it depends on the number of cattle. The engine uses 9 litres a day, which is sufficient for 9 hours of running.

**7. Committee**

There is a borehole committee. This committee counts the cattle and decides how much diesel everybody has to bring. The committee has 20 members, among which a chairman, a treasurer and a secretary. The CC told them to form a committee and consists of 'responsible people'. The operator was chosen by its members.

## 8. Finances

People have to pay Ksh 2,- per cattle per month. This money is used for the salary of the operator (said to be Ksh 3500,- a month, which seems rather much to us) and for repairs. The number of cattle and the amounts paid are written in a book. The operator keeps it at home, but he cannot read and write, only count, so somebody else fills it in for him.

## 9. Rainy season

During the rainy season the pumps is not used, but the operator is still paid. People take water from shallow wells and seasonal rivers.

### *Remarks*

When you calculate the total monthly received amount Ksh 2,- \* 1260 heads of cattle, the salary of the operator (Ksh 3500,- instead of Ksh 2500,- ?) seems rather high.

## Site 7 Imaroro borehole - Community owned

The borehole has been drilled in 1968. In 1974 the Imaroro community went to the MOWD to ask for assistance in the purchase of an engine. The engine, pump and all the necessary features (cattle troughs, pipeline, storage tank) were paid by the community. They raised initially Ksh 48.000,-. The rest was paid by a loan from the Agriculture Finance Company (AFC). The community paid from the beginning a monthly fee to the Group Ranch, which was used to pay the operator and to pay back the loan. It took them 10 years to pay back the loan. The compound of the AMREF Borehole Rehabilitation Team is situated right next to the borehole.

### 1. Site

The borehole is located about 2 kilometres from Imaroro village. Several boma's are nearby. The site is equipped with 1 storage tank and 2 cattle-troughs, there are no special domestic supplies at the site. The water in the troughs is made filthy with cattle shit, while people are bathing and drinking directly in and from this water. An other storage tank is located about 200 metres from the borehole on the AMREF compound. Domestic water is mainly drawn from this tank. compound.

Engine: Lister no. 350040 TS2A01, RPM 1500  
Pump: Submersible

The engine is located in a borehole house, made from stone with wireframe windows. Remarkable is that the exhaust is installed directly on the engine, in the house probably.

### 2. Operator

Joshua, chairman of the bh-committee and living next to the borehole, has been operator since 1974 for 18 years. The present operator is the fourth after Joshua. He is operator since one year. He didn't go to an operator course. Just before he finished his job, Joshua attended the Isinya course in 1992. All necessary things are told the present operator by Joshua. The salary of the operator is 1000 ksh. a month. He is not able to read or write.

### 3. Maintenance

The operator is able to fill the fuel tank to check and renew the oil. The present operator has never replaced the filters, he washes them from time to time. Since he is operator, there has not been any severe problems.

#### 4. Users

The borehole is used by 1400 heads of cattle and an unknown number of small stock. The operator runs the engine 4 hours in the morning and 6 hours in the afternoon. They give the engine a break to cool down. They use every day 15 litres a day. When the AMREF tank needs to be pumped they use an extra of 20 litres. The operator does not write down the operating hours or the litres of diesel used.

#### 5. Breakdowns

Before the AMREF compound was there, they went to Nairobi to find help in case of breakdowns. They went to Kenpomp for the pump and to Lucas-company for the generator. All repairs were always totally paid by the community. Now AMREF is situated next to the borehole problems will be reported to them.

#### 6. Diesel

The people pay every month Ksh 4,- per head of cattle. Small stock and water for domestic use is free.

When extra money is required the people have to contribute Ksh 6,- a month. To save personal transport costs the committee gives money to the matatu driver to buy diesel.

When Joshua was operator things were controlled much better, he noticed in his book everyday the running hours and the used diesel.

#### 7. Committee

After Joshua finished his job as an operator, a borehole committee was started on the initiative of the Group Ranch. Before this time, the management of the borehole was carried out by Joshua together with the Group Ranch. The main reason of an separate b.h.committee, is to separate financial G.R. and borehole matters.

Joshua was selected to be chairman of the committee, because he has a lot of experience with the bh. Officially the committee consists of 6 members, selected by the community. The operator is not an official member. When there are no urgent matters, the committee has a meeting every 3 months. Joshua, the operator and two members of the committee count the number of cattle, the money is collected by the committee. In the b.h. house is a very organized administration book in which the payments and the number of cattle of all the users are registrated. The treasurer writes in this book also all the expenses and the litres of diesel bought. This book is open to everyone, so everyone can control the finances. When somebody pays his monthly rate, he receives a stamped receipt with the day of payment and the amount.

#### 8. Finances

The collected money of Ksh 4,- a month a cow is used to buy diesel, to pay the operator and if necessary for repairs. Occasionally, when Ksh 4,- is not enough they ask Ksh 6,- a month a cow. A problem is that not everybody pays in time, so the committee have to chase money sometimes.

The present Ksh 4,- is not enough for running the borehole properly. The committee is thinking of new ways to collect money. Possibilities are : to ask a higher amount a cow a month, to ask higher periodical donations, to continue the payments during the rainy season.

#### 8. Rainy season

The borehole is not in use during the rainy season.

### *Remarks*

An good example of a very well organized community owned borehole.

**Site 8 Bissel - Nkoile borehole - Group Ranch owned**

#### 1. Site

Pump: Monopump, type B MK 3, Monopumps Melbourne, Australia  
 Engine: YAN, Yanmar, Japan

#### 2. Operator

The operator has been working on this borehole for two years. Before, he was employed by the County Council to run another borehole, which was equipped with a Lee Howl. He is now employed by the Group Ranch. He has been trained, but this was not the official bh-operator course. Probably some things were explained to him by mechanics who did some repairs. The operator cannot read or write. He runs the engine daily from 4 am until 6 pm.

#### 3. Maintenance

The operator knows how to renew the oil and how to change the filters. The oil filter and the air filter have both been replaced once in the two years that the operator is employed. He never washes the filters. At the site there are know spareparts or filters available. Whenever something is needed, it has to be bought. For this purpose there is no money available, so it has to be raised first.

#### 4. Breakdowns

There has been one breakdown, it was a problem with the pump. This has been reported to the MOWD. People from MOWD took care of the repair. The community paid everything.

#### 5. Users

Heads of cattle: ± 3000  
 Bomas (families): 24

Large cattle comes to the borehole every two days. The people come to take water for domestic use every day. The people are saying that they always have enough water. The only disadvantage is that the pipeline from the borehole to the cattle troughs and storage tank is a bit narrow, so the water cannot flow as quickly as they would like.

#### 6. Diesel supply

Everybody who comes to the borehole to let his cattle drink, has to contribute 4 litres of diesel. This amount was fixed by the members of the borehole committee. The engine uses 10 litres a day, so once the diesel is finished, they have to bring new.

#### 7. Committee

There is a borehole committee which consists of 5 members, including the operator. The committee fixed the amount of 4 litres of diesel that everybody has to bring. There are a lot of

complaints about this, since the number of cattle owned by the different bomas varies. The smallest herd consists of 15 head, the largest of 200 head. The members of the committee are all rich men.

#### 8. Finances

Every boma has to pay Ksh 50,- each month. This money is used to pay the operator, so he earns Ksh 1200,- a month. People do not pay any monthly amounts for spareparts or repairs of eventual breakdowns. The operator receives the money and since he is not able to write he is assisted by somebody to register the payments. The money is given to the treasurer of the committee, who keeps it in his pocket. They don't have a bank account.

#### 9. Rainy season

The borehole is not used during the rainy season. Water is taken from a seasonal river and small dams during a period that can last 2 to 3 months. The operator is not paid.

#### *Remarks*

The same amount of diesel for every boma, disregarding the number of cattle they have.

#### **Site 9 Bissel borehole - MOWD owned**

##### 1. Site

The borehole is situated on an compound where the operator lives with his family. There are now water points at the site. Water flows directly to different pipelines to various places.

Pump: submersible  
 Engine: 3698HR2A27V / HP2150 / RPM 1500  
 Generator: Markon LC32B

##### 2. Operator

The operator was employed by MOWD in 1990. There are two operators. The operators can renew the oil and fill the fuel tank, but they don't know how to change filters. The operator we talked to didn't get any training, but has a long experience in running diesel engines. He runs the engine 12 hours a day, which takes 25 litres of diesel. The operator is paid by MOWD.

##### 3. Maintenance

The operators never change filters, they just check oil and fuel and if necessary renew or refill. People from MOWD usually drop by to check the engine and replace the filters. Since 1990, there have been six filter changes. The operator doesn't report any necessary changes.

##### 4. Users

There are five pipelines leading from the borehole. Four of them lead to bomas and one to the village, a school. All pipelines lead to a storage tank.

##### 5. Breakdowns

There have been four breakdowns since 1990. Three times the generator and one time the electrical part of the pump. Breakdowns are reported to MOWD, who takes care of it.

## 6. Diesel supply

The diesel is bought and taken to the site by MOWD.

## 7. Committee

There is no bh-committee since everything is taken care of by MOWD.

## 8. Finances

Each boma pays Ksh 100,- a month to MOWD. The operator doesn't know how many bomas there are. The other operator keeps an administration of the number of bomas and the money paid.

## 9. Rainy season

The borehole is used during the rainy season, by the village as well as by the bomas. The operator thus still receives his salary.

**Site 10**            **Isinya borehole**            - NWC owned

### 1. Site

Pump:            Monopump  
Engine:          Lister

The engine and pump are placed under a shabby leaking roof and there is no borehole-house. The place looks very muddy. Oil and water are spilled all over and the pipelines are leaking heavily. Next to the bh is a remarkable neat looking storage house.

### 2. Operator

The operator has been working on this borehole for 4 years and never got any proper training. He is paid by the NCW and earns Ksh 2400,- a month. He runs the engine from 8 am until 11 am and from 1 pm until 6 pm. The break between the runs is to prevent the engine from overheating. When there is water in the Kilimanjaro pipeline, which leads through Isinya, he runs the engine less hours.

### 3. Maintenance

The maintenance that the operator can perform is renewing the filters, replacing the V-belt and renew the oil. He washes the filters when there are problems, otherwise every 3 to 4 months. The actual changing of filters however, is mostly done by mechanics from NWC, who come to check the site every two months and who were also the ones who showed the operator how to maintain the engine. Since 1990, the air- and oil filter have been replaced one time, as well as the V-belt. In the little storage house at the site the operator has a spare V-belt and a spare tap. He doesn't have any filters. Whenever he needs something he or somebody else goes to NWC.

### 4. Users

There are three direct lines from the borehole to the users: the first leads to the hospital, the second to the school and the village, the third to the slaughterhouse and some bomas. The bomas have their own storage tank. People come to take water for domestic use at the borehole site. Water can also be drawn from the Kilimanjaro pipeline, but this is seasonal. The operator says that the water is sufficient.

## 5. Breakdowns

There has been one breakdown in the last four years. This was a problem with the engine. The breakdown was reported to the MOWD and the repair was paid by NWC. There have not been any problems with the pump.

## 6. Diesel supply

The NWC brings diesel which the operator keeps in the little storage house at the site. At the site people pay Ksh 1,- for every container of about 20 litres. The operator takes this money every two weeks to the NWC. The school, hospital, slaughterhouse and bomas have meters and pay every month to NWC.

## 7. Committee

Since the borehole is owned by NWC and diesel and spareparts are supplied by them, there is no borehole committee.

## 8. Finances

Finances are taken care of by NWC.

## 9. Rainy season

During the rainy season the Kilimanjaro pipeline is used, but also the borehole, although less. The operator still receives his salary.

## *Remarks*

The site is in a remarkable bad condition.

### **Site 11          Kisaju borehole          - MOWD owned**

This borehole is working on a diesel engine. When we visited the site, the operator was not around and the place was locked, so we didn't get much information.

The borehole is owned by the government and is supposed to supply water for two Group Ranches. But since the borehole is located on the land of one Group Ranch, the members of this community don't allow the others to draw water from it. When the operator is not around, the women from the other Group Ranch use to climb over the fence and take water.

### **Site 12          Kiserian borehole          - NWC owned**

This borehole used to run on diesel, but when two years ago an electricity grid was installed, they turned to this.

#### 1. Site

Pump:                submersible  
 Engine:            3422HR2A25 / HP21.5 / RPM1500  
 Generator:        Markon CC32C

#### 2. Operator

The operator lives on the same compound as the borehole is situated. He never got any training for running a diesel engine. He is paid by NWC.

### 3. Maintenance

Since the pump is working on the electricity grid, there is very little maintenance left. The operator says he cleans the diesel engine from time to time in case the electricity collapses and they want to run the engine.

### 4. Users

Together with a nearby borehole which runs 24 hours a day, this borehole supplies the entire village of Kiserian with water. From the borehole the water is pumped into a storagetank, from which pipelines lead to various destinations. Some people don't have a storagetank nearby, so that's why the other borehole is running 24 hours a day.

### 5. Breakdowns

Whenever a breakdown occurs it is reported to the regional manager of the NWC office. There haven't been any problems after the grid was installed. The only problem is that the electricity might go down, especially during the rainy season. Then they use the diesel engine connected to the generator. The last breakdown was a strange one: while fixing the pump to the grid, the pump broke down, so a new one was installed together with the connection to the grid.

### 6. Committee

There is no bh-committee, everything is arranged by NWC.

### 7. Finances

Some people have meters in their homes, so they pay per amount of water taken. People who don't have a meter pay an estimated amount. The minimum is Ksh 60,- for one to ten cubic metres, the maximum is Ksh 140,- for ten to twenty cubic metres. This are all monthly payments to the NWC, who uses the money for the operator's salary, repairs and the maintenance of the borehole.

### 8. Rainy season

The borehole is also used during the rainy season. But in this period it quite often happens that the grid doesn't work, so the diesel engine has to be used.

### *Remarks*

The pump has not been placed deep enough to pump continuous, so extra pipe is bought. They still need some extra wiring and then they will lower the pump.

**Site 13**      **Esaikeri borehole**      - Community owned since 1994,  
before CC owned

Three different energy sources has been used at this borehole.

Energy sources:

1985 - 1991: Lister diesel engine

1991 - 1993: solar panels

1993 - now : windmill

Operator

The operator works on this borehole since 1985. He has been a borehole operator for 18 years. He has been to the bh-operator course in Isinya, although at the time he was running a solar pump. He wanted to follow this course himself to enlarge his knowledge.

*Diesel*

Maintenance

The operator knew how to change or wash the filters and renew the oil. He was showed by people from the local government.

Users

The water was used by people and cattle. In 1973 a lake was constructed by PCEA church and from then on the cattle was taken to the lake and the borehole only used for domestic use, except in the dry season when the lake is dry.

Breakdowns

Many breakdowns, mostly with the engine, sometimes the pump.

Diesel supply

Diesel was supplied by CC, but paid for by the community.

Finances

The borehole was provided with meters, so the community had to pay every month for the water taken. Before 1973, the cattle was counted and an amount was estimated. After 1973 every family paid Ksh 20,- a month to CC.

From diesel to solar

There were no problems with the engine, but the community found the diesel very expensive. A local political leader or somebody from Kenzic Solar told them about solar energy, that is was free in use and the community decided they wanted a solar powered pump. They asked this political leader for financial assistance and a solar pump was donated.

*Solar*

In the beginning people were very satisfied, but from June till October the water appeared to be too little. People had to take their cattle to a nearby lake and took water for domestic use from surface water  $\pm$  9 km away.

The system was manual tracking, the operator had to turn them sunwards a few times a day. He cleaned the panels with a dry cloth three times a week and greased the tracking system. He was told to do so by the installing company. There were no other problems. They had a watchman, also during the night, whose salary was paid by CC.

From solar to wind

The political leader saw that the people suffered from too little water and promised to help them. The community asked their diesel engine back, but the politician told them that wind would be better and cheaper. So the politician donated a windpump this time.

*Wind*

Maintenance

The operator has to grease some parts every one and a half week. Some rubber rings have to be replaced every four months. He opens and closes the taps.

Breakdowns

Since the installation there have been five minor breakdowns, due to the fact that some parts have to be replaced regularly, but no one knew. The first three breakdowns were paid for by the regional government. Since the beginning of 1994, the borehole is owned by the community so they had to find money for the last two breakdowns themselves. These were paid by CCF, Child Care Fund. CCF opened an office in a school nearby and they coincidentally heard about the problems with the windpump. They offered to pay. Next time that a breakdown occurs, the community will have to pay themselves or find a willing donor again.

Finance

Nobody is paying anything.

Committee

When diesel was used there was an active borehole committee. It still exists, but doesn't do anything any more.

*Diesel, solar or wind?*

The community prefers wind. There is always sufficient water, while they don't have to pay anything. Another advantage of wind is the low required maintenance. Although there are days without wind, there is still enough water in the storagetank.

During the dry season when the lake is dry, the windmill can't produce enough water for all the cattle so the cattle has to go to different water sources, normally shallow wells. When the engine was there they could run the engine day and night, so there was always enough water. With diesel there is always water, not depending on season or weather. When the running costs weren't so high they would prefer diesel. But regarding the high diesel costs, compared to the low wind costs, they absolutely prefer wind.

Solar is definitely the worst option because of the low pumped water volume and stays out of question.

## ENCLOSURE II - Report solar site visits

### Day 1, site 1 - Kitirwa well

#### 1 Site

The well is situated in Amboseli National Reserve. It is near to a small seasonal swamp, which is a water source for game and Maasai cattle. The pump is in working order. Water can also be pumped with a handpump, which can be put upon the borehole. The system is provided with only one panel, placed on the roof of the pumping house. The panel is captured in a metal frame, which can be closed and locked. The storage tank is placed at the rangers' camp, about 150 meters from the well. At the camp, other solar panels are installed for use of the radio and the telephone which is to be installed.

#### 2 Purchase

The system is financed by Kenya Wildlife Service, KWS. They give three reasons for choosing solar:

- 1 The costs for fuel are too high.
- 2 Solar needs very little maintenance, which is an advantage because the KWS staff has a lot of other things to do.
- 3 Donors are interested in solar energy.

There is no technical specialist around and in the case of a breakdown, KWS will be financially responsible. The site has no diesel history.

#### 3 Installation

#### 4 Use

The source is primarily meant for domestic use by the KWS rangers, four in number. When there's enough water, local people are allowed to come and take water for domestic use. The water is distributed from the well to the tank and from there to taps inside the rangers' houses. No drinking troughs for cattle. The users don't have to pay for the water.

#### 5 Maintenance and repair

There are no spareparts, tools or know-how available. The panels are cleaned every morning and afternoon with a dry piece of cloth. This happens on turns by the rangers, when they open and respectively close the panel's box. In case of a breakdown the rangers will report this to KWS, who will be further responsible.

pipeline	150 m
storage tank	16 m <sup>3</sup>
panels - number	1
- size	1.20 * 0.30 m <sup>2</sup>
- type	M 75
- company	Siemens Solar Industries Camarillo, CA 93011
inverter - type	-
- company	-

**Day 1, site 2 - Embaringoi borehole  
no. C 3043**

**1 Site**

The borehole is located at the border of Amboseli National Reserve and used by Olgulului Lalashi Group Ranch. The system consists of 32 panels, attached to the roof of the pumping/watchman-house. The storage tank is built 50 meters from the borehole and has no coverage. The water is used for domestic purposes and cattle. Main problem at this site is that each night, the storage tank is emptied by elephants. A previous coverage was destroyed by them. The elephants cannot be chased away by humans or fire.

**2 Purchase**

Friends of Amboseli financed the installation of solar equipment, the watchman is paid by the campsite, which is near to the borehole and owned by the Group Ranch. There are no special reasons known for the choice of solar. The owner of the borehole is the GR and so they are responsible in case of a breakdown. The GR makes money by exploiting the campsite and since Amboseli game grazes their land, they receive a quarter of the gate's income. Before solar was installed, the borehole was provided with a diesel engine. The watchman who was employed then, has left.

**3 Installation**

NESTE Advanced Power Systems. The company's people have checked the site three times during the last year. They just looked around, according to the watchman. The training of the watchman consisted only of showing the on/off switch.

**4 Use**

The borehole is used by 8 bomas. One boma consists of an average of 50 people and a minimum of 200 heads of cattle and 400 goats. There are three bomas owning 600 heads of cattle. Four of these bomas can also make use of other water sources. Water is used for domestic use and small stock. The GR has made up an agreement that large stock will not use the water from the borehole, since it is not enough. The lack of water is partly caused by the thirst of the elephants. There is always a watchman at the site. He's paid by KWS. He doesn't know how the system works, except for how to turn it on and off.

**5 Maintenance and repair**

The watchman cleans the panels twice a week with a dry cloth. Since solar was installed two years ago there haven't been any breakdowns or other problems. In case of breakdowns, there is nobody around to fix it.

pipeline	50 m
storage tank	32 m <sup>3</sup>
panels - number	32
- size	1.20 * 0.30 m <sup>2</sup>
- type	M 55
- company	Siemens Solar Industries Camarillo, CA 93011

Inverter - type	Solartronic SA 1500
- company	Grundfos

**Day 1, site 3 - Olgulului Primary school**      **borehole**  
no. C 4874

## 1 Site

The system is situated about 1 km from Olgulului Primary School. The 32 panels are fixed upon four sun-tracking frames. The angle of the panels is related automatically to the angle of solar irradiation, so that a maximum of power is captured. These frames are fixed to the ground and surrounded by a fence. The only persons who can unlock the fence are the headmaster and the watchmen. There is a big storage tank for the school and a little one for the dispensary, both near to these buildings.

## 2 Purchase

After the borehole had not been working for two years, solar equipment was installed. ASAL paid 1,2 million Ksh and the school contributed 80,000 Ksh. ASAL decided for solar. Askaris are on the school's payroll.

## 3 Installation

ASAL paid for the digging of the 1 km pipeline from the borehole to the storage tanks.

## 4 Use

The borehole is used by the school, 320 children and 10 teachers, the dispensary and about 160 local families. No cattle, just domestic use. There are three taps, one at the dispensary, one in the school's kitchen and one in the school. During the cold months, June and July, the families are not allowed to take water because otherwise, there will not be enough for school and dispensary. Everything has always been working properly. There are two askaris, one during the day and one during the night. After their shifts are over, they report to the headmaster who has final responsibility.

## 5 Maintenance and repair

The panels are cleaned twice or three times a week by the askaris. They use a sponge and water. A technician comes to check the site a couple of times per week. He is not employed by the school, he lives near the borehole and he just seems to be very interested. In case of a breakdown, the school is financially responsible. Part of the schoolfees are saved for this purpose, but when anything will happen, they will try to get some money from ASAL. Up until now, there have not been any problems.

pipeline	1 km
storage tank	number 1 : 45 m <sup>3</sup> number 2 : 3 m <sup>3</sup>
panels - number	32, 4 groups of 8
- size	

- type	MSX 56
- company	Solarex
inverter - type	SA 1500
- company	Solarex
tracking system	STIMA JUA SOLAR SYSTEMS

**Day 2, site 1 - Ipartimaro borehole  
no. C 4934**

**1 Site**

The system is not operating since one of the 35 panels has been stolen. People are now taking water from shallow wells, which are near to the borehole. Cattle and goats are taken to these wells also. They don't have a lack of water, so nobody is in a hurry to undertake any action to rehabilitate the system. The water from the shallow wells however, is not very clean. The panels are fixed to the ground upon frames. These are surrounded by a fence. The storage tank is 200 m from the borehole.

**2 Purchase**

The water from the borehole is free. The installation of solar was financed by Ministry of Water Development, MOWD. The borehole has especially been drilled for solar.

**3 Installation**

Members of the community assisted in the digging of the pipelines and were paid by MOWD.

**4 Use**

The water is used by 210 people, 700 heads of cattle and 1000 goats (ASAL). There are drinking troughs. People have first priority, since cattle and goats can also drink from the shallow wells. The GR is responsible with the chief as their spokesman.

**5 Maintenance and repair**

Since the installation of the system ten years ago, there once occurred a breakdown, but it was within the guarantee period and immediately repaired by the company. The chief arranged this. Recently, water leaked into the control box, which was taken by MOWD to be repaired. Since there is no theft in this area, the community did not see the need of a watchman. Now that the panel has been stolen, they do see the need and watch the panels at night. This is done on turns by community members and unpaid. The theft has been reported by the chief to ASAL. The community is expected to contribute 50 percent of the repair costs. When it is raining, the pump is turned off for 'saving' energy.

pipeline	200 m
storage tank	70 m <sup>3</sup>
panels - number	35
- size	1.20 * 0.30 m <sup>2</sup>
- type	M 53
- company	Arco Solar PO Box 4400 Woodlandhills, CA 91365
inverter - type	Solar Switchbox SB 1000 P code 825024 Model A
- company	Grundfos

**Day 2, site 2 - Ololoitikoshi borehole**  
no. C 4936

1 Site

The system is not operating, since all 28 panels have been stolen in three thefts. The inverter and control box have been stolen also. The borehole was especially drilled for the installation of solar. There is a storage tank ca. 50 m from the borehole. Apart from the cold month of June, there used to be enough water for people and cattle. Now, people are using water from a tank 8 km away, which is filled with water from a spring. Cattle is taken to Tanzania, since the amount of spring water is not sufficient. After heavy rains, there is enough water to use for 3 to 4 months. There used to be a watchman during two and a half year, but the people decided he was no longer needed, because there were no thefts. The theft was coincidentally discovered by ASAL, the people had not reported it.

2 Purchase

Financiers were the Swedish Government, MOWD through RDF. This is still a bit unclear. The water is free, the borehole was drilled for installation of solar equipment.

3 Installation

4 Use

The borehole was used by 12 bomas with an average of 50 persons each. One boma has 700-1000 goats and 300-400 heads of cattle. There is one tap for domestic use, one tap for small stock from which the water floated into a small drinking trough and a large drinking trough for large cattle. During the cold month, people used to come to the tap early, so there would still be water. Later, the cattle would have drunk it all.

5 Maintenance and repair

There were two responsible persons, whom we have not spoken to, since they are in Tanzania with their cattle. They used to clean the panels once a week or once in two weeks with a wet cloth. There never were any problems and in case of a breakdown it would be unclear who would be responsible. They don't have any technical knowledge of the system.

pipeline	50 m
storage tank	50 m <sup>3</sup>
panels - number	28
- size	no information, all panels were stolen
- type	
- company	
Inverter - type	
- company	

## Day 2, site 3 - Enkusero borehole

### 1 Site

The 30 panels are fixed in 5 groups of 6 on 4 meter high standards, with no possibility to reach them. The borehole is situated in a very dry, semi-desert area. The place looked very lonely. The pump broke down two weeks ago and this was immediately reported to GTZ in Nairobi by the responsible person. Solar was used during the day, during the night they used a diesel engine. The storage tank was built 20 meter from the borehole and there are drinking troughs. No special tap for domestic use.

### 2 Purchase

The borehole was drilled by KWS in 1976 and provided with a Lister. This was a donation. The Lister broke down 4 years later. MOWD took the broken engine and donated a new one. This one lasted 10 years. Then solar was installed, this was paid by GTZ. Because the community did not trust the solar, they wanted a diesel also, so a combination was installed. The pump installed is a Monopump.

### 3 Installation

KWS paid all costs made in 1976, including the digging.

### 4 Use

The borehole is used by ca. 400 people and ca. 20,000 heads of cattle. The cattle is now taken to a place 20 km further, water for domestic use is taken from the Olgulului Primary School borehole. There were two operators/watchmen day and night. When we visited the site, however, they were not around. The users of the borehole take diesel to the pump. The amount of diesel depends on the amount of cattle they have. The pump uses 16 litres diesel every 24 hours.

### 5 Maintenance and repair

The panels were never cleaned, because nobody told them to do so. The construction on which the panels are fixed does not give any possibility to reach them or see their dusty surfaces. The small Lister never broke down.

Remarks: The community wants a big Lister again. They say that when using solar, the amount of water pumped is considerably less than when using the small diesel. We think this is a consequence of not cleaning the panels.

pipeline	20 m
storage tank	60 m <sup>3</sup>
panels - number	30
- size	no information,
- type	panels were fixed too high
- company	
inverter - type	
- company	

**Day 3, site 1 - Ittil borehole**  
no. C 8520

**1 Site**

The borehole is located about 1 km from a school and close to some shallow wells. Since almost every panel from the 28 (40 own estimate) has been stolen, the system is not working. The inverter and control box have also disappeared. The panels were fixed upon frames, 5 meter up in the air. There is a ladder to reach them. The construction was surrounded by a fence.

**2 Purchase**

The equipment was paid by RDF. The school paid for the storage tank next to the school, MOWD paid the pipelines. The problem is that the borehole does not belong to anyone, so nobody feels responsible and nobody knows who is going to pay for the repairs. The headmaster thinks that the community always has to contribute 50 percent of the costs, but Moses says there are other ways. Since the amount is too high for the school and the responsibility is not taken by anyone, nothing is undertaken.

**3 Installation**

The borehole was drilled especially for solar, financed by RDF.

**4 Use**

The water was used by the school, 200 pupils, 6 teachers and the dispensary. The community using the water is said to consist of 12,000-15,000 people, which seems to be a very high number. Water is now taken from shallow wells near the borehole. Since the breakdown of the pump, the number of malaria victims has considerably increased. The responsibility is put on the shoulders of the headmaster, just because he is the headmaster. He does not like this very much, also because the community does not show any consideration towards the problem.

**5 Maintenance and repair**

The headmaster and a nurse from the dispensary cleaned the panels. They were not told to do so, but found it out themselves. There was no watchman. Even after the first panels were stolen, they didn't put a watchman at the site, so thieves could repeat their criminal act.

Remark: They just seem to be waiting for a donor to solve their 'problem'. The fact that there is enough (not very clean) water in the shallow wells is also a reason for their passive attitude.

pipeline	1 km
storage tank	unknown
panels - number	40
- size	no information
- type	
- company	
inverter - type	no information, stolen
- company	

**Day 3, site 2 - Enkil**  
no. C 4093

### 1 Site

The system is in working order. There are 32 panels, fixed on a metal frame near to the ground. They are surrounded by a fence. There is a little metal tank and a new one, which will replace the first, is under construction. Drinking troughs for cattle, no tap for domestic use.

### 2 Purchase

The borehole was drilled in 1974 and supplied with a diesel engine and facilities. This one broke down 9 years ago. People had to take water for cattle and themselves from shallow wells 30 km away. The women used to go there every two days. In February 1994 Friends of Amboseli installed the solar system.

### 3 Installation

F.o.A. decided for solar.

### 4 Use

The water is used by 100 families, small stock and a little number of large stock. Large stock is usually taken to a pipeline distribution point from another borehole/Kilimanjaro water (???). People are very happy with the system, although the amount of water is not sufficient.

### 5 Maintenance and repair

The system never broke down, but it is still very new. When there is a lot of sun, the pump is turned on automatically and starts working again after half an hour. This seems to be caused by the fact that the inverter is not tropicalized. There is no technical knowledge available. There are two watchmen and one operator. The only thing the operator knows is how to turn the system on and off. Panels are cleaned by the watchmen five times a week with a dry cloth. They were not told to do so, discovered this themselves. The watchmen are paid by Friends of Amboseli. When it is raining, they turn off the pump to 'save' energy. When the storage tank is filled, the operator also turns it off.

pipeline	10 m
storage tank	11 m <sup>3</sup> (old one, to be replaced)
panels - number	32
- size	1 m x 0.5 m
- type	Multicrystal, model LA 361K51
- company	Kyocera, Japan
inverter - type	SA 1500 V03 M93244401
- company	Grundfos

**ENCLOSURE III - Literature**

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**ENCLOSURE IV- Explanation of abbreviations and Swahili words**

<b>AMREF</b>	<b>African Medical and Research Foundation</b>
<b>ASAL</b>	<b>Arid and Semi Arid Land</b>
<b>CC</b>	<b>County Council</b>
<b>FoA</b>	<b>Friends of Amboseli</b>
<b>KWS</b>	<b>Kenyan Wildlife Service</b>
<b>MOWD</b>	<b>Ministry of Water Development</b>
<b>NWC</b>	<b>National Water Conservation</b>
<b>askari</b>	<b>Watchman</b>
<b>boma</b>	<b>Group of traditional huts, usually inhabited by one Maasai family and surrounded by twigs and thorn bushes</b>
<b>harambee</b>	<b>Organized voluntary fund raising</b>
<b>wazee</b>	<b>Plural of 'mzee', which is a respectable title of an elderly man</b>

