DECISION GUIDE

for

Diesel and Solar Powered Water Pumping Technologies

November 1994

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CONTENTS

PREFACE

This guide is a result of a comparative research on solar and diesel water pumping technologies carried out between May and September 1994 by both authors for AMREF, Nairobi, Kenya. All background information is included in 'A Comparative Selection Guide for Diesel and Solar Water Pumping technologies in Kajiado, Kenya, Main Rapport', November, 1994. This main rapport is available at AMREF Documentation Centre, Nairobi, NETWAS Documentation Centre, Nairobi and CICAT Documentation Centre, Delft, the Netherlands. A copy can be obtained by sending a request to one of the authors.

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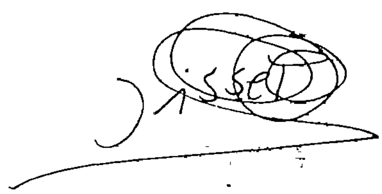
We hope that the use of this guide will be profitable.

November, 1994



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1 INTRODUCTION

This document is a decision guide for the choice between diesel and solar powered options for pumping water from boreholes.

Research has been done on technical, economic and organizational fields by carrying out a thorough literature study, visiting sites and interviewing borehole operators and borehole users.

The study is specified for Kajiado District, Kenya. But with some adjustments it might be useful to NGO's, communities and other bodies involved in water pumping who have decided to buy pumping equipment. In this guide a Decision Chart is included. This Chart gives an indication of the most suitable pumping technology in varying situations, since one can adjust it to specified cases.

2 BOREHOLES

2.1 The District

The boreholes included in this study are all located in very remote, semi-arid areas, where no electricity grid or reliable fuel supply is available.
Research has been done on two types of boreholes, communal and institutional boreholes. The communal boreholes in the District supply water to communities consisting mainly of Maasai. Maasai are largely depending on their livestock. About 90% of the water produced by communal boreholes is used for watering livestock, the other 10% is for domestic use. Institutional boreholes supply water to schools, dispensaries or hospitals. No cattle is allowed at the last.
Boreholes for irrigation purposes are not included in this research. The average depth of the boreholes is 100m.

2.2 The Site

A site is the place where the borehole is located. There is a small house, the pump house, usually built out of concrete or iron sheets. In here one will find the engine and possibly the generator -in case of diesel- or the electronic components -in case of solar. The pump is always lowered into the borehole. Electric pumps are powered by submersible motors. Mechanical pumps are powered by either an electric motor installed on the ground in the borehole house (solar) or direct by the diesel engine.
Water is pumped into a storage tank. This storage tank can be open or covered.

Communal boreholes
From the storage tank there are usually some pipelines leading to cattle troughs. A cattle trough can also be integrated with the storage tank. The drawing of water for domestic use is usually done by women. There is almost never a special tap. The women take water from the inlet of the storage tank, the inlet of the cattle trough or, worse, from the cattle trough it'self. In some exceptional cases pipelines are leading to distant distribution points.

Institutional boreholes
From the storage tank different pipelines are leading to taps in the institutional buildings. Usually there is also a water point at the storage tank where women can draw water for domestic use. There are no cattle troughs.

3 TECHNICAL OPTIONS

In choosing a pumping system for the raising of water from a borehole two principal decisions have to be made. The first decision concerns the energy source, the second concerns the type of pump. In Figure 1 the five possible combinations of energy sources and pump types are shown. More types of pumps are available, but for the Kajiado circumstances, very deep waterlevels and high required volumes, only the mentioned types are suitable.

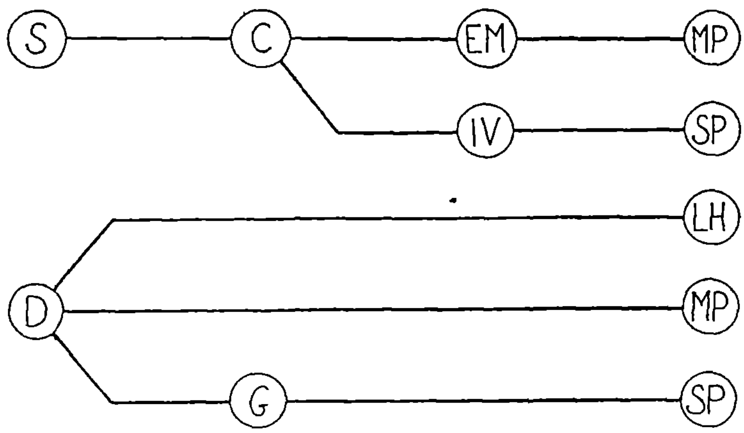


Figure 1- *Technical energy source and pump options*

Explanation used symbols:

S Solar panels

C Control box, containing an on/off switch and electronic components, including a MPPT, maximum power point tracker, for an optimal use of the produced power.

D Diesel engine

EM Electric motor

G Generator. A generator produces the electric energy needed to feed a submersible pump.

IV Inverter. Turns the direct current (DC) produced by the solar panels into alternating current (AC).

LH Lee Howl. This is a very old type mechanical reciprocating pump. The rotation of the crankshaft of the diesel engine is directly transferred by a V-belt into the reciprocating movement of the pump. The Lee Howl pump is not produced anymore.

MP Monopump. This is a mechanically driven pump. Mechanical energy is delivered by a DC electric motor (solar) or directly transferred to the pump from the motion of the engine crankshaft via a belt.

SP Submersible Pumps. Submersible pumps are lowered into the boreholes. An electric motor working on AC is integrated in the pump. Expensive wiring is needed to conduct the current from the inverter or generator to the motor.

4 THE COMMUNAL BOREHOLE ORGANIZATION

4.1 Initial factors

The active concern of the community is required to maximize the efficient use of a borehole. Communities feel more concerned for their borehole when they have contributed to the initial construction costs. Especially with solar it often happens that equipment is donated by donors without any efforts of the community. These boreholes are doomed to failure since the community doesn't feel any responsibility.
Most of the successful boreholes are constructed on request of the community and partly paid by her members.

Initial factors for the successful running of a borehole are:
* The borehole must be wanted by the communty itself.
* The community has to contribute to the costs.

A lot of organization is required to ensure the proper running of the borehole. To acquire this there have to be an operator and a borehole committee. The borehole committee should consist of at least four responsible and motivated members, a chairman, a secretary, a treasurer and the operator. The first three members are usually respected wazee[1], who have a lot of influence in the community. Their tasks consist of all the financial and organizational matters concerning the borehole. These members should be chosen by the community or Group Ranch. The prime task of the operator is to carry out all operation and maintenance tasks. The operator should be an official member of the borehole committee, since he is the one who knows everything about the borehole and the borehole users.

4.2 The operator

The job of an operator is a responsible job. His knowledge and skills make him indispensible for the community. The job should be done by a suitable, motivated person. It is recommended for the operator to follow an operator course. His improved skills and enlarged knowledge will positively effect the running of the borehole. The official 'operator's certificate', obtained after the operator training course, will give him more appreciation and respect from the community, which will encourage him to perform his tasks as good as possible.

The salary of the operator must be according to his function and capacities. To be able to attract the right, literate person, a salary of at least Ksh 2000,- a month, continued in the rainy season, must be offered.

[1] Plurism of the Swahili word 'mzee', which is a respectable title of an eldery man.

The tasks of the operator can be divided into two main components:

A Technical
B Administrative

Diesel driven systems

A Technical tasks

These systems need an operator who performs the operation and maintenance tasks. These tasks mainly consist of:
* Daily checking/adding fuel and oil.
* Changing oil and airfilters every 250 hours of running.
* Changing fuelfilter every 1000 hours of running.
* Keeping equipment and surroundings clean and tidy.

B Administrative tasks

The condition of a diesel engine depends largely on a proper performance of the maintenance tasks. The registration of the running hours makes it very easy for the operator to see which maintenance task has to be performed next. The collecting and registration of maintenance and regular running data has to be done by the operator in the 'operator's book'. An example of this book is included in Enclosure II.

Contents of the 'operator's book':
* Hours of running.
* Performed maintenance tasks.
* Special events like breakdowns.
* Litres of used fuel and oil

Solar driven systems

A Technical tasks

Solar systems need very little maintenance. An operator is not necessary, but there should be a watchman. He should be around day and night, since the solar panels are very attractive to thieves. This watchman should perform the following tasks:

* Cleaning the panels every other day.
* Keeping all equipment and the surroundings clean and tidy.
* Detect any abnormality of the system and report this if situation may demand.

B Administrative tasks

No operator's book is needed. The maintenance of a solar system has to be performed every other day (cleaning of the equipment), there is no need to register operating hours. Major maintenance has to be registered by the borehole committee (see further).

4.3 The borehole committee

The borehole committee should take care of all financial and organizational matters concerning the borehole.

Diesel sites

Especially the running of a diesel powered borehole requires a lot of organization, since a constant flow of money is necessary to buy the daily diesel. Besides, money is needed to pay the salary of the operator and to pay the expenses on spare parts and repairs.

Tasks:

1 Collecting cash from the users of the borehole.
2 Buying diesel.
3 Buying oil and spare parts.
4 Arranging repairs in case of breakdowns.
5 Administration.

Ad 1
To provide the borehole with diesel, people can contribute money or diesel. In most cases a certain monthly amount per cow is paid to the borehole committee or the operator. This money is used to buy diesel. This is recommended instead of contributing diesel, since it is an easy and fair way to collect the required money. Domestic water and watering smallstock is usually free.
The contributing of diesel is not recommended for the following reasons:
- Different qualities of diesel will be mixed (water is a common contaminent).
- The danger exists that people want to see their own diesel used entirely. This has the consequence that after every portion of diesel, the fuel line has to be bled. This means an unnecessary wearing of parts.

Both situations will harm the engine.

Ad 2
The best thing is to buy diesel in bulk to avoid mixing of different qualities of diesel.

Ad 3
It is recommended to collect monthly more money than is required to buy diesel only. This extra money has to be used to pay the expenses on other regular costs like oil, filters and the salary of the operator. It can also contribute to long term maintenance.

Ad 4
The following actions should be undertaken in case of a breakdown:
- Reporting the breakdown to an involved organisation like ASAL, AMREF or to a repair company.
- Buying spare parts (if necessary).
- Arranging a technician to come to the borehole.
- Raising money to finance the repair.

It was found that normally the monthly raised amount is not sufficient to finance repairs, so the committee has to raise extra money.
The popular options to raise this money are:
- Organize a harambee[2].
- Determine how much every boma[3] has to contribute considering the number of cattle.
In case of a breakdown the committee can ask ASAL for organizational and financial assistance.

Ad 5
There should be an administration book of which an example is included in Enclosure II. It has to contain the following:

* The monthly payments of the people. Including registration of name, number of cattle, date of payment and paid amount.
* The expenses on oil and spare parts.
* The number of litres of diesel bought.
* All other expenses, including the salary of the operator.

This book should be accessible to all community members, so everyone can check the expenses.

Solar sites

With solar less organization is required, since the only regular cost is the salary of the operator. The advice to community owned boreholes is to maintain a borehole committee with the following tasks:

1 Collecting cash from the users of the borehole.
2 Arranging repairs in case of breakdowns.
3 Administration.

Ad 1
It is recommended that community members contribute a certain amount a month until an amount is raised which will be sufficient for major repairs. This amount should be paid per boma and be based on the number of cattle and/or users. However, it will be very difficult to convince the people of the need to pay, since the water is also flowing when they don't pay. This amount has to be put on an account. From then on only a little amount a month has to be raised to pay the salary of the watchman.

Ad 2
Since the technical principle of solar is not easily understood by the watchman or borehole committee members, professional assistance has to be arranged by the committee in case of breakdowns. If they haven't saved a sufficient amount, money has to be raised by the committee.

Ad 3
A record of the following should be kept:

* The amounts of money paid by the community members.
* The monthly payments (salary of the operator).
* All other expenses.

[2] Organized voluntary fund raising

[3] Group of traditional huts, usually inhabited by one Maasai family and surrounded by twigs and thorn bushes.

5 THE INSTITUTIONAL BOREHOLE ORGANIZATION

There is no need for a borehole committee at institutional sites since the responsible bodies are the institutions themselves. The institutions or some selected persons take care of the organization and finances. Operation and maintenance can be performed by either an employed operator or by the responsible persons themselves. It is advised to appoint one individual as the responsible person to ensure his commitment to the system. All operative and organizational tasks are the same as described under the communal borehole organization. The collecting of the necessary cashflows will be different at these sites. Money will be subtracted from schoolfees, governmental or institutional budgets.

6 CALCULATIONS FOR SOLAR

To calculate the required array size the following parameters should be specified:

1. The total pumped head h
2. The daily required water volume V
3. The daily solar insolation I
4. The efficiency of the system e

ad 1. The total pumped head (in metres) is the sum of the static and the dynamic head. The static head is easy to measure. This is the total height, from the bottom of the borehole to the inlet of the storage tank, over which the water is pumped. The dynamic head is caused by frictional losses. Since it is neglectable compared to the static head it is not further considered.

ad 2. The daily required water volume, expressed in m^3/day can be calculated from table 1.

Table 1- *Water requirements for various purposes*

Use	*Daily requirement*
Domestic	
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
Livestock	
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
Irrigation	
including conveyance and field application losses	5 to 10 mm or 50 to 100m^3ha

ad 3. The insolation rate is expressed in $kWh/m^2/day$. The insolation rate is depending on latitute and varies during the year. In calculations one should use the insolation rate of the 'design-month', which is the month with the lowest insolation. Global maps for daily insolation in summer and winter are included in Enclosure I.

ad 4. The efficiency of the system is influenced by the following factors:

* The pumped head
* The insolation rate
* Years of operation

In calculations one can use an average efficiency factor e of 0.25 to 0.30.

If these parameters are known, one can calculate the total number of Wattpeak with the following formula. Wattpeak (Wp) is the number of Watts one panel produces under ideal circumstances.

$$Wp = 1000 \times VHP / (367 \times I \times e) \qquad (1)$$

VHP is the Volume Head Product to be found by multiplying the volume V by the head h.

Assuming I = 5.5 $kWh/m^2/day$ and e = 27%, this formula can be simplified to:

$$Wp \times 0.55 = VHP \qquad (2)$$

The total amount of Wattpeaks of the system, Wp_{total}, is the sum of all individual Wattpeaks, Wp_{ind}, of the panels.The number of panels can be determined with the following formula:

$$Wp_{total} = \text{number of panels} * Wp_{ind} \qquad (3)$$

Standard situations

To determine whether solar energy has enough capacity to power a waterpump, some calculations have been made. To do this the following was assumed:

* A daily insolation rate of 5.5 kWh/m^2.
* The hydraulic energy proportional to the insolation and to the number of Wp.
* An efficiency factor of 0.27.
* The Wp or Wattpeak is the number of Watts the panel produces under ideal circumstances.
* The Wp of one solar panel is equal to 53 W.
* The amount of water needed by people and animals is as given in Table 1.

From the information of all the sites visited, three solar 'standard situations' have been drawn up.

<u>Situation I</u>
Large and small livestock and domestic use.

Large livestock:	2000 head - every two days
Small livestock:	4000 head - every day
People:	500 - every day

This makes the required daily amount of water $60m^3$.

Situation II
Small livestock and domestic use. Large livestock is taken to other water sources.

Small livestock: 4000 head - every day
People: 500 - every day

This makes the required daily amount of water 25m^3.

Situation III
A school and a dispensary.

School: 250 persons
Dispensary: 5 members of personnel
50 patients a day

This makes the required daily amount of water 8m^3.

In table 3 the number of required panels is calculated for each situation and varying heads, using formula (2) and (3).

Table 2- *Number of panels needed in standard situations*

	I	II	III
h = 50m	103	43	14
h = 100m	206	86	27
h = 125m	257	107	34

Solar only can be remunerative for communal boreholes when cattle is not allowed.
Using the given formulas and using 53Wp panels, it is calculated that when the maximum number of panels is 32 and the number of people is 500 and the number of goats 4000 (situation II, V=25 m^3), the maximum head is 37m. When the number of goats is reduced to 2000 (V=15 m^3), the head may be 62m.

In table 3 an indication is given of the volumes that can be pumped, given the head and the number of panels.

Table 3- *Volumes of water pumped (in m^3 per day) according to number of panels and pumped head (following formula (2))*

Number of panels (53W)	50m	70m	90m	110m	130m	150m
12	7	5	3.9	3.2	2.7	2.3
16	9.3	6.7	5.2	4.2	3.6	3.1
20	11.7	8.3	6.5	5.3	4.5	3.9
24	14	10	7.8	6.4	5.4	4.7
28	16.3	11.7	9.1	7.4	6.3	5.4
32	18.7	13.3	10.4	8.5	7.2	6.2
36	21	15	11.7	9.5	8.1	7.0
40	23.3	16.7	13	10.6	9.0	7.8

The price of one 53W-panel is Ksh 34,950. This is equivalent to about 700 US dollars (July 1994). In costs calculations a maximum of 32 panels in one system is assumed. This is also the maximum number of panels in one system appaering in the field

7 CALCULATIONS FOR DIESEL

All information used in these calculations is derived from Lister manuals.

7.1 How to select your engine

To find the right engine it is necessary to determine the capacity needed. The capacity is exprssed in horse power (hp). Lister gives the following formula:

hp = ((litre/minute * head (m))/4578) * 100/efficiency (4)

Litre/minute is the pumped volume of water per minute. Head is explained in the previous chapter. The efficiency is the efficiency of the pump and is 50 percent (Grundfos, Denmark).

Once the engine is chosen, one can determine the fuel consumption per hour of running:

l/h = (((gram/kWh) * kW)/839) * L (5)

The fuel consumption, as well as the oil consumption, can also be found in Lister tables. In these tables a full load is assumed. To come to the actual fuel consumption a load factor (L) of 0.6 should be used.

Table 4- *Common Lister diesel engines info. All prices in Kenyan shillings (Ksh)*

Lister Type	Hp	Fuel l/h	Engine Price	Oil l/24h	Filter fuel	Filter oil	Filter air
HR2	22.6	4.88	n.a.	0.87	995	634	2098
SR2	10.0	2.35	n.a.	0.42	541	1396	1477
TS2	12.0	2.57	551.508	0.46	718	1396	1178
TS3	18.0	3.86	665.820	0.69	718	1396	1178
ST2	14.6	3.18	n.a.	0.57	542	1396	697

n.a: Not available. These types of engines are not sold anymore.

Note: When these calculations were made 50 Ksh were equivalent to 1 US Dollar (July, 1994). However, this rate is not stable.

7.2 Standard situations

For the calculations to find the required capacity in horsepowers, the standard situations have been used again:

Situation I V = 60m^3, h = 50, 100, 125m
Situation II V = 25m^3, h = 50, 100, 125m
Situation III V = 8m^3, h = 50, 100, 125m

Table 5- *Required number of horsepower in standard situations, given a certain running time*

		50m	100m	125m
60m³	10 hours	2.2 hp	4.4 hp	5.5 hp
	6 hours	3.6 hp	7.3 hp	9.1 hp
25m³	6 hours	1.5 hp	3.1 hp	3.8 hp
	4 hours	3.6 hp	7.3 hp	9.1 hp
8m³	4 hours	0.7 hp	1.4 hp	1.8 hp
	2 hours	1.5 hp	3.1 hp	3.8 hp

Capacities of common Lister engines in the District:

HR2/1500rpm: 22.6 * 0.35 = 7.9 hp
SR2/1500rpm: 10.0 * 0.35 = 3.5 hp
TS2/1500rpm: 12.0 * 0.35 = 4.2 hp
TS3/1500rpm: 18.0 * 0.35 = 6.3 hp
ST2/1800rpm: 14.6 * 0.35 = 5.1 hp

The factor 0.35 is the efficiency factor of a Lister engine.

Considering these data, the most demanding job, pumping 60m³ from a depth of 125m, should be done by a TS3, running 10 hours. The least demanding job, pumping 8m³ from 50m, should be done by a SR2, running 2 hours. This engine is not sold anymore so calculations are made with the most suitable available engine, the TS2, running 2 hours. It is assumed that the borehole yield is sufficient.

TS3, 10 hours : 23.2 litres of diesel, 0.29 litres of oil
TS2, 2 hours : 3.1 litres of diesel, 0.04 litres of oil

7.3 Filterchanges

Table 6- *Filterchanges*

Type of filter	Filterchange (in hours of running)
fuelfilter	1000
airfilter	250
oilfilter	250

According to table 5 the following filter changes are necessary during one year:

TS3:	fuel	4 times	SR2:	fuel	1 time
	oil	14 times		oil	3 times
	air	14 times		air	3 times

Although it appeared that in the field the necessary filterchanges are usually not performed, the calculations are based on the advised number of changes.

7.4 Annual operation and maintenance costs

The annual operation and maintenance costs for the described cases are:

TS3, running 10 hours a day, $V=60\ m^3$, $h=125\ m$

item	l/day	days	number	price(Ksh)	total (Ksh)
diesel	23.2	365		24	203,232
oil	0.3	365		98	10,731
fuelfilter			3	718	2,154
oilfilter			13	1396	18,148
airfilter			13	1178	15,314
TOTAL					249,579

TS2, running 2 hours a day, $V=8\ m^3$, $h=50\ m$

item	l/day	days	number	price(Ksh)	total (Ksh)
diesel	3.1	365		24	203,232
oil	0.05	365		98	1,786
fuelfilter			1	718	2,154
oilfilter			3	1396	18,148
airfilter			3	1178	15,314
TOTAL					240,634

8 COMPARITIVE COSTS

To be able to compare the costs of diesel to solar powered pumping technologies several cost factors should be determined. There are the initial costs, divided into general site costs and capital costs, and the operation and maintenance costs.

8.1 Initial costs

All costs involved with the construction of the borehole and supplying it with pumping equipment are initial costs.

1 General initial site costs:

- digging of the borehole
- storage tank
- cattle trough
- borehole house
- cattle dip
- pipelines
- distribution taps
- fencing
- installation and construction costs

2 Capital costs

Diesel:
- Lister engine
- foundations

Option 1:	Option 2:
- generator	- monopump
- submersible pump	
(including electric motor)	
- wiring	
- controls	

Solar:
- panels
- inverter

Option 1:	Option 2:
- submersible pump	- monopump
(including electric motor)	- DC electric motor
- wiring	- wiring (only surface)
- controls	

8.2 Operation and maintenance:

Diesel:
- fuel
- filters
- oil
- salary operator
- spares and repairs

Solar:
- salary watchman
- spare parts and repairs

In this comparison only capital and regular operation and maintenance costs are considered. General site costs are the same for both solar and diesel powered systems. To make a viable cost estimate they should be determined but in this case they are not differentiating and are not considered further.

Remarks:
* All costs are just rough indications. In all cases prices should be rechecked.
* Only regular running costs are considered under maintenance and operation.

8.3 Costs example

Calculations belonging to Situation III:
$V = 8m^3$ $h = 100m$

Diesel TS2, running 1.5 hour

Initial costs:	Engine TS2	551,508 Ksh
	Engine + generator	720,000 Ksh
	Submersible pump	86,000 Ksh
	Wiring	26,000 Ksh
	Monopump	147,000 Ksh
Annual O & M costs:	Fuel filter 0.5/year	359 Ksh
	Oil filter 2/year	2,792 Ksh
	Air filter 2/year	2,356 Ksh
	Fuel	20,261 Ksh
	Oil	1,028 Ksh
	Salary operator	24,000 Ksh

Solar

Initial costs:	Panels 28 * 53W	978,000 Ksh
	Inverter	106,000 Ksh
	Submersible pump	86,000 Ksh
	Wiring	31,200 Ksh
	DC electro motor	
	Monopump	
Annual O & M costs:	Salary watchman	12,000 Ksh

8.4 Costs tables

$V = 60m^3$ $h = 100m$ (Situation I)

	Initial costs	O & M cost	O&M in % In. costs
Diesel TS3-SP 14A-18	970.000,-	200.750,-	20 %
Diesel TS3-MP P301	812,800,-	200.750,-	25 %
Solar-SP			

$V = 25m^3$ $h = 100m$ (Situation II)

	Initial costs	O & M cost	O&M in % In. costs
Diesel TS2-SP 5A-25	871.000,-	114.300,-	13 %
Diesel TS2-MP P301	698.500,-	114.300,-	16 %
Solar-SP			

V = 8m³ h = 100m (Situation III)

	Initial costs	O & M cost	O & M in % of In. costs.
Diesel TS2-SP 2A-27	832.000,-	51.000,-	6 %
Diesel TS2-MP P301	700.000,-	51.000,-	7 %
Solar-SP 2A-27	1.202.000,-	12.000,-	1 %

Solar is more economical after 9½ years.

$V = 15m^3$ $h = 60m$ (Most demanding situation where still solar can be used)

	Initial costs	O & M cost	O&M in % In. costs
Diesel TS2-SP 5A-8	795.600,-	51.000,-	6.5 %
Diesel TS2-MP P301	700.000,-	51.000,-	7 %
Solar-SP 5A-8	1.327.200,-	12.000,-	1 %

Solar is more economical after 13 years.

note: All price information is dirived from Kenyan componies (September, 1994)

9 SOLAR VERSUS DIESEL

9.1 SOLAR: Positive points

General

1.
There are no technical skills required to control the system. The person who cleans the panels and from time to time might switch the system on and off, doesn't need special education.
2.
There are no daily running costs (diesel).
3.
There is very little maintenance required.
4.
Solar energy is an environmental friendly technology

Institutional

1.
There is an obvious responsible person: the headmaster or the headnurse.
2.
Donors are very willing to sustain projects like schools, dispensaries and hospitals. They can pay for the system and leave, there are no continuous costs. When the installation is done the actual project is finished, so the donor does not commit herself to a longlasting responsibility.
3.
There is a continuous source for money: the schoolfees. From this money the watchman can be paid and when every month something is put aside, there will be money in case of a breakdown.

4.
A school, dispensary or hospital needs every day a certain amount of water. When a breakdown occurs, there are no persons who have time to go and get water for everybody elsewhere, so the need of having the system repaired is urgent. They will soon undertake action to get it fixed.
5.
No specific operator is needed to control the system. At institutions there will already be a watchman. This person can carry out the operator/watchman tasks, so there won't be extra salary costs.

Communal

1.
Only a watchman is needed, which lowers the salary costs, since a watchman earns less than a skilled operator.
2.
Since the capacity of solar isn't enough (under the Kajiado District circumstances) to pump water for domestic use as well as for livestock, the borehole will be mainly used for domestic water. This will make the water cleaner and safer, since there are no cattle around to soil the water. This concerns especially sites without a specific domestic water supply.

9.2 SOLAR: Negative points

General

1.
Solar is not a common technical principle. Repairs have to be carried out by experts who are expensive and not local available.
2.
Repair and replacement costs are high.
3.
Solar panels are attractive for thieves.
4.
When solar is the only energy source at the site the chance exists that there will not be enough water on cloudy days (no energy back-up).

Institutional:

1.
When the system breaks down and money is needed, it will probably be a high amount. So the treasurer of the school, hospital or dispensary has to be able to make some monthly savings. It may be possible that e.g. schoolfees are not sufficient so money has to be found somewhere else. This will obviously not be easy.
2.
Local people will inevitably come to draw water. It is not easy to ask money from these people, as they don't see how this money is used -there are no expenses like fuelcosts- and they don't regard servicing the pump as their responsibility as it is not theirs.
3.
The quality of water from alternative watersources, like shallow wells, is not high enough to be used for institutional use. When irradiation is too low, there are no alternative water sources available.

Communal

1.
The system's purchase costs are too high to be raised by a community on their own.
2.
When a donor donates a solar system or pays a considerable part of the purchase costs the communities won't consider the installation as their property and therefore not as their responsibility. When a breakdown occurs, the chance that they will have it repaired is very little. Certainly when there are other watersources like shallow wells, seasonal rivers or small dams around.
3.
Every boma should pay a monthly amount to pay the salary of the operator and to build up some reserves for future breakdowns. But when people don't pay, the water will still be flowing so it will be hard to convince them to pay.
4.
The job of the watchman is quite boring. Apart from cleaning the equipment and surroundings there is not much to do. This makes his concern with the job low. When he can get another job, he might just as well leave. Or when he gets too bored he may neglect his work and leave the site, giving thieves a chance.
5.
There is no active committee needed to run the borehole properly, this will decrease the concern of the committee and community. When action is needed in case of a breakdown, nobody will feel responsible and the chances will be high that nothing will happen.

9.3 DIESEL: Positive points

General

1.
Diesel engine theory is a common technology in Kenya, since it is used for a lot of purposes, e.g. posho mills and car engines. This makes knowledge and materials easily available.
2.
The technology of the engine is understandable for the operator. In most of the cases he can see whether there is something wrong with the pump or the engine and he can inform the right technician.
3.
The job of an operator is an intensive job. There is a lot to do, so he stays busy and his concern with the work is high.
4.
The amount of pumped water is depending on the diesel input. When there is enough diesel, the engine can run as many hours during day and night as required to pump the needed volume of water.

Communal

1.
It is easy to collect money and to determine how much every boma has to pay (a month a cow). No money is no diesel is no water. A certain amount can be saved to have something in case of repairs.
2.
There is a high concern of the community, since they have to pay every month for their water.

3.
A lot of organizational tasks has to be carried out by the borehole committee. This encourages an active attitude of the committee and, as a result of the committee's members position in the community, of the community.

9.4 DIESEL: Negative points

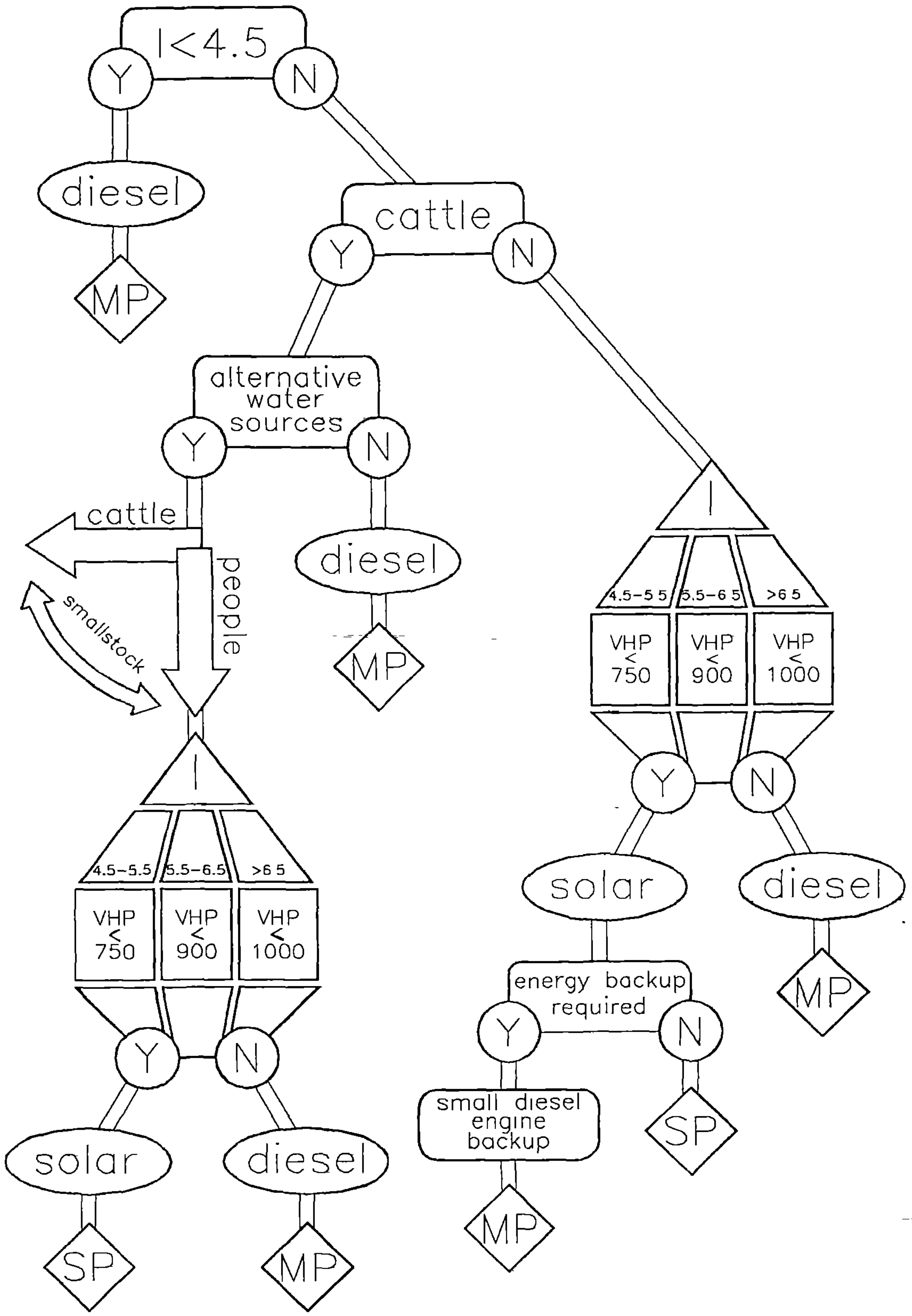
General

1.
Continuous costs for fuel, oil and spare parts.
2.
A lot of maintenance is needed to prevent breakdowns and assure an efficient running borehole.
3.
A diesel engine produces a lot of pullution, noise and smoke.

Institutional

1.
An operator has to be employed, this means extra salary costs.
2.
It will be more difficult to determine how much everybody has to pay since there is no cattle to be counted.

10 DECISION CHART



The Decision Chart gives a rough indication in the choice between diesel and solar powered borohole water pumping technologies. Given certain circumstances, you will be guided to the most suitable energy source and to the best type of pump. In the previous chapters advice is given on the borehole organization. This organization is of crucial importance for the succesful running of the borehole. No technology option can be succesful without a proper consideration of the points mentioned in the chapters 4 and 5, about the communal and the institutional borehole organization. This division is in the Decision Chart marked by step two, livestock; yes or no. The answer 'yes' indicates the communal boreholes, 'no' implicicates institutional boreholes, but can also indicate communal boreholes in areas where no livestock is kept. The Chart can also be used to give an advice on pumping technologies for irrigational or private purposes.

I = Insolation rate
Global maps for daily insolation rates are included in Enclosure I.

VHP = Volume Head Product (in m^4)
To calculate the required water volume one should use table 1, which containts daily requirements for various purposes.

Alternative water sources are water sources like shallow wells, rivers, small dams, lakes, where livestock can be watered. For a positive answer on this question these sources have to be operational during the whole year.

MP = Mono pump

SP = Submersible pump

Energy backup required. When during the whole year a certain amount of water must be guaranteed, a small diesel engine as an energy backup can be considered. In this case a mono pump is the most economical pump type.

11 RECOMMENDATIONS

11.1 Solar for institutional use

Solar panels as energy source for water pumping are a renumerative option for institutional use. Reasons for a possible succesful implementation of solar for this purpose are mentioned in chapter 9.1, Solar: positive points for institutional use.
However, one should be aware of the basic conditions for a succesfull use of solar in these situations.

Important 'succes-factors' are:

* There should be at least one responsible person at the site. This person, who can be the headmaster or a nurse, should be fully aware of his/her responsiblity and has to control all organizational and financial matters and should undertake action whenever needed.
* A watchman is indispensible for the protection of panels and equipment. This watchman should be around day and night.
* In order to built up an account for eventual future breakdowns there should be done monthly savings since the sum of money required to finance repairs is to high too be raised at once.

To avoid insecurity in the cold season and at rainy days it is recommended to have an energy back up. A small diesel engine is the most economical option in combination with a monopump.

11.2 Solar for communal use

Solar is **not recommended** for communal use for the reasons mentioned in chapter 9.2, Solar: negative points for communal use. This study has proven that the capacity of solar is under the Kajiado circumstances not sufficient to pump enough water for both people and livestock.

However, in some situations it will be possible to use solar as a power source for pumping water. The Decision Chart is a usefull mean to get a quick indication whether solar is possible for communal use. When the Decision Chart gives solar as a possible option for pumping water one should ensure the the following conditions:

* The community should participate in the choice and should be aware of the consequences considering financial and practical (no cattle allowed) matters before the installation.
* The community contributes in the initial costs.
* In no cases cattle can be allowed at a solar site. At relative shallow boreholes (max. 60 m deep) smallstock is possible.
* In all cases there should be a watchman around, during day and night.
* There has to be a committee who takes responsibility of financial and organizational matters.
* Borehole users should contribute a monthly amount, in order to be able to build up an account.

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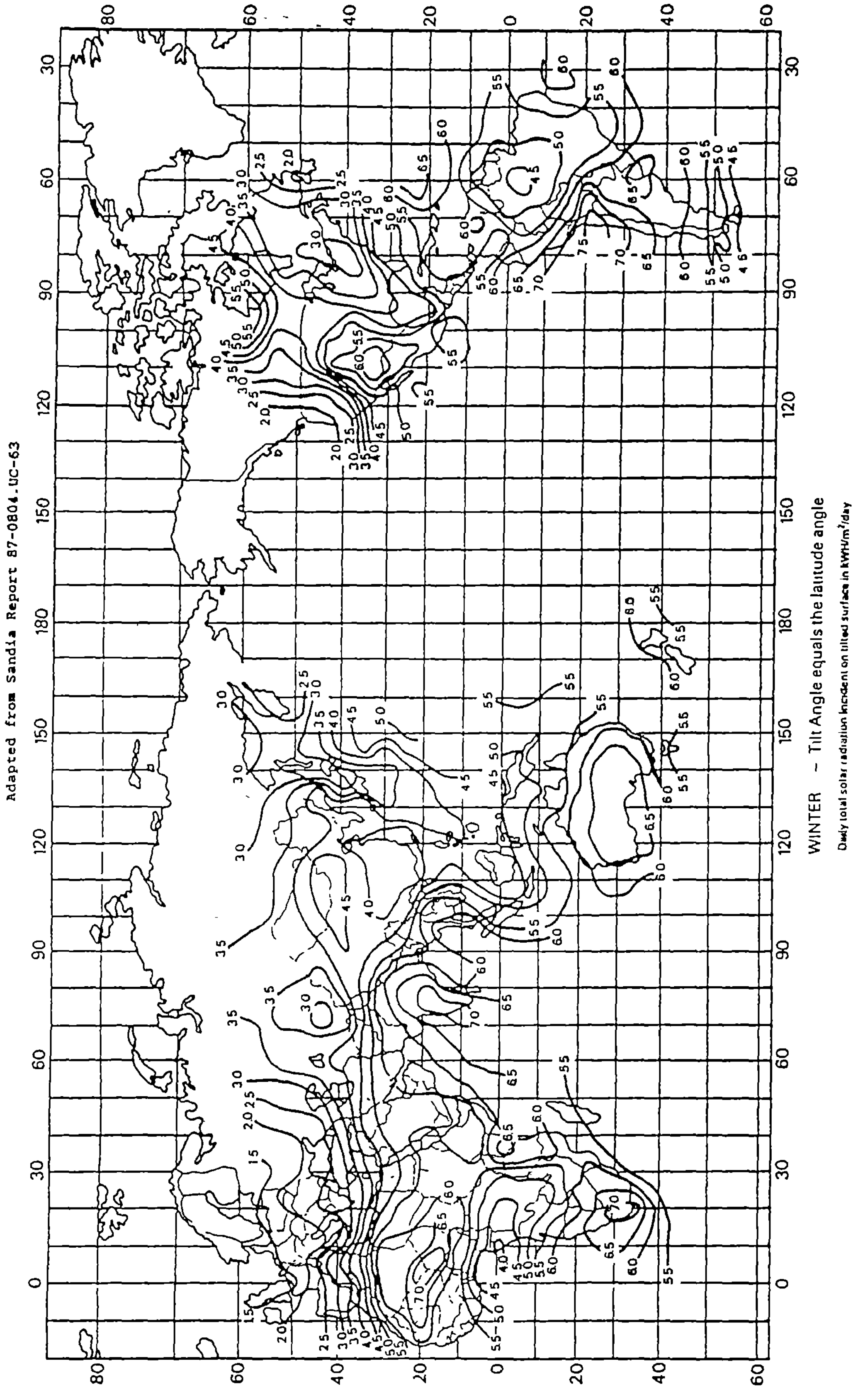
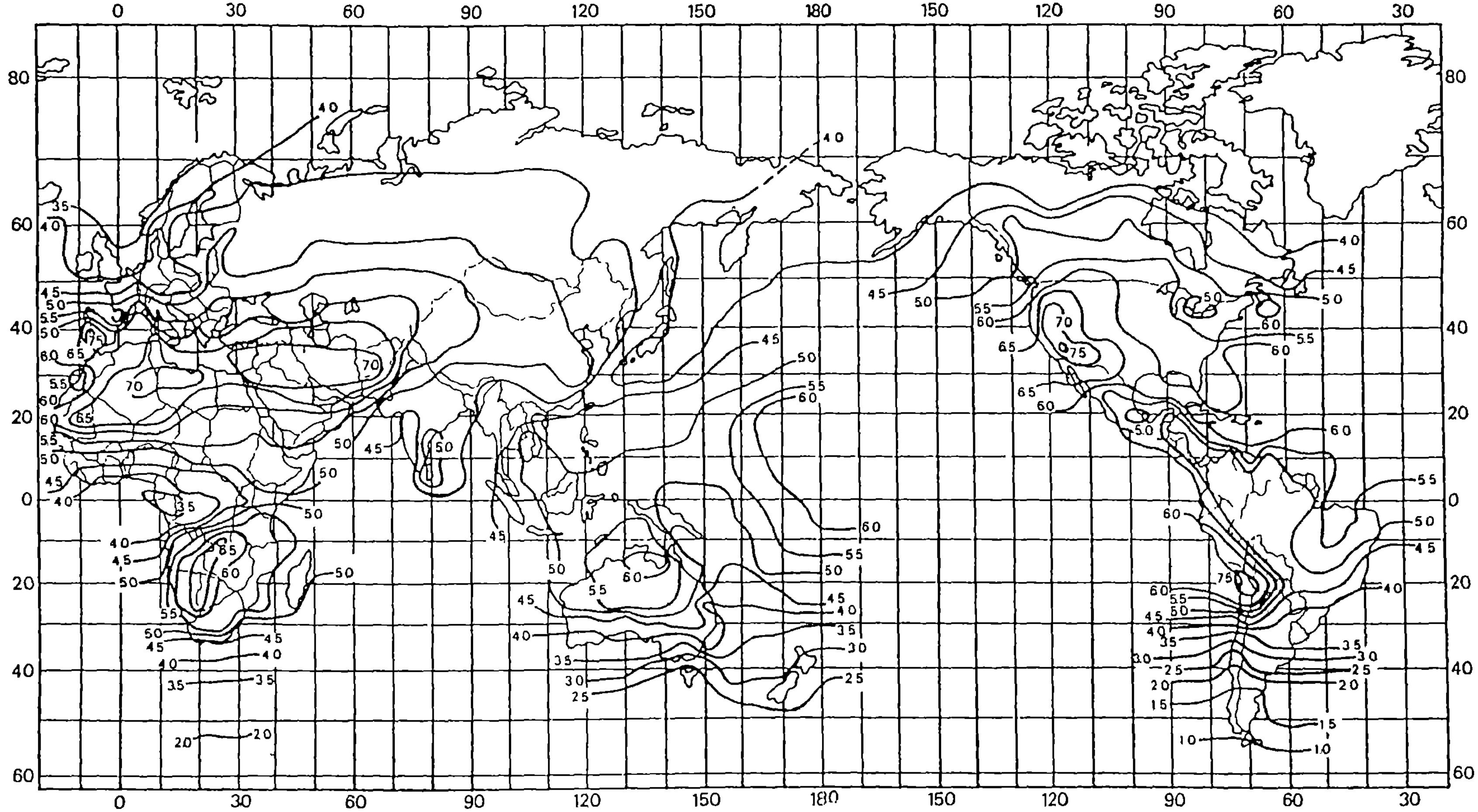
Enclosure Ib : Global Insolation Map in Winter (December to February)



Enclosure Ia : Global Insolation Map in Summer (June to August)

Adapted from Sandia Report 87-0804.UC-63



SUMMER – Tilt Angle equals the latitude angle

Daily total solar radiation incident on tilted surface in kWH/m²/day

Enclosure II : Examples of Administration Books

Date	Start time	Stop time	Hours	Litres diesel	Performed maintenance, remarks

Date	Name	Cows	To pay	Paid	Balance	Signature treasurer, remarks

Date	Expense	Product / Repair	number, litres	Signature treasurer and remarks