# Mission Report:

**Access to Modern Energy Services – Mozambique**

**Equipment of Social Infrastructure with Photovoltaic Systems:**
**Definition of System Requirements and Costs**
**Further Directions of Project**

**Project Name:** **Access to Modern Energy Services Mozambique – AMES-M**

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**Abbreviations:**

| | |
|---|---|
| AC | Alternating Current |
| AGM | Absorbing Glass Mate |
| AMES | Access to Modern Energy Services |
| CE | Conformité Européenne |
| CFL | Compact Fluorecence Lamp |
| DC | Direct Current |
| DDP | Deep Discharge Protection |
| DOD | Depth of Discharge |
| EMU | Eduaro Mondlane University |
| FL | Fluerscence Lamp |
| GSM | Global System for Mobile Communication |
| GTZ | Gesellschaft für Technische Zusammenarbeit |
| IT | Information Technology |
| IEC | International Electrotechnical Commission |
| KWh | Kilowatthour (Energy) |
| LED | Light Emitting Diode |
| lm | Lumen |
| MZM | Mozambique Metical |
| NGO | Non Government Organisation |
| PCM | Phase Change Material |
| PV | Photovoltaic |
| SHS | Solar Home System |
| SME | Small & Medium Size Enterprize |
| TV | Television |
| WHO | World health Organisation |
| Wp | Watt peak power |
| UL | Underwriters Laboratories |
| UV | ultraviolette Light |

# I) Status Report

## A) Health Centres

**There are four kinds of health centres in rural Mozambique:**

**1) "Rural Hospital"**

**Rural hospitals are fully equipped hospitals in charge of several districts. They have more than 10 beds, operation rooms and sundry doctors.**

**2) "Centro de Saude Rural Tipo I"**

**These are medium sized well equipped hospitals with an average of ten staff.**

**3) "Centro de Saude Rural Tipo II"**

**These health centres are small, local hospitals. Their main responsibilities are to provide the community with access to prenatal and antenatal maternity care, vaccination for children and general health care. They have on average, four staff. These health centres service around 14,000 to 18,000 people.**

**4) "Posto de Saude"**

**These health centres are small and only for local health care. According to a Ministerial decree adopted in 2002 many of these places will being upgraded to "Centro de Saude Tipo II". Currently the posto de saude health centres are operated by volunteers and are typically opened several days a week for few hours.**

**Our visits concentrated on the health centres designated as "Centro de Saude Rural Tipo II". These centres are spread all over Mozambique. The province of Sofala alone has approximately 80, while in whole of Mozambique there are around 600. We visited five centres[1] in Goonda, Savana, Xiluvo, Gondola and Muda Serracáo. Our visits gave us a good overview about the existing situation and the modern energy demand.**

**The health centre in Xiluvo is the only one of the centres we visited, connected to the grid. Most centres had a gas powered refrigerator, but in three out of four cases, no gas was present at the time of our visit. Only the refrigerator at the Savana health centre was working during our visit.**

**In the Goonda health centre there was a PV powered refrigerator (from general electric). The doctor in charge said that it had stopped working after few days. The PV system was used solely for the refrigerator, not for light.**

**In another location, we found another PV system, but we discovered that this system is only used for water pumping into a salty water layer, rendering the pump useless.**

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[1] Dondo District: Savane; Chibabava District: Goonda, Revue; Nhamatanda District: Xiluvo (grid-connected), Gondola District: Muda Serração (solar-powered fridge)

Health centre in Savana

**General observations:**

**From our visits, we have the impression that many of the investments for health centres have not reached the intended target. For example the refrigerator system in the Goonda health centre that is not functioning and the useless PV pump in another of the health centres. In both these instances the systems are not working or are useless for various reasons. The situation is similar where gas refrigerators were found. In most cases continued support for the material that is consumed and for the repair is absent. This factor is significant, as the maintenance and supply chain is at least as important as the system itself.**

**The worst situation, in terms of energy, was found in the Xiluvo health centre. This health centre has grid connection; however, power fails on average every two weeks. The typical duration of blackout is one to seven days. This makes the situation at this health centre unpredictable. The health centres, equipped with gas refrigerators, are at least able to predict when the gas will run short.**


Xiluvo was the only health centre we visited with a grid connection

**All health centres have an urgent demand for electrical light. Currently, paraffin lamps and occasionally candles are used. These materials should be provided by the province but quite often there is a shortage. Even when the paraffin is available, the brightness and quality of light is not sufficient for the needs of the health centres. (A paraffin lamp provides about 20-50 lm, a candle even less than 10lm.) In one case a midwife reported to us that she often uses the light of her mobile phone for illumination, to support the women during birth. Light from a mobile phone will not provide much more light than a candle and will certainly limit the ability of the midwife to assist the birthing mother effectively.**

Paraffin lamps are the main source of light

**All health centres, we visited, had refrigerators. In three cases these were absorption refrigerators powered by gas or paraffin. In one health centre an electrical refrigerator had been installed. Only one of these refrigerators (an absorption refrigerator) was working during our visit. The other two refrigerators were out of gas. In such circumstances, the doctors and nurses have to organise to bring the vaccine to the central hospital or another place to keep them stored. The power consumption of these refrigerators is two 10 Kg bottles of methane or butane gas which represents about 250 KWh of thermal energy (roughly 8 KWh of thermal energy per day). The lack of available gas seems to be one of the major problems of the health centres.**

**A 50l refrigerator is large enough to keep necessary vaccine for this type of health centre.**

**Beside a cooling compartment is there a freezing compartment. This is used to freeze water in "cooling accumulators" or ice packs which are used, together with portable cooling boxes, to transport the vaccine to the place of vaccination (or often to take the vaccine for temporary storage in the central hospital, if there is no gas to run the refrigerator in the health centre).**

**The freezing compartment could be very small as the “cooling accumulators” are small in volume.**

**In one health centre we saw an electric refrigerator. It was powered by a battery that is charged by a 400Wp amorphous solar generator. The refrigerator used AC, this means an inverter was required. This refrigerator broke down after only a short time.**

Gas refrigerator in Savana

**In the hospitals sterilizers are used, these operate with a wood fire. It seems to work in an acceptable way. However, in one instance a nurse told us that she had to pay out of her own salary for the firewood that was needed, since the money did not arrive from the government.**

**In all the health centres we visited, there were wells. Mostly these operate by hand, which is acceptable. In one case a solar system had been used to power a water pump, unfortunately the well was improperly dug and the well pumps only salty water. Salty water cannot be used, rendering the pump a useless investment.**

**Some of the health centres also have houses for the staff in the same neighbourhood. The staff that we spoke to expressed a wish to supply these staff houses with electricity for light, radio (and probably TV).**

**Comments:**

**The situation with light is unacceptable. To have no light poses a risk to the mother and the baby in the maternity wards, as treatments during birth cannot be properly done without light. Also, in other cases of emergencies medical staff is very limited by the lack of light. Mistakes with procedures as well as reading medical dosages etc. can be made.**

**The current situation with the refrigerators is inefficient since gas is often unavailable as well access to gas or the funds to purchase it is limited.**

**Sterilisation seems to work effectively under the current system.**

**Water pumping, by hand, seems to be effective and acceptable.**

**Recommended requirements:**

**All of the health centres that we visited had 4-5 rooms each with a lamp (250lm) for at least 6h/day. In the consultation room and in the birthing room it would be advisable to have 800-1000lm with an average usage time of 2h/day.**

**A 50l (or more) refrigerator should be bought and installed in each centre. In order to be robust, energy saving and reliable, it should have a brushless DC compressor (e.g. Danfoss BD35).**

**Besides cooling the vaccines it is also important to have a space for "cooling accumulators" or ice packs. These "cooling accumulators" are used to keep the vaccines at a low temperature during transportation so that they remain viable. Proper transportation is necessary when bringing the vaccine to a remote school or village to vaccinate people there. Also proper transportation is often necessary to bring the vaccines to other hospitals, when gas is not available.**

**To sterilise water or medical equipment a temperature of 60-70℃ is sufficient. To be sure that a sterilisation process is done very well water should be boiled for a few minutes. Due to the existence of gas bubbles in boiling water it is very easy to know when the correct temperature is reached, even for untrained people. Therefore, boiling water is a safe and reliable way to sterilise.**

**The recommendation for water pumps needs to be assessed on an individual basis. The water table is very different in different locations. This has a significant influence on the type of pump and the power consumption that is required to run the pump.**

## B) Schools

**In the province of Sofala there are about 850 schools. It is estimated that there are around 10.000 schools in Mozambique.  In the country side the schools are mainly primary and secondary schools. Most schools would like to offer evening classes for adults if they could have light in the evening. However, it is more likely that offering evening classes would be feasible only at schools where a sufficient number of people live within walking distance (2-3 km)**

Simple School from outside and inside

**Status:**

**Most schools in rural areas do not have access to electricity. Out of the 850 schools in Sofala Province, only 70 are currently connected to the grid, 6 have a generator, and 5 have solar panels. We visited 5 schools[2].**

**Classes for adults, which would be preferably held in the evening, are often given in the afternoons during months when people are less busy tending to their crops (June-November). Sometimes candles and paraffin lamps are used.  In several cases the teachers and school directors have indicated that it would be enough to illuminate 2 to 3 classrooms for the purposes of holding evening adult education classes.**

**In secondary schools, the national curriculum intends to implement IT classes. This implies that ideally each school should have an IT classroom equipped with 30 computers (1 computer per 2 students) and a projector (for the students to follow the teacher's actions). Note: The projector is an idea of the author. Since such projectors are not common and often unknown in rural areas. No teacher asked for a projector.**

**Often, besides the classrooms, dormitories exist in larger schools that board pupils. These dormitories are lit by candles or paraffin lamps. This is insufficient for pupils to study and has safety concerns for fire.**

[2] Escola Primaria Completa e Escola Secondaria: in Savane (Dondo District) and Vunduzi (Gorongosa); Escola Primaria 1: in Mecondeze and Matengo (both Nhamatanda); Escola Primaria Completa: Muda Mufo (Nhamatanda; this school has a solar system).

In most cases in Mozambique the teachers live near to the schools. For many teachers it is not very attractive to teach in rural areas. Electricity in the schools, even for basic needs could help to attract teachers to rural schools.

Often the schools offer lunch for the children. This is sometimes a reason for the parents to send their children to school. The storage of large quantities of food often makes it necessary to have a watchman. The school directors have indicated a need to have a security light on at night to deter thieves and increase the general safety of the school.

In the schools kitchen, firewood is used for cooking. Mainly open fireplaces are used. These open fires consume a lot of firewood. One school had a wood saving stove, however, it was not in use because it was perceived to be slow in cooking and impractical (the opening for the firewood is too small, requiring finer chopped wood).

We had the chance to visit one school which had already been electrified with solar, installed in December 2008. This school is equipped with a solar generator of about one KWp. The solar part of the system is separated in two individual solar generators with two charge controllers but only one large battery. This system has a high value charge controller (from Morningstar) and an expensive industrial battery. The system voltage was 12V.

The load on the system includes three class rooms, each equipped with 6 pc of 18W DC CFL lamps (estimated not more than 700lm). In addition, are there two such lamps in the teachers' room and two outdoor DC CFLs with 9W (estimated 500lm).

School with Solar electrification

Except for two 9W lamps, all 18W tubes had broken only three months after installation. The teachers have not been able to get spare lamps since that time (it was unclear whether they tried). In addition, in one class room some of the cables were stolen during school holiday as these class rooms were not locked.

Two teachers' houses were also equipped with solar systems for lighting (each had two 9W CFL lamps and one desk lamp). These lights were still working at the time of our visit.

Comments:

Good light could help to make much better use of the school facilities for adult education. It might not be necessary to illuminate all classrooms. Only those which are needed for evening classes should be electrified.

**It would be good to introduce modern technology, such as computers and internet, at least to secondary scholars. It also would help the teachers to have better access to educational content.**

**Computers and projectors open totally new opportunities in student and adult teaching.**

**Wood saving stoves need to be adapted to the local needs. Fast cooking stoves would help to save firewood. Some training or sensitisation may be required.**

**The existing PV system, we have seen, is generally proper sized (even oversized) but it suffers from bad or not working load. One problem might be that inexpensive, but inefficient and unreliable loads had been chosen. Maintenance and supply of spare part also seems to be an issue.**

**Requirements and Recommendations:**

**For a typical classroom two lamps with about 800-1000lm, close to the blackboard, would help pupils to see the teacher and the blackboard clearly. Four more lamps in the classroom, with about 500lm, would enable the students to read and write.**

**In the dormitories it would be beneficial to have one corner illuminated where kids could read books. As well there should be a basic illumination in the rest of the dormitories for pupils to be able to move safely.**

**The same illumination would be good in the teachers' homes.**

**An outdoor LED security light (40lm) on at night would help the guard to protect the goods of the school.**

**To have two computers (one for the teacher but also one for the students to use) would give the children many opportunities for personal and professional development. The teachers could update their knowledge over the internet.**

**Equipment with low maintenance requirements should be used. Supply of spare parts should be organized together with maintenance.**

**Comment:**

**In all types of schools it would be advantageous to have access to a digital projector to show videos and slide shows to support teaching. A projector can help in IT classes to function with a lower number of computers. The projector might also be an ideal medium for adult classes. Projecting short videos would be an effective way to educate illiterate people on many topics.**

## C) Solar Home Systems

**Most homes in rural Mozambique have paraffin lamps for lighting. These lamps are expensive to use, dangerous, dirty and not very bright (about 30lm). Candles are even more dangerous and less bright (10lm). Small radios are often powered by dry cell batteries. This kind of energy supply is expensive. People pay up to 250 MTM (about 10$) per month for paraffin and batteries. The used batteries are not disposed of well in the local environment and may harm ground water and other resources in the long term.**

Paraffin lamp made out of an old tin

**There is a strong desire to use solar energy for above applications. Often people expressed a desire to be able to use TV and loud audio speakers for entertainment.**

**Comments:**

**It would be highly economical to use solar systems in homes to get this kind of electricity service.**

**People use 50l or more paraffin every year. Due to the general price trend it has become more and more expensive.**

**Each year houses burn down from accidents with paraffin lamps and candles.**

**The rooms where candles and paraffin lamps are used get smoky, creating an unhealthy living environment.**

**The light is not bright enough to be able to read and write without putting strain on your eyes.**

**Dry cell batteries harm the environment and are very expensive, particularly in local contexts (over 50$ per KWh).**


The end of an African dry cell battery.

**Comments on existing SHS (Solar Home Systems):**

**SHS have been seen on the market on Moxungue, but also on the road along the route where we have been travelling. We interviewed the owners of privately bought SHS and concluded the following:**

**Most SHS we have seen where installed along the road and bought by people privately. A small amount of these systems have been bought over AMES and Kulima, which are NGO partners of GTZ.**

**Existing SHS's have the following problems:**

**The solar module is mostly a cheap Chinese made, amorphous module. These are coming from former "Chronar" factories in Shenzhen and Harbin in China. These products have quite a short life span but a very low cost.**

**The modules are also at high risk for being stolen. So owners put the module in the sun during the day and then return it to the house every night. Partial shading of the module (and the power losses combined with that) and the increased risk of broken cables (non UV resistant cables are used) are a problem.**

**On these systems, the connection to the battery does not use a charge controller and overcharging can harm the battery.**

**Since a charge controller is absent, there is also no blocking diode to prevent discharging of the battery over the module at night. This can happen if the module is disconnected from the battery every night,**

**The connection to the load is also done without a charge controller. Deep discharging and especially sulphation very often shorten the life span of the battery. Sulphation happens if a battery is uncharged for a longer period of time.**

**The connection between modules, battery and load is done using clamps. These clamps often lead to short circuit or loose connections.**

"Battery pack" with connectors
(seen on the market in Moxungue)

**The used batteries (AGM or flooded) are acceptable but not best for this application. Gel batteries would be better suited, since gel batteries experience low sulphation.**

**The used lamps are drastically insufficient. Low efficiency and a short lifespan do not provide people with a good service. One of the tubes in a system we saw at ISE institute was measured with about 34lm/W. To make the situation worse, the lamps often only last a few months.**

**The radios used are of a cheap quality.**

**Often (mainly in the private systems but also in few cases of the NGO systems) the loads were operated over a small inefficient inverter. This wastes more than 50% of the energy, increases the cost and lowering the lifespan of the system.**

**TV sets are too large for the small systems and lead to a short battery life.**

**Conclusion: The existing systems are inefficient and can be much improved. The design of the current systems shortens the life span of the components and results in a high cost for energy.**

**The local GTZ office suggested a compact solar home system. A compact system would help to solve the quality problem. It is our opinion that this kind of compact system should be introduced to the people and implemented in the market.**

**Recommendations:**

**People mainly need electric light. It should be brighter than a paraffin lamp. The exact demand of lumens would depend on the individual circumstance but it would likely be between 100 and 600lm, which is 3 to 20 times brighter than a paraffin lamp and 10-60 times brighter than a candle.**

**There is also a strong demand to power radios, cassette players and TVs. Most people can afford a radio, only a few can afford a TV.**

**Thief protection is an important issue.**

**Refrigeration is in discussion with shop owners but out of reach for people at home.**

## II) Suggestions

**General suggestions (for social infrastructure projects)**

**All loads should be professional DC loads to increase efficiency. This practice also limits the risk of misuse of the system as standard AC plugs are not available.**

**In all systems it is recommended to use charge controllers with data loggers. These data loggers allow easy identification of problems and failures. In a SHS it is also recommended to use the data loggers, at least for the pilot phase.**

**The systems should be sized and designed in a way that maintenance is not necessary for a long time period (even years). The user poses a high risk to the system as the user may add loads to the system and cause an overload of the system.**

**To ensure that the system is not misused, but also to have an early replacement of broken components, it would be strongly recommended implementing a maintenance service. This maintenance service should be privately run. A maintenance service could also help to electrify Mozambique on a private basis.**

**A two to three month maintenance time would be adequate. The maintenance should be documented and monitored by using a report sheet and by collecting the read out the data logger. The reports should be collected and brought to a central place.**

**System Sizing Philosophy (for all system suggestions including SHS):**

**To create an excellent system, a high quality load with high reliability and low power consumption must be chosen. Even if an efficient and reliable load is more expensive, the overall system will become much less expensive since the solar system itself would become much smaller.**

**The solar module and battery should be oversized to have system stability and long battery life (due to less sulphation). A high quality Gel battery should be used to limit sulphation.**

### a) Health Centres

**Light:**

**Since people are used to kerosene lamps (30lm) it is hard to know precisely what level of illumination should be suggested. However, it is suggested to use 5W lamps which should provide at least 50lm/W (means 250lm totally) for all rooms for basic illumination. This is about 8 times brighter than a kerosene lamp. For calculation 6h working time per lamp is estimated.**

**For the birthing and treatment rooms a lamp with 800lm is suggested. This can be done with a lamp of about 13W (with 60lm/W).**

**Refrigeration:**

**Each health centre should have at least one refrigerator for vaccine. It is estimated that the power consumption will be max. 160Wh/day.**

**Beside the demand on refrigeration for vaccine it also is necessary to have the ability to freeze ice packs.**

**Eventually it will be ideal to have a second refrigerator to freeze the ice packs for vaccine transportation. Depending how often the ice packs are needed it probably could be switched on only when there is demand. In a worst case the constant use of the second refrigerator may require an extension of the system.**

**Another option could be to use a phase change material (PCM) in the ice packs to be able to freeze them at 2-4℃ (which would reduce the power consumption). This option would have to be tried out carefully in a pilot before implementing this on a wider basis to better understand the variables at play. If it is possible to implement use of PCM ice packs, the system would become much simpler, less expensive and more reliable.**

**Mobile phone:**

**Mobile phones are increasingly necessary for people in rural areas and require charging. Mobile phones are used by the staff during the day in the health centre and in the evening for emergency calls. Mobile phone use could also help to establish communication over the internet.**

**Sterilisation:**

**It is not recommended to use PV electricity for sterilisation. Sterilisation in only needed once or twice a week. To boil water a PV system would need to generate several times the energy of all other loads put together. The peak of energy consumption on the days that sterilisation is required, would disturb the system design and lead to a significant increase in cost.**

**The following alternatives can be discussed:**

**For sterilisation the existing method is sufficient and practical, except in cases were there is not enough money provided for firewood. It is recommended to use wood saving fireplaces.**

**Alternatively gas cookers can be used. Presently gas is used for refrigeration. For sterilisation one bottle would last at least six months. In some provinces in Mozambique this method is already used.**

**In a few health centres it is recommended that solar cookers be tried to see if they can be used effectively and efficiently for this purpose. Using solar cookers for food preparation had so far been unsuccessful, since people typically do not eat hot meal during the daytime. For sterilisation this should not an issue. In all probability, the existing sterilisation pots can be kept. It might be necessary to blacken them by a special selective light absorbing colour.**

Solar cooker can be used for sterilisation

**The author prefers a solution with a so called "solar cooking box" These solar cookers need not to be adjusted all the time to the sun. They are not expensive and are easy to operate. Such cookers have been criticised for cooking because they need 2-3h of sunshine to start the cooking process. For sterilisation it is not so important how fast the water heats up.**

Solar cooking box

**Water Pumping:**

**A general solution cannot be suggested for water pumping since the ground water level is different in each situation. However, usually only small quantities of water are necessary. Therefore a "Solar ram" can be used with a separate module. This solution would be good for a pump head of 20-30m.**

Solar ram pump

**Since the water consumption seem to be relative low (below 1000l/day) a so called "Solar Ram" can be used. This has to be seen as an individual small system. This pump is robust and it costs less than 1000€.**

**Total power consumption of a health centre:**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light | All rooms | 4 | 5 | 250lm | 6 | 120 |
| Light | Labour ward/ Treatment | 2 | 15 | 900lm | 3 | 90 |
| Cellphone | | 1 | 2 | | 1 | 2 |
| Refrigerator | | 1 | 60 | 3℃ | 3 | 180 |
| | | | | | Sum | 392 |
| | | | | | Ah/day | 32,67 |

**The power consumption in the health centre will be at about 400 Wh/d (33 Ah/d). The necessary level of illumination should be tested in an actual situation to confirm this. Electric water pumping is not necessary and for sterilisation a gas or solar cooker could be used. There is also enough energy to freeze the PCM ice packs.**

**The necessary system will be;**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 200 | 800 |
| Battery [Ah] | 233,33 | 466,67 |
| Regulator [A] | 40 | 90 |
| Lamps [pc] | 8 | 80 |
| Refrigerator | 1 | 700 |
| Others | | 500 |
| Installation | | 500 |
| | Total cost[$] | 3136,67 |

**All costs are estimated using ex works distributor prices, excluding custom tax. The prices in Mozambique will be higher since different taxes have to be added. Complicated transportation may also increase the cost.**

**In case the use of PCM ice packs do not lead to a satisfying result, a second refrigerator would be required. This refrigerator would have its temperature set below 0℃ to be able to freeze ice packs. A pilot test is required to see if it is necessary to operate this refrigerator all the time or if it is possible to switch it on only when there is demand. The following table is the worst case scenario with a continuously running second refrigerator.**

**Extension if a second refrigerator is needed:**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Refrigerator | | 1 | 60 | -3℃ | 4 | 240 |
| | | | | | Sum | 240 |
| | | | | | Ah/day | 20 |

**This will cause additional extra costs of:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 100 | 400 |
| Battery [Ah] | 142,86 | 285,71 |
| Refrigerator | 1 | 700 |
| Others | | 30 |
| Installation | | 30 |
| | Total cost[$] | 1445,71 |

**The extension for the second refrigerator would not an independent system. The module size and the battery have to be added to the system which has been calculated for one refrigerator.**

**Risks:**

**Main risk is that the refrigeration system is misused (e.g. to cool drinks for visitors and staff or offering charging service to local people).**

**Possible extensions:**

–**TV set for waiting Area**

**A TV set with 15" screen diameter will consume about 15W. If it is operated for 6h a day it will need a total of 90Wh/day. If there is no TV signal, a DVD player might be needed, consuming an additional 90Wh/day.**

**It is recommended to allow TV only if the state of charge of the battery is over 70%. Therefore an extra deep discharge protection (DDP) would be needed. It has a higher set point as the general DDP which is built in the charge controller. It also would be possible to buy a second charge controller and use only the DDP for this controller.**

**– Charging of excess batteries for staff**

**It would be possible to use excess energy to charge batteries only when excess energy is present. Therefore the module of the system does not need to be enlarged. It only needs a special electronic to divert the excess energy to the second battery.**

**– Using an inexpensive cooling box to cool drinks with excess energy**

**The module does not need to be enlarged. A special electronic would be used for the second battery.**

**All these methods can help to keep the battery relatively full and prevent sulphation. The use of excess energy can motivate the staff to keep the main battery relative full and to produce as much excess energy as possible. Ensuring that the main battery remains full the majority of the time will increase the reliability of the system and the life span of the battery. The organized use of excess energy could also help to prevent the misuse of the system.**

**– To enable better communication and information it might be helpful to use computers and the internet. See detailed description below at schools.**

**All extensions should be first tried out in few locations before they are used in a large number of systems. We are confidant about the technical function but need to learn more about the social impact of the extensions.**

## a2) Alternative design:

**It would also be possible to design the health centre based on AC loads.**

**At first glance it seems to be an advantage to design an AC System. The following arguments have been made for AC:**

– **AC loads are more common and it is easier to get spare parts**

– **AC loads are cheaper because of mass production**

– **Installers are more familiar with AC systems**

**Upon closer look, these advantages do not actually exist in reality:**

**In an AC system the loads which are needed for a hospital, are mainly lamps and refrigerators. In case of the lamps CFL of FL types could be used. They could be equipped with the same spare tubes whether there is a DC or AC power supply. These lamps have an efficiency which is high enough for a solar PV power supply. If the lamp breaks usually only the tube needs to be replaced. DC and AC CFL lamps have in principal the same tubes. This means the same spare parts are required and have the same availability. Rather than simply using an AC system it would be more practical to use DC or AC lamps with such tubes which are commonly available.**

**For cooling, a special refrigerator with high efficiency and high reliability would be necessary. Normal AC refrigerators, as they are used for households, should not be used. They are not reliable enough and have very high energy consumption. Since a special refrigerator is needed anyhow, it would not make any difference if a DC or a special AC refrigerator is bought. Both cannot be found on the normal local market.**

**Solar Systems are by nature DC systems. The solar module is generating DC and the battery also needs DC supply current for charging and discharging. If AC loads are used, it is necessary to use an inverter to transform DC into AC. The use of an AC refrigerator makes it necessary to have very powerful inverter which is able to start the AC compressor. The power surge of such a compressor can easy achieve 2KW. The nominal power of an AC compressor (after it is running) is only 80-150W. This means that after the compressor is started, the power demand drastically decreases. An inverter with high power operated under low power will have only limited efficiency. The efficiency will decrease ever further when only one or few CFL tubes are switched on.**

**In addition AC loads typically have higher power consumption than DC loads. This lowers efficiency, add the efficiency losses from the inverter, and the total power consumption is much higher than of a smart DC system. The price of the system will be significantly higher since the system requires more energy to account for the losses as well as the cost of the inverter have to be considered.**

**Beside higher cost there are several more arguments against AC:**

**AC systems fail in the field more often as it is very easy for the user to buy a lot of different AC loads (hairdryer, iron, phone chargers etc) which could be connected to the system. Due to this misuse of AC systems many projects (School project in Brazil 2000; Rural electrification project in Thailand 2004) have failed completely.**

**The inverter (especially an inverter which is able to start a refrigerator) is an additional important source of complication that leads to failure. As the inverter that is needed is of a very special, high quality and is not locally available.**

**220V AC is a voltage which is already very dangerous to people. Since in many cases the system installers are under qualified, the installation material is of unknown origin and the tendency for manipulation tends to be high in Africa. With an AC system it has to be expected that accidents, sometimes with the deadly results, will happen.**

**12V DC is absolutely safe. This voltage can be touched and is even used in toys, without any insulation. This safety argument is important for health centres, but it is even more important for schools.**

**Calculation of a Health centre with AC power supply:**

**The power consumption for a system with AC loads would be higher since the load is less efficient. In addition the inverter generates some losses.**

| pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|
| 4 | 5 | 250lm | 6 | 120 |
| 2 | 15 | 900lm | 3 | 90 |
| 1 | 2 | | 1 | 2 |
| 1 | 60 | 3°C | 10 | 600 |
| | | | Sum | 812 |
| | | | Ah/day | 67,67 |
| | Efficiency Inverter 0,8 | | | 84,58 |

**Due to the higher energy consumption and due to the fact that an inverter is needed the cost for a system with AC loads will be higher.**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 500 | 2000 |
| Battery [Ah] | 604,17 | 1208,33 |
| Regulator [A] | 40 | 90 |
| Lamps [pc] | 8 | 40 |
| Refrigerator | 1 | 700 |
| Inverter | 1 | 600 |
| Others | | 500 |
| Installation | | 500 |
| | Total cost[$] | 5638,33 |

**An AC system designed for a health centre is about 80% more expensive than a system that uses DC loads with one refrigerator. If two refrigerators are be needed, the AC system for a health centre would cost about 25% more.**

## a3) Design with WHO compatible refrigerator

**It could be, that it is required to use an refrigerator which is compatible to the WHO standard (E03/RF06). The author know only one refrigerator which fulfill this requirement. It lead to higher cost since the unit itself is more expensive and because the power requirement is higher as well.**

**Calculation of a system with WHO compatible refrigerator:**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light | All rooms | 4 | 5 | 250lm | 6 | 120 |
| Light | Birth Place/ Treatment | 2 | 15 | 900lm | 3 | 90 |
| Cellphone | | 1 | 2 | | 1 | 2 |
| Refrigerator | | 1 | 60 | 3℃ | 9 | 540 |
| | | | | | Sum | 752 |
| | | | | | Ah/day | 62,67 |

**Cost estimation for this system:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 400 | 1600 |
| Battery [Ah] | 447,62 | 895,24 |
| Regulator [A] | 40 | 90 |
| Lamps [pc] | 8 | 80 |
| Refrigerator | 1 | 2500 |
| Others | | 500 |
| Installation | | 500 |
| | Total cost[$] | 6165,24 |

**Since the power consumption and the cost of such a WHO compatible refrigerator is much higher, it should be considered to use a system based on AC.**

## b) Schools

**For school electrification it would be possible to design different independent systems to fulfil the demand:**

- **Illumination for the classrooms**
- **Light and a computer for the school office.**
- **A computer and projector for the secondary schools**
- **Illumination for the teacher houses and dormitories**

**The systems, which are used for the different tasks, could be also combined. Therefore only the power of the modules and the capacity of the batteries must be added. It also must not be forgotten to have a charge controller which allows the higher current. The decision to combine systems should be decided on site. If the locations are close together then a combination is possible. If long distances exist between the systems then it is better to separate the systems.**

**Illumination for classrooms:**

**In one school, which we visited, we found 6 lamps of 18W. According to the school authority each lamp gives 800lm.**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light CFL | Classroom | 2 | 15 | 900lm | 4 | 120 |
| Light CFL | Classroom | 4 | 11 | 700lm | 4 | 176 |
| Outdoor LED | | 1 | 1 | 40lm | 12 | 12 |
| | | | | | Sum | 308 |
| | | | | | Ah/day | 25,67 |

**The power consumption would be a little over 300 Wh/d.**

**The necessary system will be:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 170 | 680 |
| Battery [Ah] | 183,33 | 366,67 |
| Regulator [A] | 20 | 60 |
| Lamps [pc] | 6 | 60 |
| Others | | 400 |
| Installation | | 500 |
| | Total cost[$] | 2066,67 |

**All cost are estimates using ex works distributor prices, excluding custom tax. Complicated transportation may also increase the cost.**

**Alternative design with AC loads:**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light CFL | Classroom | 2 | 15 | 900lm | 4 | 120 |
| Light CFL | Classroom | 4 | 11 | 700lm | 4 | 176 |
| Outdoor LED | | 1 | 1 | 40lm | 12 | 12 |
| Losses Inverter | | 1 | 1 | | | 77 |
| Self cons. Inv. | | 1 | 1 | | 24 | 24 |
| | | | | | Sum | 409 |
| | | | | | Ah/day | 34,08 |

**The power consumption with AC load is significant higher because of the different losses of the inverter.**

| Material | Quantity | Cost |
|---|---|---|
| Module [Wp] | 300 | 1200 |
| Battery [Ah] | 243,45 | 486,9 |
| Regulator [A] | 40 | 90 |
| Lamps [pc] | 6 | 30 |
| Inverter | 1 | 400 |
| Others | | 400 |
| Installation | | 500 |
| | Total cost[$] | 3106,9 |

**The system with AC loads is about 50% more expensive.**

**School administration office with computer:**

**There is a modern low power laptop computer used (Atom N270 controller) with Windows XP. We estimate that the average computer use would be 6h/d. Light will be used in the evening. It is estimated that 4h of light are needed in the offices of the secretaries and the directors.**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light CFL | Secretary&Director | 2 | 7 | 350lm | 4 | 56 |
| Computer Asus | Secretary&Director | 1 | 10 | N270 MC | 6 | 60 |
| Outdoor LED | | 1 | 1 | 40lm | 12 | 12 |
| | | | | | Sum | 128 |
| | | | | | Ah/day | 10,67 |

**The design is made with Laptop computers.**

**The cost for the administration part of the school will be:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 70 | 280 |
| Battery [Ah] | 76,19 | 152,38 |
| Regulator [A] | 10 | 50 |
| Lamps [pc] | 2 | 20 |
| Computer | 1 | 400 |
| Others | | 300 |
| Installation | | 300 |
| | Total cost[$] | 1502,38 |

**If desktop computers are required the power consumption will be about 4 times higher for the computer. The cost for the system will be at least 2000$ higher.**

**Alternative design with AC loads:**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light CFL | Secretary&Director | 2 | 7 | 350lm | 4 | 56 |
| Computer Asus | Secretary&Director | 1 | 10 | N270 MC | 6 | 60 |
| Outdoor LED | | 1 | 1 | 40lm | 12 | 12 |
| Losses Inverter | | 1 | 1 | | | 32 |
| Self cons. Inv. | | 1 | 1 | | 24 | 24 |
| | | | | | Sum | 184 |
| | | | | | Ah/day | 15,33 |

**Cost structure with AC laods:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 140 | 560 |
| Battery [Ah] | 109,52 | 219,05 |
| Regulator [A] | 10 | 50 |
| Lamps [pc] | 2 | 20 |
| Computer | 1 | 400 |
| Inverter | 1 | 400 |
| Others | | 300 |
| Installation | | 300 |
| | Total cost[$] | 2249,05 |

**Again the cost of the AC Design would be about 50% higher than the DC design.**

**Secondary School equipment:**

**For secondary schools computers are required to hold IT classes. To give the scholars the chance to have access to the computer it is suggested to have two computers in a school (one is used by the teachers). To involve the whole class with one computer it is recommended to use a projector.**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Projector Acer | Classroom | 1 | 40 | 150 ANSI Lumen | 4 | 160 |
| Computer Asus | Classroom | 2 | 10 | N270 MC | 6 | 120 |
| | | | | | Sum | 280 |
| | | | | | Ah/day | 23,33 |

**Power requirement is about 300 Wh/d.**

**Necessary system is:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 170 | 680 |
| Battery [Ah] | 166,67 | 333,33 |
| Regulator [A] | 10 | 50 |
| Lamps [pc] | 2 | 20 |
| Computer | 2 | 800 |
| Projector | 1 | 600 |
| Others | | 300 |
| Installation | | 300 |
| | Total cost[$] | 3083,33 |

**Alternative Design with AC loads**

| Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|
| Classroom | 1 | 40 | 150 ANSI Lumen | 4 | 160 |
| Classroom | 2 | 10 | N270 MC | 6 | 120 |
| Losses Inverter | 1 | 1 | | | 70 |
| | 1 | 1 | | 24 | 24 |
| | | | | Sum | 374 |
| | | | | Ah/day | 31,17 |

**The cost for the system with AC design is:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 200 | 800 |
| Battery [Ah] | 222,62 | 445,24 |
| Regulator [A] | 10 | 50 |
| Lamps [pc] | 2 | 20 |
| Computer | 2 | 800 |
| Projector | 1 | 600 |
| Inverter | 1 | 400 |
| Others | | 300 |
| Installation | | 300 |
| | Total cost[$] | 3715,24 |

**The costs are about 25% higher than with DC loads.**

## b2) Teachers Homes and Staff Homes

**The demand in SHS is for teachers and staff in health centres is similar. It is estimated that about 4h of light is needed in each of these homes as well as for a small powered radio. The system also allows charging of a mobile phone.**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light CFL | Inside | 1 | 5 | 250lm | 3 | 15 |
| Light LED | Outside | 1 | 1 | 40lm | 12 | 12 |
| Cellphone | | 1 | 2 | | 1 | 2 |
| Radio | | 6 | 0,3 | | 3 | 5,4 |
| | | | | | Sum | 34,4 |
| | | | | | Ah/day | 2,87 |

**Estimated cost for such a small system:**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 20 | 80 |
| Battery [Ah] | 20,48 | 40,95 |
| Regulator [A] | 5 | 20 |
| Lamps [pc] | 2 | 20 |
| Radio | 1 | 5 |
| Others | | 0 |
| Installation | | 0 |
| | Total cost[$] | 165,95 |

The system could be built as a compact system (as described under SHS). Therefore no installation would be necessary.

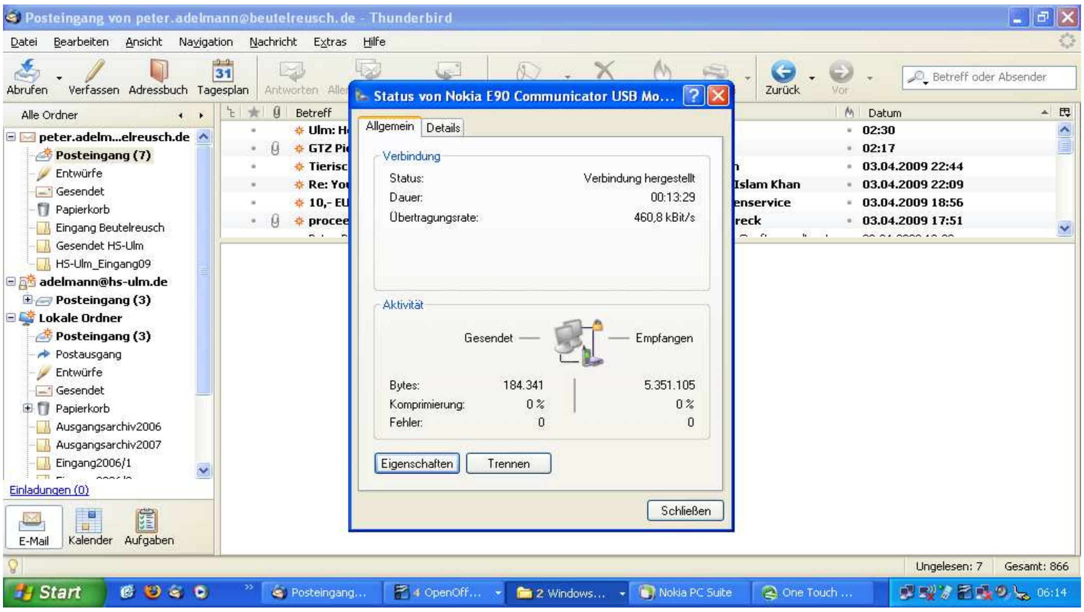
**For teacher and staff homes it would also be possible to use excess energy to charge a separate battery. This battery could be brought to the teacher/staff homes. This is possible because the systems are generally oversized. This use of excess energy could motive the teachers and the staff to keep the battery in the main system always relative full and prevent sulphation.**

## b3) Internet connection for schools and health centres

**For schools and health centres there is tremendous potential in having access to the Internet. Teachers can get the latest information over the internet. Small videos, images and animations can be downloaded and used together with the projector to enhance and enrich learning environments.**

**For health centres in addition email and internet could be an important way of communication and access to potentially life saving information. Also statistic and formal information from the schools or health centres can be collected via internet communication.**

**With some experiments it has been figured out that the internet access via mCel (one of the national mobile phone providers) is available in many places. The data speed, in locations, where the internet have been tested, was surprising high. The cost are with about 7 MZM (0,2€)/MByte which is surprisingly low. The recorded down load speed was more than 5 Mbyte/10min. This means that relative high speed is possible.**



Even high data volumes could be downloaded relative fast.

**Technically it is only necessary to use a mobile phone with internet ability or a USB stick which has the GSM receiver/transmitter integrated.**

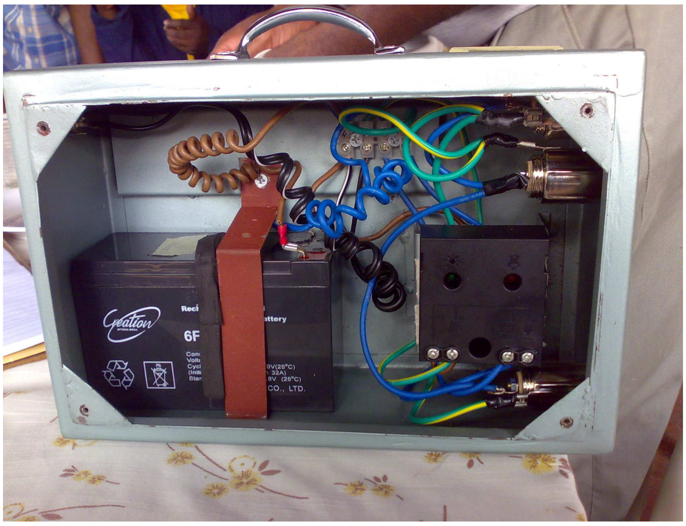

Internet access can be realized over cellphone or special data USB stick

**For the Internet there essentially no additional extra power necessary. The system sizing would not need to be changed.**

## C) Solar Home Systems (SHS)

**So far, the tradition in Mozambique is to use SHS with poor quality modules, no charge controller, batteries that are too large and an inverter to operate the load. This system design is expensive and performs poorly. Even the first investment for such systems is higher than properly designed systems.**

**GTZ/AMES Team in Mozambique found a good solution to solve many of the problems. A compact system has been designed and it could be introduced to several companies for production.**

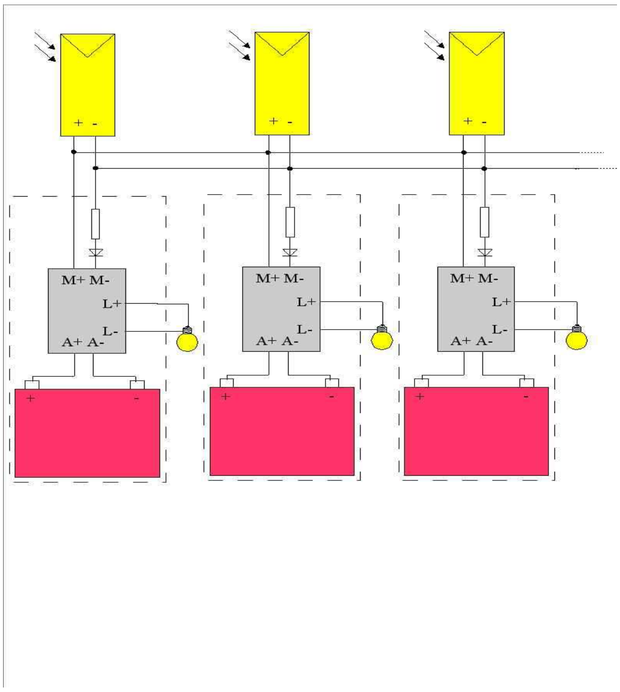


GTZ SHS is much better than traditional SHS in Mozambique

**There is very little to improve upon this system. Our suggestions would be to use a Gel battery instead of an AGM battery for less sulphation and to consider to use a plastic housing for lower cost.**


A plastic housing for the compact system could make the product less expensive

**The SHS could also be easy combined to be used together with the microhydro stations. The built in charge control is as serial controller and in principle is able to be connected in series with larger power sources. Only the maximum charging current has to be reduced over a simple serial resistor. The built in deep discharge protection prevents the battery from sulphation which is the main problem in such applications. Just by adding a solar module it can be transformed into an independent SHS.**




A solar or micro hydro charging station could be used for charging the compact system. By adding a solar module is can be transformed in an individual SHS at any time.

**By using modern LED lamps with a small solar module, a quite high energy service can be provided. It is possible to create a system for light (totally about 7h, mobile phone and radio).**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light LED | Inside | 1 | 2 | 150lm | 3 | 6 |
| Light LED | Outside | 1 | 1 | 40lm | 4 | 4 |
| Cellphone | | 1 | 1 | | 1 | 1 |
| Radio | | 1 | 0,3 | | 3 | 0,9 |
| | | | | | Sum | 11,9 |
| | | | | | Ah/day | 0,99 |

**The cost for such a system could be very low.**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 6 | 18 |
| Battery [Ah] | 7,08 | 7,08 |
| Regulator [A] | 5 | 5 |
| Lamps [pc] | 2 | 4 |
| Radio | 1 | 3 |
| Others | | 0 |
| Installation | | 0 |
| | Total cost[$] | 37,08 |

**Note: The prices are estimations for industrial prices ex works factory.**

**It seem to be possible to create a system, including all margins for 80-100US$ to the end-user. This is what an end-user normally pays in a 10 month period.**

**By using a charging station the user would be able to buy at first just the battery pack and the load. This will cut his first investment cost by factor 2 (40-50US$). Later he could complete it to a SHS just by buying the module.**

**Alternative design with AC loads:**

**The power consumption for an AC system is significantly higher compared to a system with DC loads. Especially when the stand by losses of the inverter significantly increase the power.**

| Load | Location | pc. | Power [W] | Service | Usage [h] | Engery [wh/d] |
|---|---|---|---|---|---|---|
| Light LED | Inside | 1 | 2 | 150lm | 3 | 6 |
| Light LED | Outside | 1 | 1 | 40lm | 4 | 4 |
| Cellphone | | 1 | 1 | | 1 | 1 |
| Radio | | 1 | 0,3 | | 3 | 0,9 |
| Losses Inv,& Pows. | | 1 | | | | 4,17 |
| Stand by inv. | | 1 | 1 | | 24 | 24 |
| | | | | | Sum | 40,07 |
| | | | | | Ah/day | 3,34 |

**Also the cost would increase a lot if an AC design is used.**

| | Material | Cost |
|---|---|---|
| Module [Wp] | 20 | 60 |
| Battery [Ah] | 23,85 | 23,85 |
| Regulator [A] | 5 | 5 |
| Lamps [pc] | 2 | 4 |
| Radio | 1 | 3 |
| Inverter | 1 | 100 |
| Others | | 0 |
| Installation | | 0 |
| | Total cost[$] | 195,85 |

**The cost of a design with an AC load would be 400% higher compared to a system designed with a DC load.**

**C1) Combination of SHS and charging stations**

**Based on micro hydro system and also based on a solar system it would be possible to create a charging station for the above mentioned SHS. The same charging station could be as well used for mobile phones.**

**If the described DC compact SHS would be connected to the charging station, an outlet with limited current at the charging station could be needed. In most simple case this could be done over a resistor. Inside the SHS box there would have to be a serial type charge controller used.**

**Charging ability for the SHS and for mobile phones would provide opportunity for several different business opportunities just with one charging station. This lowers the risk to fail with a charging station.**

**In cases of the mobile phone chargers it will be important to use quality original chargers from the mobile phone manufacturer.**

## D) Maintenance and Recycling:

### D1) Maintenance

**The systems are designed in a way that no regular maintenance is necessary. The foreseen gel accumulator do not need or even allow refilling with purified water.**

**Nevertheless it would make sense that somebody controls the system regularly to make sure that all components, wires and the loads are working. A service plan, which should include a checking of all components, must be worked out.**

**The maintenance would be also an excellent chance to strengthen the private sector, which is necessary for rural electrification of private homes. Small or medium enterprises or entrepreneurs (SME) should be used for the maintenance work. It is important that only qualified technicians or engineers should be allowed to do the maintenance work. As proof of their education they should hold qualifications in the field of photovoltaics.**

**It would make sense that companies, doing maintenance, also take care of the private market for rural electrification in the region where they do the maintenance. The schools and health centres that use solar systems would be excellent marketing objects for them. The payment for the maintenance work should be high enough to keep the entrepreneur and company interested to stay in the region. There should be, at the same time, a demand for them to make some extra money by selling SHS to the private market.**

**The maintenance work should be guided by a central organisation which coordinates maintenance (could be an existing organisation like FUNAE or the existing service for health centres, but it must be organised efficiently). This organisation should also make sure that maintenance is done and spare parts are always available wherever systems are in place.**

**To prove that maintenance work has been done, a check list should be filled out and signed by the headmaster of the school or the responsible doctor in the hospital. At the same time an integrated data logger would provide a second piece of evidence of maintenance having been done. The data file of the data logger should be sent to a central office. By cross checking the data logger with the data file assurances can be made of maintenance work being done.**

**The data logger would also help the central organisation for material planning of some spare parts like batteries.**

**The maintenance service could also assist in the recycling of broken components of the solar system.**

## d2) Recycling:

**So far it appears that there is no working recycling ability for lead acid batteries. Since such recycling systems work in other places in Africa (lead has a high material value) it should be possible to establish one in Mozambique as well. Solar modules are less crucial since they last quite long and usually contain non toxic material.**

**The move away from dry cell batteries and paraffin would be a benefit for the environment even if there is no recycling procedure for the solar systems established. The empty batteries are lying everywhere on the ground and together with spilled paraffin, poison the soil and the groundwater. Nevertheless it is possible and worthwhile to develop a recycling strategy for batteries, modules (and glass), broken electronic and also CFL and FL tubes.**

**It is important to take care with all broken components and to make sure that all toxic material is collected. All material which can be recycled should be recycled.**

**Most important is the lead acid battery (or other batteries) since the lead (or other battery materials) could harm both people and the environment. Also all kinds of CFL and FL tubes should be collected as they can contain mercury. For this project tubes with low mercury content should be used.**

**The above mentioned maintenance services could collect the broken batteries (as well as other broken components) and move them to a central collection point. Many of the collected materials (e.g. lead acid batteries) have a quite high material value which would make the whole procedure economical.**

**By having a kind of bookkeeping for the components, in the systems and as they are replaced, it should be possible to make sure that most of the components are recycled.**

## d3) Time frames and Quantities

**The most sensitive part of the system would be the batteries and the tubes of the lamps. The average life span of a good gel battery is about 5 years. A CFL Tube will last on average about 8000h.**

**If the lamps are used for 2000h a year (about 6h/day), it is expected that after 3 or 4 years replacement of a larger quantity will be needed. For 10,000 schools and health centres a quantity of 15,000 replacement tubes have to be calculated. The factory price for this quantity should be about 5,000 - 8,000US$/Year. After 3 to 4 years a replacement peak is expected. This peak will equalize after some time.**

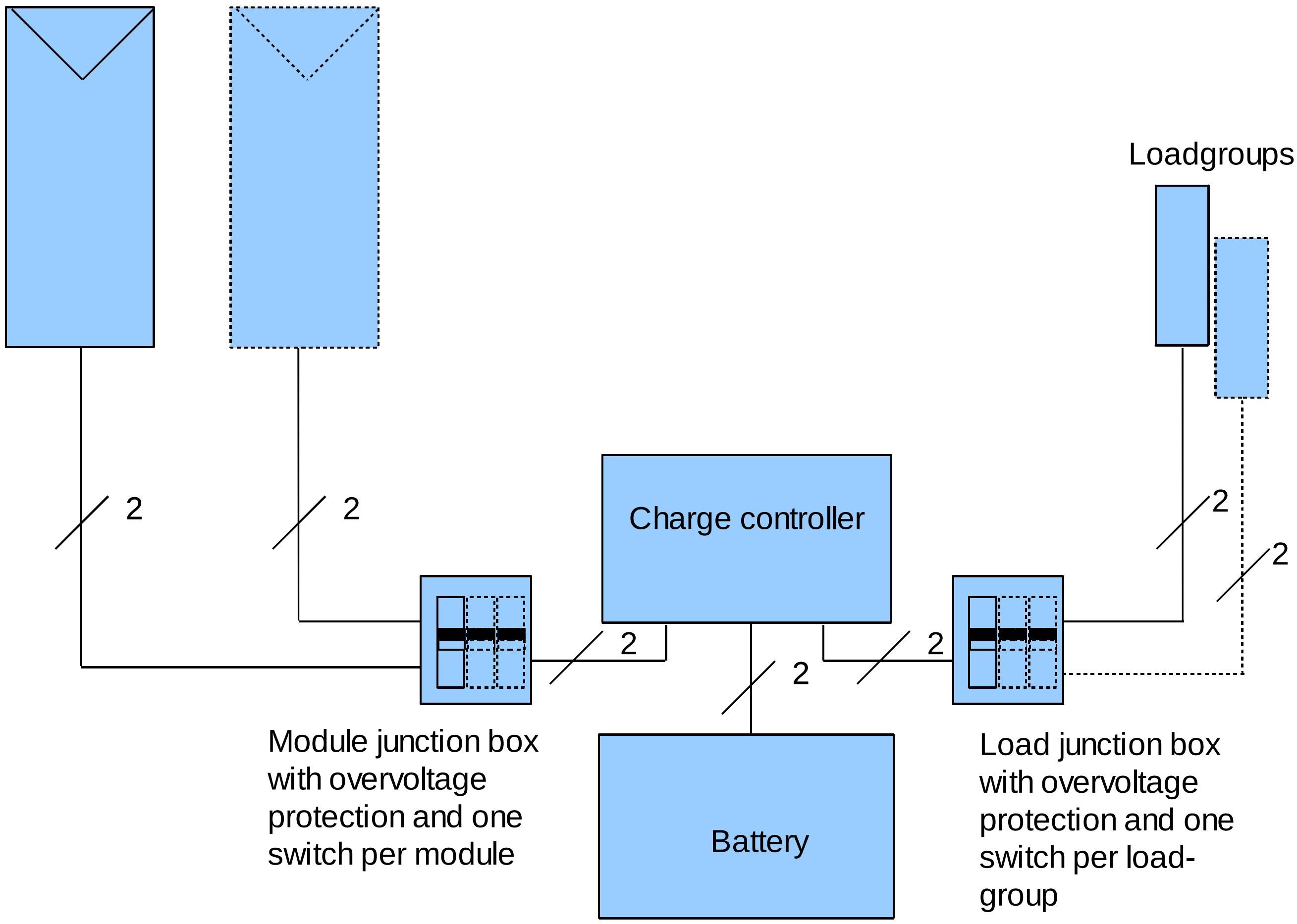
**For batteries it is expected that after about 5 - 6 years a large quantity must be replaced. In the long run a quantity of 2000 batteries per year will be needed.**

**For the charge controller a life span of 10 years or more is expected. This means that in the long run about 1000 spare controllers per year will be needed.**

**The solar modules are expected to last for 20 years or more. This means a quantity of modules for 500 systems are necessary. A certain number has to be added since it is expected that some of the modules will get stolen.**

**Spare part and recycling logistics needs to been built up from the beginning, together with the maintenance service. But it is expected that it needs to work completely after 3 or 4 years.**

## e) General System Design (not for SHS which is plug & play)




**Modules: UL or CE Tested**

**Charge controller: ISE tested or similar test; (or tested with new IEC norm);**

**CFL lamps: ISE tested or similar test; min 50lm/W; 50K switching cycles;**

**Battery: Lead Acid Battery Gel Type; min 1000 cycles at 50% DOD;**

**Wires: max. cable losses 3% at max current; Outdoor cable UV resistant;**

**Load grouping: According kind of load (e.g. refrigerator) and room**

**Grounding: No grounding required.**

**Different system design can be allowed after reconfirmation.**

## III) Further Actions – Electrifying Mozambique

### a) Project for Infrastructure

**In Mozambique there are nearly 10000 schools and health centres to be electrified. It would be possible to electrify all these locations with an amount of $40-60 million US.**

**If all donors would be willing to follow a 5 years master plan about 10 Mio. US$ per year would be required to fulfil this target.**

**This money and project should strengthen the private company sector in Mozambique.**

**It is my suggestion to develop common specifications during 2009, with other donors. It would be suggested to initiate about 10 pilot installations of above system designs. In these pilot installations the different options and variations should be tried out, monitored, researched and reported.**

### b) Electrification for private homes

**It is not necessary nor is it advisable to subsidise private SHS. Currently many people purchase poorly designed systems at a high cost. By educating installers and small dealers the price for systems can be reduced easily by factor 2 - 3 (based on the cost for the given service). If subsidy is given, there is the risk that all end-users expect to get subsidy and that they stop buying when they do not get any incentives.**

**Mozambique has about 2 million households without electricity. To electrify them for basic demand such as light and radio, it would need an amount of about $200 million US. At the moment these families cumulatively spend approximately $20 million US per month for kerosene and dry cell batteries (about $240 million US per year). To electrify these households what is needed is a mechanism to direct part of this money to the solar market.**

**This can be reached by offering inexpensive, simple systems that work well; offering a good service to people.**

**To achieve this it will be necessary to have well trained installers and dealers on the market. It might also be necessary to help these market players to establish qualified purchase channels. The GTZ designed compact system is a good first step. Further steps towards less expensive products and products requiring less work, need to be taken.**

**One step for market initiation could be to introduce local system integrators to a global manufacturer. GTZ may help to initiate the market by buying some compact systems for the hydro power stations and try out the rental system.**

**Beside the main goal (to electrify Mozambique) it is also important to take care of such systems which have already been sold into the market by the partners of GTZ. These systems have to be brought up to a technical status which is acceptable.**

**c) Education**

**An important part of any electrification strategy will be to qualify technicians and engineers. At the Eduardo Mondale University (EMU) some courses are already offered. These courses seem to have good theoretical basis. It might be helpful to establish more field experience into the lessons.**

**Together with the teachers of EMU it would make sense to offer to young professors of the newly established University of Zambezi to participate in the lessons. Also the people from the vocational school in Maputo could participate. Last but not least, it would be good to invite all relevant people from donor groups to the courses.**

**It would be a good outcome if the participants would get motivated in the workshops and work together to synchronize their activities.**

**To the existing lessons for students, such for entrepreneurship,  should be added. For rural electrification it would be valuable to have a lot of small and medium sized enterprises (SME) to carry out the majority of sales, installation and service. Young people need to be motivated to start such companies.**

**d) Financial demand, financial feasibility and economic impact**

**The following numbers are just rough estimations. Our goal is to show in the scope of the financial demands and to show that widespread rural electrification is realistic.**

**d1) Infrastructure Objects**

**This evaluation should only give a very rough overview about the scope of financial demand.**

**To electrify 10000 schools and health centres will cost about $5,000 for each system. This means in total $50 million would be necessary for first installation.**

**To maintain the systems, having maintenance service and replacing broken components about 1000$/system should be necessary.  This is an additional 10 Mio US$/year.**

**d2) SHS**

**There are about two million families in Mozambique without electricity. If an amount of $100 is needed for a simple SHS the capital demand would be $200 million US. The cost for replacing the batteries, lamps and other components would be estimated on about $40 million US per year.**

**In Mozambique each family spends about 250 MZM (about $10 US) per month for paraffin and dry cell batteries. This means about $20 million US is spent a month and $240 million US is spend per year for this kind of energy. It should be possible and advisable to leave the financing of rural electrification completely to the private sector.**

**In countries like Mozambique it is primarily the rural people living in farms who have no electricity. The farmers usually get their income from selling agricultural products. This means they earn their whole income primarily in a short period of the year. If the amount of money which they have to spend for a SHS is below their annual spending for energy, they would likely not need any financing. This amount in Mozambique, should be at least $120 US.**

**In addition, after the systems have been set up, the available amount of money for people will be significantly higher than before.**

**d3) Impact on SME**

**If the infrastructural projects could be finished in 5 years, on average every year $10 million US would be spend on building up the systems and another $10 million US would be spend on maintenance. If the private sector could be electrified in a period of 10 years, about $30 million US will be spend to set up the systems plus about $40 million US for service and replacement of components. This means that every year about $90 million US would be spent for solar systems. This should be by far enough to guarantee income for several hundred or even a few thousand SME doing the job of electrification and servicing the systems.**

**In particular the infrastructural projects financed by the public sector could help to initiate SMEs activities.**