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Life-Cycle Analysis and Optimisation of Solar Home Systems

Interim report over 1999 of ENGINE project 74513

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Abstract

This report describes the activities and outcomes of the first six months of the three-year ENGINE project Life-Cycle Analysis and Optimisation of Solar Home Systems (project number: 74513).

The whole project is divided into four main activities that cover different perspectives of the use of solar PV equipment by households: monitoring of solar home systems, conducting a household survey, socio-economic and institutional analysis and lifetime tests of PV equipment. In this phase of the project we focussed on hardware development for a data acquisition system, on preparation of a survey questionnaire and on general socio-economic and institutional aspects of solar home system programmes.

An analysis was made of experiences with data loggers for solar home systems. Furthermore, a prototype was developed of a small data logger. After testing the prototype it was concluded to postpone further development activities and rely for the near future on equipment that is readily available on the market.

Several versions of an advanced user interface were tested. Improvements were discussed with the manufacturer, AME. Until now the modifications have not yet resulted in a version that can be tested in the field.

As preparation for the household survey, which will take place parallel to the monitoring, a first draft questionnaire has been formulated. This needs to be expanded to include questions regarding lifecycle, socio-economic and institutional aspects. Zimbabwe has been selected to conduct the household survey and the monitoring.

The socio-economic impacts discussed in this study deal with improvement of the quality of life, the stimulation of commercial activity and associated employment and getting acquainted with electricity.

In the first phase of this project, the preparations have been made for the experimental work in the next phase. We are ready to start survey and monitoring work soon.

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1. INTRODUCTION

1.1 Background

Solar home systems for rural electrification in developing countries and grid-connected PV-systems in industrialised countries are the backbones of the global PV-market and the corresponding renewable energy policy. Grid-connected solar PV systems are primarily sources of electricity, while solar home systems can supply services for the two billion people, which are not connected to an electricity grid. Apart from appropriate financing mechanisms, the price/quality ratio is still a major barrier for large-scale introduction. Only with a substantial decrease in costs and improvement of quality one can expect that solar home systems will have a rapid breakthrough. When solar home systems have to contribute to sustainable development it is essential to spend sufficient attention to socio-economic and environmental aspects. Because relevant and representative data about the use of solar home systems in households are very rare, the pace with which solar home system components are being improved is slower than desirable.

There is a serious lack of knowledge world-wide about the following topics:

- Reliability of solar home systems under field conditions;
- Lifetime of PV-system components in relation to their use;
- Environmental effects of solar home systems over the complete product cycle;
- Effects on the socio-economic development of the areas where PV-systems are introduced;
- Preferences and wishes of (potential) end-users.

November 1999 ECN and University of Utrecht started a Novem project that complements this ENGINE study. The project 'Monitoring and Evaluation of Solar Home Systems' is intended to target these issues by conducting a large literature survey into experiences with solar PV for households in developing countries. Lessons learned from projects documented in the (grey) literature will be summarised and analysed. May 2000 is the deadline for the Novem project. Its outcomes will be useful in focussing the scope of the ENGINE project to those issues where the lack of information is most serious.

1.2 Objectives and Scope of Work

The main objective is to improve the price/quality ratio of solar home systems. Quality is defined here as the extent to which users are satisfied with the services provided by the system in a sustainable way. The project has to contribute to increased knowledge of how solar home systems are used by households in developing countries. Manufacturers can use these insights to design more appropriate components and systems and to improve system sizing.

Intended results are the following:

- Information about the causes of failures of PV systems and their components;
- Insight in the influence of the feed-back of user information on actual use of SHS;
- Overview of the life-cycle of SHS which will lead to recommendations for new products and product improvements;
- Insight into the strengths and weaknesses of the institutional framework;
- Knowledge about how solar home systems are used over longer periods of time (years);
- Information about preferences of users of solar home systems;

- A methodology for duration tests of solar home system components;
- Conclusions about the lifetime of a number of solar home system components;
- Insight into the effect of climate circumstances on performance of a solar home system.

The project is divided into four major activities:

1) Monitoring

In a representative group of households, data loggers will be integrated into their solar home systems. In some households in Indonesia a new user-interface will be tested. This user-interface has been developed by ECN and the Indonesian company PT Cilengka. A number of other households act as control group. Outcomes will be used to formulate recommendations for modifying charge regulators and the user-interface and for sizing of the different components.

2) Survey

Information from the monitoring activity will be linked to results from a household survey. A number of households will be visited a few times over a number of years. With the help of a survey questionnaire the following issues will be assessed among others: failure rates of the different components, maintenance and waste disposal.

3) Socio-economic and institutional analysis

An analysis will be made of the social and economic circumstances of the users in relation to the solar home system, and conclusions that can be drawn regarding productive applications. Furthermore we will assess how solar home systems fit into regional and national energy and environmental planning.

4) Duration tests

Lifetime tests will be conducted for a number of components: charge regulators, batteries and lights. Based on the monitoring outcomes, a selection of components for the duration test will be made.

1.3 Project progress in 1999

Start

In July we received formal permission to start work on the first phase of this project. However, some preparatory activities were conducted already earlier in 1999. We were explicitly asked to take the following three remarks into account:

1. Beware for an overly ‘high-tech’ approach, especially focussing on demands of the user and owner;
2. What is new with respect to monitoring in Swaziland?
3. This project focuses only on Indonesia and that makes the project vulnerable. Spread the risks. See if it can be applied in other countries for example Swaziland or Botswana.

The first remark will be taken care of through the survey questionnaire. As can be seen in Annex 1, a number of questions explicitly enquire about user experiences (especially questions 8-13). Also indirectly, via the monitoring results, we intend to learn more about household demands.

ECN was involved in evaluation of solar homes systems in Swaziland with a survey as the major instrument to obtain the required information. In this Engine project, additional to the surveys, is the data gathering via data loggers, which provide detailed information about the actual use of the PV-system. This information is limited in scope and quantity, but can be much more reliable than behaviour distilled from survey questions. By the parallel use of the tools of data loggers and surveys we intend to obtain a more complete picture of household demands than we have at the moment.

The third remark is very well taken. For the activities in 2000 we propose to apply the research both in Indonesia and in Zimbabwe. The background for the selection of Zimbabwe is discussed in chapter 4.

Monitoring module

Due to the circumstances where the monitoring takes place, an ideal solar home system data logger is small, reliable, has a large data storage capacity, a low electricity consumption and has a low cost. There is no data logger available in the market that is really suitable and meets all these requirements simultaneously. Therefore, a large effort was made to develop our own data logger for this specific purpose of monitoring solar home systems. At the moment we have a version which is currently being tested, but which still has a number of flaws. For the second phase of this project in 2000, we propose to postpone development of our own data logger and use off-the-shelve products. We propose to continue development of a data logger only after the use of existing data loggers have demonstrated that they are less suitable for monitoring solar home systems.

User interface

A prototype of an advanced user interface was produced by AME based on a concept developed by PT Cilengka in Indonesia in cooperation with ECN. Via a small LCD screen the user receives information about the use of their solar home system in the last week. This prototype was tested by ECN, and a number of problems were found. Suggestions for improvements were formulated, and these were implemented by AME. Additional tests have been conducted, which show that the user interface still needs further improvements. For field tests in Indonesia we intend to use an older version of the user interface.

Preparation of the survey

Some first preparations were made for the survey that will be conducted parallel to the field monitoring. An inventory of important issues has been made, and a first draft questionnaire has been formulated.

Socio-economic and institutional aspects of introduction of Solar Home Systems

A global review was conducted regarding the role of solar home systems in regional and national energy planning. Furthermore, we looked into socio-economic impacts of the introduction of (solar) electricity, the financing mechanisms and the different institutional arrangements.

2. DATA ACQUISITION IN A SOLAR HOME SYSTEM

2.1 Experiences of others with monitoring of solar home systems

Parallel to this ENGINE project, a study is being conducted for Novem called ‘Monitoring and evaluation of solar home systems’. It aims to assess world-wide experiences with solar home systems, solar lanterns and battery charging stations. Final results of the Novem study, which is due May 2000, will provide more detailed insights into the actual requirements for field monitoring. However, in the framework of this ENGINE study some preliminary findings are outlined in this section 2.1.

By conducting literature research that was supplemented with contacts with a number of institutes involved in monitoring, the following picture emerges of existing, world-wide monitoring experiences. Three modes of data gathering can be distinguished: surveys with only questionnaires, surveys supplemented with one-time measurements and the use of data loggers, which regularly measure a number of relevant system parameters.

2.1.1 Monitoring of solar home systems with the help of surveys

Kenya

Most of the publicly available information on the performance of solar home systems comes from surveys. One of the most useful publications is by Acker and Kammen, describing a survey conducted in Kenya[1] in about 40 households. One of their findings was that 40% of the smaller solar home systems (<25Wp) is only partly operational and 13% is inoperational. Large systems fare somewhat better: 25% are partial operational and only 8% are inoperational. Amorphous silicon modules mainly power small systems. According to the authors, the higher failure rate is “.. doubtless due to the small size of the systems, which often cannot produce enough electricity to satisfy the demand of the household. When the family tries to use more energy than the panel can supply, it leaves the battery in a continuously low state of charge, resulting in a damaged battery with a shorter life.”[2] However, according to ECN experience it is very unlikely that the size itself is the main reason for the lower performance. A common practice in smaller systems is to leave out the battery charge regulator, which saves on the first-time investment costs but is detrimental for the quality of the system. This discussion will remain unsettled before more monitoring data from data loggers become available. Only by analysing the link between the user behaviour and performance of the system, one can trace the real reasons for these high failure rates.

Swaziland

ECN has conducted surveys in Swaziland as described in a report by Petra Lasschuit[3]. Survey results showed that 86% of the respondents were happy with their systems and 96% would recommend a PV system to others. A much lower percentage than in Kenya (25%) had problems with their systems. However, the lifetime of the batteries is shorter than the expected three years. Of the people who had to replace their battery once or more, 73% had to do so within 2 years and 42% even within one year! Also in this case, monitoring with data loggers will provide more insights into the determinants of the short battery lifetime.

Indonesia
Monitoring with surveys only provides a good overview of the technical and non-technical problems occurring with the use of solar home systems. However, to be able to analyse these problems and identify solutions, one needs to obtain more detailed information. Part of this can be obtained by adding more specific questions to survey questionnaires. But there is a limit to the extent to which one can gather information via surveys. Ideally, it should be complemented with on site measurements, as was also concluded by Angele Reinders in an article regarding the experiences in Sukatani[4]: " The combination of an analysis of monitoring data, a field survey and interviews of SHS-users show some contradictions. For instance, on the basis of monitoring data we could not conclude whether users had to adapt their electricity consumption in the rainy season. In interviews, however, they told us that they did have to do this." "By comparing the number of installed lights with the lights actually used according to the villagers, we noticed that their answers were influenced by the information given in the instruction sheet. **Due to deviations between real and narrated experiences, we conclude that a field survey that comprises only interviews may not be sufficient to assess an SHS-project**."

2.1.2 Complement survey information with in situ measurements

Brazil
Solar home systems have been installed in Brazil by a number of utilities[5]. One of these, CEPEL, has developed a performance evaluation methodology that can be easily applied by the utilities' technicians, using only simple instrumentation. Periodically, or after a fault has been reported, a performance evaluation form is filled out. In situ measurements are made with a digital multimeter, a current probe, a portable solar radiation meter and a temperature probe. The following measurements are made:

- Battery voltage and current during charge and discharge;
- Battery open circuit voltage;
- PV panel short circuit current;
- Solar radiation at measuring interval;
- Ambient temperature.

No PV-panel open circuit voltage measurements have been made because of reliability and cost reasons according to the authors.

FhG-ISE
Fraunhofer-ISE developed a 'Solar Home System Tester', a cheap, easy to use, hand-held device which can assist in checking the performance of a solar home system in a short time. The tester can measure all the parameters as measured by CEPEL in Brazil plus the module open circuit voltage. For these measurements the tester is connected between the charge regulator on the one hand and the module, battery and load on the other hand. This requires some time and effort, and a short measurement is only possible if the solar home system is already adapted for the use of the tester. January 2000, one of the developers of the tester, J. Kuhmann of Fraunhofer-ISE stated that the tester is not yet commercially available.

Conclusions
From the monitoring results in Brazil it can be concluded that the extra on site measurements provide useful quantitative information about the performance of the systems. This can be very helpful for maintenance purposes, which is one of the main objectives of the utilities in Brazil. However, with this type of monitoring, one still lacks information on time development of performance (e.g. degradation of the battery). What is even more important, one still does not know how the systems are actually used by households: during what part of the day the energy is consumed, how often is the battery empty, and what is the extent of shading of the module etcetera. To obtain this type of information one has to use data loggers.

2.1.3 Experiences with the use of data loggers

FhG-ISE

Fraunhofer Institut fur Solare Energiesysteme has experience in using data loggers in solar home systems in a number of developing countries. In Balde de Leyes in Argentina, data loggers were installed in two solar home systems[6]. Information that was obtained from the data loggers was:

- 95% of the electricity consumption occurs during the night;
- energy demand over the year is proportional to the lenght of the nights. Where the seasonal irradiation varies between 3 kWh/m^2/day in winter and 8 kWh/m^2/day in summer, the average energy consumption per household was only between 200 Wh per day in winter and 120 Wh per day in summer.
- There was not much difference in energy consumption between larger and smaller families;
- There was no energy cut-off caused by a deep discharged battery!

FhG-ISE usually applies data loggers that measure three currents and three voltages. A reason given for having separate load and module voltage measurements is that it provides information about the low-voltage and high-voltage disconnect. For example, if the measured load current is zero, but at the same time the load voltage is unequal to zero, it shows that the user switched off the load and not the low voltage disconnect.

NREL

Different groups at the National Renewable Energy Laboratory NREL have experience with data loggers for remote power systems. Some of these can also be relevant for monitoring of solar home systems. Despite years of efforts they are still looking for an ‘ideal’ logger for remote power systems, that is reliable and does not consume too much energy. They usually apply Campbell Scientific data loggers that are of high quality. However, the own energy consumption of the Campbells is high, which makes independent operation difficult. Alternatives such as the weather loggers of NRG have lower own consumption, but have fewer channels for the same costs. A few years ago a proposal was formulated to develop a data logger especially for monitoring of small PV systems. However, no funding was obtained.

One of the problems that occurred in the field was that tampering with the battery bank resulted in damaging the data logger. Furthermore, incorrect installation and accidental disconnection of wires have resulted in loss of data. Lessons learned from a workshop with FhG-ISE and Sandia, held at NREL on October 19th, 1999 were the following:

- It costs time to check and process data;
- Collecting data can be difficult;
- Take time for installation and checking;
- Include redundancy in measurements (even when a parameter can be calculated from others, still measure it);
- Total Watt-hour input and output to the batteries is required;
- The Data Acquisition System (DAS) needs its own power supply: the interesting things happen when the system is dying;
- Data cards are the most practical method to gather data;
- Review of accurate log books is essential;
- Simple is best.

Utrecht University

Angele Reinders formulates the most detailed description of monitoring of solar home systems with data loggers in an article[7]. In Sukatani, Indonesia, four-channel data loggers were used of the Squirrel type, manufactured by Grant. Measurements were made of battery voltage, current from the array, current to the load, and irradiance in the plane of the array or temperature in the battery box. Sample interval was 18 seconds and data were stored in half-hourly averaged values.

Based on an extensive analysis of the monitoring data over the period 1988-1993, Reinders arrived at the following conclusions:
1. For more accurate analyses and better insight into battery performance, measurements are recommended by JRC or IEC of a) power instead of current, b) power into the battery and from the battery, and c) non-availability of power to the load.
2. For determining the state of charge of the battery, the recording interval needs to be decreased to less than one minute.
3. Irradiance sensors (and modules?) need to be cleaned once every two days.
4. Use of a portable reference cell gave problems with correct orientation of the sensor and having simultaneous array current and voltage measurements. Measurements of irradiance taken during site visits were therefore not used in the analysis.

2.2 Formulation of specifications for the data logger

In an early stage of the project, a number of research questions were formulated regarding the use of solar home systems by households in developing countries, which could possibly be handled by obtaining monitoring data:
1. Is there (partial) shadowing of the modules during the day?
2. What part of the electricity is used during the day and what part during the night?
3. What is the power consumption of the equipment used (the load)?
4. What is the state of charge of the battery at the beginning and at the end of the evening?
5. At what time of the day does low voltage disconnect occur?
6. What is the actual capacity of the battery?
7. What are the losses in the battery?
8. What are the different components of the system losses due to: a) non-optimal position and orientation of the module, and b) losses in cables, charge regulator and battery?
9. Does it happen that the battery is also charged in a battery charging station?

Based on these monitoring demands the following parameters were chosen for data logging (in brackets the number of the questions in the above list):
a) System voltage stored as minimum voltage and maximum voltage per hour (4,6,9)
b) Module current stored as average module current per hour (1)
c) Load current stored as average load current per hour (2,3)
d) Battery charging current stored per hour as Ampere hours in and Ampere hours out (4,6,7)
e) Flags per hour for low voltage disconnect and high voltage disconnect (5)

Answering question 8 about the different system losses can not easily be achieved just with a data logger alone. This requires additional on-site measurements. Furthermore, it requires measurement of irradiation that is not planned by us, due to the fact that it requires additional equipment and extra wires, thereby increasing the expected chances of malfunctioning of the data logger.

In this stage, only the parameters that need to be measured were formulated. No other specifications were formulated such as environmental conditions, level of accuracy and cost limits.

2.3 Building and testing of the first prototype

As far as we knew at the start of this project, there is no suitable data logger available in the market place that is small, cheap and reliable, has a large memory and a low own consumption. Therefore we decided to develop a customised data logger for monitoring solar home systems.

The first design ideas for the data logger were based on a charge controller with an Ampere hour balance for the battery, which was developed earlier by Mark Vervaart. For the Ampere hour balance data acquisition and storage is required. We expected that this could be expanded to a data logger measuring the specifications under a) to e) above. Data are stored in an EEPROM, which can be taken from the data logger and can be read via a special computer interface module. In a relatively short time the prototype of the data logger and the computer interface were built.

Tests were conducted on this prototype in a small solar home system located in Alkmaar. This solar home system is meant for test purposes and consists of a 19 Wp multi-crystalline PV module, an old 76 Ah battery, two fluorescent lights (Suntec of 7 Watt and PT LEN of 5 Watt) and a timer for switching the lights on and off.

Some minor problems were detected in the tests. The data of the first few hours were stored in one single location, and only after an unknown number of hours the actual data logging started. This problem was solved.
Results for a three-day period in June 1999 are presented in figure 1, which shows hourly averages of system voltage, the current from the module and the current to the load. The first day was a completely clear day. The low module currents before noon are due to shading. Direct sunlight only reaches the module after about 13.00 hours (MEST). Especially during the second day, the energy consumption of the load was larger than the energy generated by the module, resulting in a decrease of the system voltage due to a lower state of charge of the battery.

Figure 1 Monitoring results for three days in the summer: hourly averages of system voltage and currents from module and to the load.

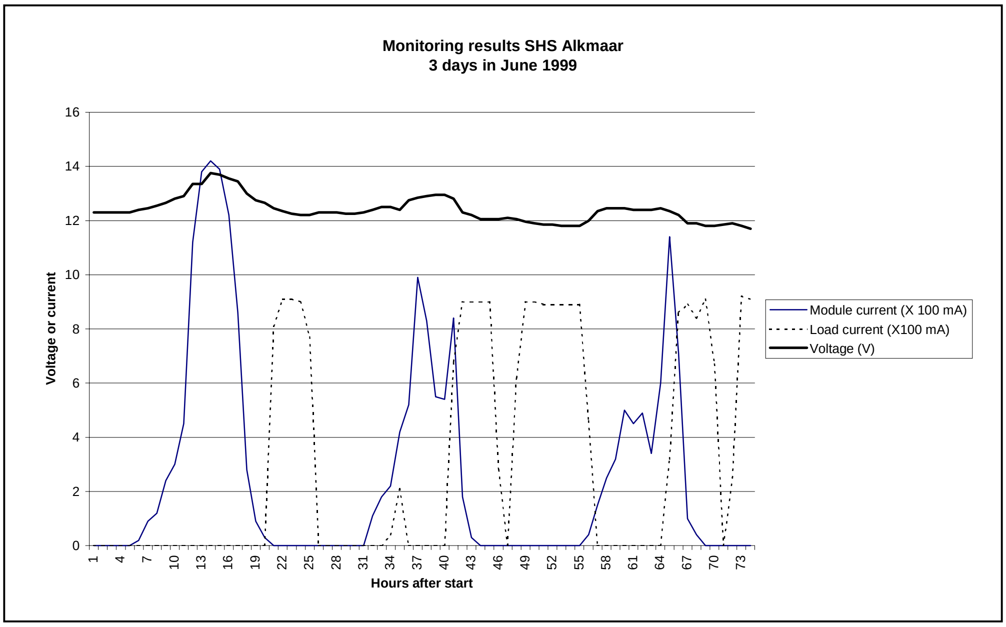
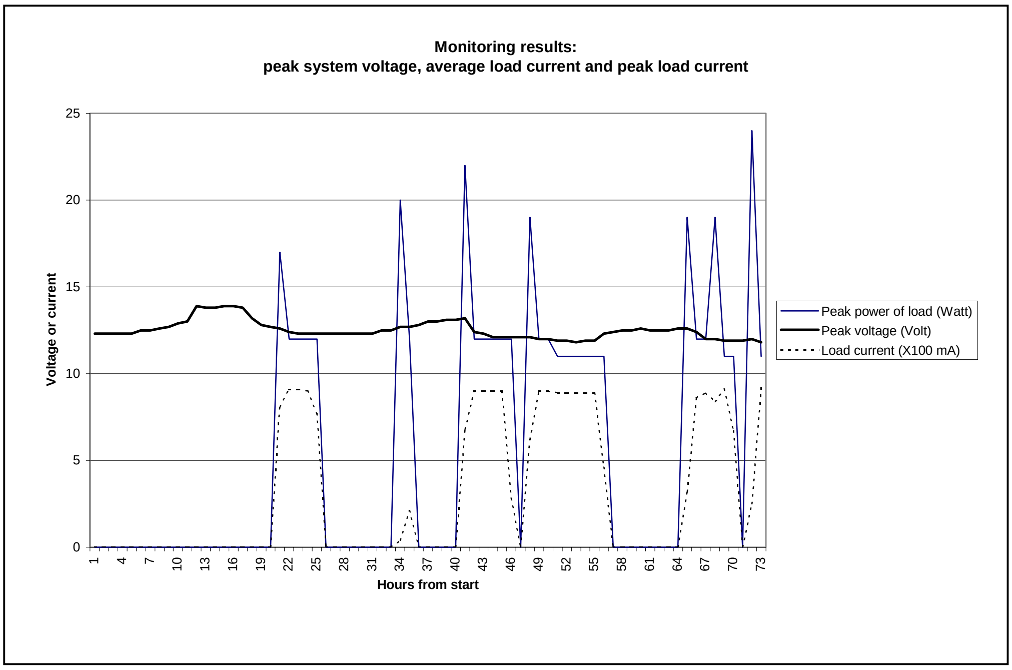


Figure 2 Monitoring results for the same days as in figure 1: peak system voltage, hourly average load current and peak load current.



2.4 Second prototype of the data logger

With the successful tests of the first prototype it was illustrated that in principle the data logger can operate well. However, being integrated in a charge controller that is not commercially available is a barrier for normal use of the data logger. Ideally you want to be able to use the data logger in all different types of solar home systems. Therefore, the next logical step is to develop a version that can operate independent from the charge regulator. Given the relative ease with which the first prototype was developed, it was assumed that modifying the design to make it independent would be a simple, straightforward job which should be easy to accomplish. In reality it turned out to be a long and tedious process.

A disadvantage of having the data logger separate from the charge regulator is that the information about the status of the charge regulator (e.g. a disconnected load due to low voltage disconnect) is no longer easily available. This limits the parameters which can be measured to four: system voltage, PV-module current, battery current and load current.

A new circuit diagram was drawn for the second prototype. In the summer, a student was asked to draw a diagram for a PCB. Inadvertently, a number of errors were introduced in the PCB design. This resulted in serious delays because the errors had to be repaired manually.

Laboratory tests of the second prototype showed problems with the data. It took a considerable amount of time before some of the causes were traced. The following problems were encountered and solved:

- The sample time was not accurate enough. Load and insolation pattern shifted in the order of one hour per week. This was corrected by using a slightly different crystal oscillation frequency.
- A separation byte between the seven data bytes was accidentally overwritten due to a change from eight to seven data bytes.

- Measurements of the Ah of the battery were wrong. This was caused by a mistake in a counter.
- The load current measurements were wrong. This was solved.

Since early December 1999 the second prototype is being tested in the solar home system in Alkmaar. However, there are still a number of unsolved problems, which require further research:

- There were problems with EMC. The data logger module appears to be sensitive to all kinds of spikes. Additional capacitors have been placed in the data logger, but it is unlikely that all the EMC problems have been solved.
- Measurements in the first hour show values that may be too low. Causes are still unknown.
- Voltage measurements are 0.1 to 0.2 Volt lower than the actual values.
- Current measurements for battery and load current are not linear. With a simple software correction some improvement have been achieved, but measurements below 1A are still not accurate enough.
- The data from the measurements in the solar home system have not yet been analysed. It is therefore unclear what the influences of positive and negative switching are on this data logger.

2.5 Conclusion

The problems with designing a data logger module do not seem insurmountable. However, they probably require substantial changes in the current design. Given the uncertainty in time requirements for these modifications, it was decided to postpone the development of an ECN data logger and rely instead on data acquisition equipment that is readily available on the market. When there is more experience at ECN with the use of data loggers in solar home systems we are better suited to formulate the right specifications.

3. ADVANCED USER INTERFACE

First prototype
Users of solar home systems have limited information available about the state of charge of the battery. Sometimes only two or three LEDs show if the battery is empty or full. For users it can be helpful to be informed beforehand that they are depleting their battery too fast. To assist users in determining if their demand is line with supply an advanced user interface has been designed. The user interface shows in the form of histograms the highest and lowest voltage reached by the battery in the past week. With the help of the trends shown by the display the user can adjust its electricity consumption.

A first prototype for a user interface for solar home systems was developed in an earlier project (ENGINE project Autonomous Systems 74433). This is one of the solar home system components that will be included in the process of design and modification by taking into account life cycle aspects. Before field testing can start, the prototype was tested in the laboratory to see if it meets the specifications and if it can operate under developing country conditions. Within the current preparatory phase of this ENGINE project, only the laboratory tests were conducted. Field testing has to start in the second phase of this project.

The user interface shows the actual voltage of the battery in the range of about 11.5 to 13.5 volt in steps of 0.2 Volt. Displayed is a histogram with bars consisting of a number of small blocks of 0.2 Volt each. It displays minimum and maximum battery voltage for the past 6 days. This provides the users with information about how their electricity use is related to daily electricity supply.

Laboratory tests
A number of laboratory tests have been conducted to test accuracy and reproducibility of voltage indications and to determine if the values are shifted correctly from day to day.

The first laboratory test was to check if the value of the voltage as shown by the user interface differs from the actual voltage as measured with a separate voltage meter. The average difference found was 0.1 volt, which is equivalent to half a block. The maximum difference was 0.4 Volt, occurring in 7% of the 42 measurements.

Furthermore, tests were conducted in a small solar home system. 14 user interfaces were connected parallel in groups of 2 or 4 for periods of a few weeks each. Because the interfaces were working in parallel, they are expected to display the same patterns. This was not the case. The main problems that were encountered are the following:
1. A large discrepancy between voltage displayed and the actual voltage occurred with one sample;
2. Large differences between displayed voltages of one or more days ago and actual voltages occurred twice;
3. In one sample the display of the previous days did not shift every day;
4. With symbols (thumbs up and down) the users are informed about the status of the system. However, three samples showed at the same time the two different symbols that users behaved well and not well.

AME, the producer of the interface, offered to add a software filter to reduce the first two problems and software modification for the fourth problem. 50 interfaces were returned to AME and reprogrammed.

Second prototype
ECN tested the interfaces with the adjusted software. They were connected to a solar home system in two groups of 16 each. In a period of three days the battery was discharged from 14.5 Volt to 11 Volt. This resulted in the following findings:

- When the input voltage is within the range of 11.5 to 11.7 Volt the interfaces all displayed level 12 instead of level 2. Depending on the length of the measurement interval, these values also show up in the history.
- Twice the voltage accidentally dropped to below 4 Volt. No problems occurred due to the low input voltage.

The interfaces were returned to AME for the second time. According to the manufacturer a software error was traced and repaired.

Third prototype
Testing of the latest version showed the following:

- When the voltage drops below a certain threshold, all levels in history become equal to 1. After this happens, the history can not be updated anymore, not even by using the reset button. Consequently, when the voltage drops below a certain level (which could not be determined precisely) the interface becomes permanently destroyed. In practice, the interface will usually be connected directly to the battery. There is a real chance that low input voltages would occur.
- The ‘old’ problem with the voltage range of 11.5 to 11.7 volt still occurs.

Conclusions
The problems that occur are too severe to have this third prototype of the user interface tested in the field. Therefore we decided to test user reactions on the first prototype before further changes to the design will be made.

4. PREPARATION FOR THE HOUSEHOLD SURVEY

The technical monitoring process will be complemented with interviews among the end-users. The aim of the interviews is to get answers on questions that can not be derived from the technical monitoring process. The information thus collected will include the following issues:

- the quality of installations;
- the maintenance of the systems;
- use of appliances;
- lifetime of components;
- disposal of redundant system components;
- impact of PV system on social and economic development;
- user satisfaction.

The survey will consist of one comprehensive interview and biannual follow-up visit. Trained enumerators will accompany the technicians installing the data loggers and conduct the initial interviews using a standard questionnaire (see draft questionnaire annex 1). After the first comprehensive interview, a shorter questionnaire will be prepared to update the collected data especially on the technical issues. Follow up interviews will be combined with the data readings (data loggers) and carried out by the technicians for 2 times a year, viz. once in summer, once in winter.

The country selection has long been debated. Initially one country, viz. Indonesia was selected as a study case for this project. From a representative point of view, the selection of a second country on another continent has been envisaged. With most of ECN's PV implementation activities being carried out in Africa the choice for this continent seems obvious. Below the pro's and con's of three potential countries are presented.

Swaziland

ECN-IDE carried out several energy surveys in Swaziland and through its long presence in the country has established a substantial network, making the organisation of the survey rather easy. In addition, ECN-IDE together with its local partner Swazitronix has installed about 500 solar homes system and has access to another 500 solar systems identified in a previous survey.
Despite the relative easy of organisation, Swaziland is a rather small country and has a higher per capita income than most other countries in Africa.

Kenya

Kenya has a substantially developed PV market, probably the largest among the developing countries. From this perspective Kenya would be an interesting and representative case study.
Discussions with local Kenyan organisation took place early December and suitable partners have been identified for the organisation of the survey.
A disadvantage of Kenya as a case study is that ECN has no ongoing activities in Kenya in the field of PV. As such the organisation of the organisation of the survey will be more time consuming and costly.

Zimbabwe

Zimbabwe is a country that overcomes both problems. It has the second most developed PV market on the continent and ECN-IDE has been actively involved in the country. ECN has established a large network in the PV sector and will have permanent ECN staff in the country for the next 2 years.

Through one of our local partners, viz. PV supplier, ECN will get easy access to a large customer data base and can make use of a team of qualified technician for the installation and readings of the data loggers.

5. SOCIO-ECONOMIC AND INSTITUTIONAL ASPECTS OF INTRODUCTION OF SOLAR HOME SYSTEMS

As set out in Chapter 1 the study will also entail a socio-economic and institutional analysis of the SHS market. That analysis will be further explored in this chapter. Its objective is to analyse social and economic circumstances of the users in relation to the solar home system, and to draw conclusions regarding productive applications. Furthermore it will be assessed how solar home systems fit into regional and national energy and environmental planning.

Unfortunately, the implementation of this analysis was delayed by a number of factors that affected also the overall implementation of the project. First, the late date of approval of the project diminished the availability of persons to implement the project. Secondly, the approval resulted in a reduced budget available for the whole project, which led to redefining of priorities and subsequently a re-division of activities to be implemented for the socio-economic and institutional analysis. Thirdly, and foremost, the selected target area suffered from severe political and violence problems during the course of the year. Therefore, no field work could be undertaken to actually conduct the survey and identify and evaluate the main socio-economic and institutional aspects relevant for the introduction of solar home systems.

Therefore, the analysis presented in this chapter is of a more general nature and provides a framework for the actual analysis, which is envisaged in the second phase of this project.

The analysis presented in this chapter draws heavily on work done by S. Dlamini who was seconded at ECN for a period of three months. Mr Dlamini’s research is reported in a separate document (ECN-I-99-005). In this chapter, a number of main issues resulting from that study will be presented. First, the role of SHS in national and regional energy planning is outlined. Next, the socio-economic impact of rural electrification in general and SHS in particular is explained and finally the financial and institutional aspects of the introduction of SHS is elaborated upon.

5.1 The role of SHS in national and regional energy planning

In developing countries, urban households consume the largest part of residential electricity. Although since 1970 approximately 800 million people in rural areas gained access to electricity, the problem still remains that, of the approximately 3.2 billion people living in rural areas of developing countries in 1990, 1.8 billion are still without access to electricity.

This means that the development options of the vast majority of rural households are seriously hampered and production and service establishments in these areas are disadvantaged. As a result, the already existing social gap between urban and rural communities will further increase and will stimulate the migration to urban areas. This situation is regarded by the national government as highly unsatisfactory and usually the energy policy formulated in developing countries is addressing this problem by initiating various activities to promote rural electrification and to analyse the options to increase the rural connection rate in the most cost-effective manner.

However, the decentralised character of the population of rural areas and their small per capita commercial energy consumption has made these areas less attractive for grid extension. The extension of the grid to rural areas is in many cases less cost-effective as compared to urban areas. Therefore, the present emphasis in the energy policy with regard to supplying electricity to small and scattered loads is on decentralised generation of electricity. The main options are:

- minihydro
- photovoltaics
- wind
- biomass
- diesel

Facing the social pressure to address the energy needs of the rural population, governments in developing countries are increasingly considering off-grid PV systems as an attractive means to address some of the energy problems in rural areas and to improve the quality of life. A good example in this regard is Kenya with the highest penetration rate of household photovoltaic systems in the world. To date, more than 80,000 systems have been installed and current annual sales amount to approximately 20,000 systems. Some 50 local and 15 international companies import, assemble, install and provide after sales in this market.

Although the example of Kenya clearly shows the potential role SHS systems can play in regional energy polices, there is still a tremendous need for strengthening the local PV industry in many developing countries through studying the credit arrangements and standardisation of equipment.

5.2 The socio-economic impact of the introduction of SHS

The socio-economic impact of the introduction of SHS is related to the improvement of the quality of life, the stimulation of commercial activity and associated employment and getting acquainted with electricity.

Improvement of the quality of life of rural population is brought about by the fact that electric lighting enables people to undertake a range of additional activities in the evening hours at home and in public facilities such as schools, clinics and community buildings. Outdoor lighting may also bestow a perception of improved security. Electricity for radio and TV gives people access to mass media for entertainment, but also for extension services and distance education. Electric pumps powered by PV may facilitate access to safe drinking water. Electricity for small local health facilities enable conservation of medicines and emergency distance communications.

Stimulation of commercial and agro-industrial activity and associated productive employment is brought about by the establishment of a PV market consisting of dealers, assemblers and after sales providers of the PV systems. In addition, improved lighting is an inherent benefit for shop owners stimulating their trade.

Electrification by means of PV can be seen as an interim measure to provide electricity services until the national grid will have reached the area. However, PV acquaints the consumer with the use of modern electricity usage. This means that when a household eventually gets connected to the grid, it is used to electric devices such as the radio and the TV and, consequently, electricity consumption after grid connection will be higher compared to the situation whereby electricity is introduced for the first time. Higher consumption, of course, contributes positively to the financial performance of the rural electrification programme.

5.3 Financing Solar Home Systems

Two main potential consumer groups can be identified for SHS. The first group comprises of potential consumers that do not have access to grid electricity. The second group involves households connected to the grid but, because of the frequent power interruptions, uses the SHS as a backup device.

Most SHS however are meant for rural households which are not connected to the grid These households usually belong to the low income group of households which cannot afford the high initial investment that is required for the purchase of a SHS. This raises the important question of how to finance a SHS programme ?

In general, the following constraints and impediments in financing frequently encountered in SHS programmes can be distinguished:

- *access to finance*:- this is claimed to be a cardinal pre-requisite for SHS projects, and renewable energy projects in general;
- *cost of finance*:- when financing involves loans, raising and servicing the financial arrangements comes with a cost;
- *perceived risks*:- all projects are exposed to risks, which are often considered high when the project involves relatively new technologies. Avoiding, reducing and sharing risks amongst key players is essential for success.

Three finance-related concerns can be identified that stand out as being critical if the SHS industry is to grow successfully, namely

- consumers need to obtain credit from banks or distributors
- suppliers and retailers must be able to secure working capital if they are to be able to provide in-turn credit to their customers
- investors need credible financing opportunities to sway capital towards the solar industry

Close inspection of literature reveals three main categories in the finance process arranged in a fixed vertical structure viz; international financiers, several (institutional) intermediaries who handle the funds and the end user of the funds. In practice one can see a pattern which further breaks down these categories into five levels of actors, again vertically integrated. These are illustrated by figure 1.

The level 1 actors are involved in supplying of capital, usually as a grant, subsidies and/or loans with “strings” attached. These may be organisations like aid agencies, UN related bodies or multinational banks.

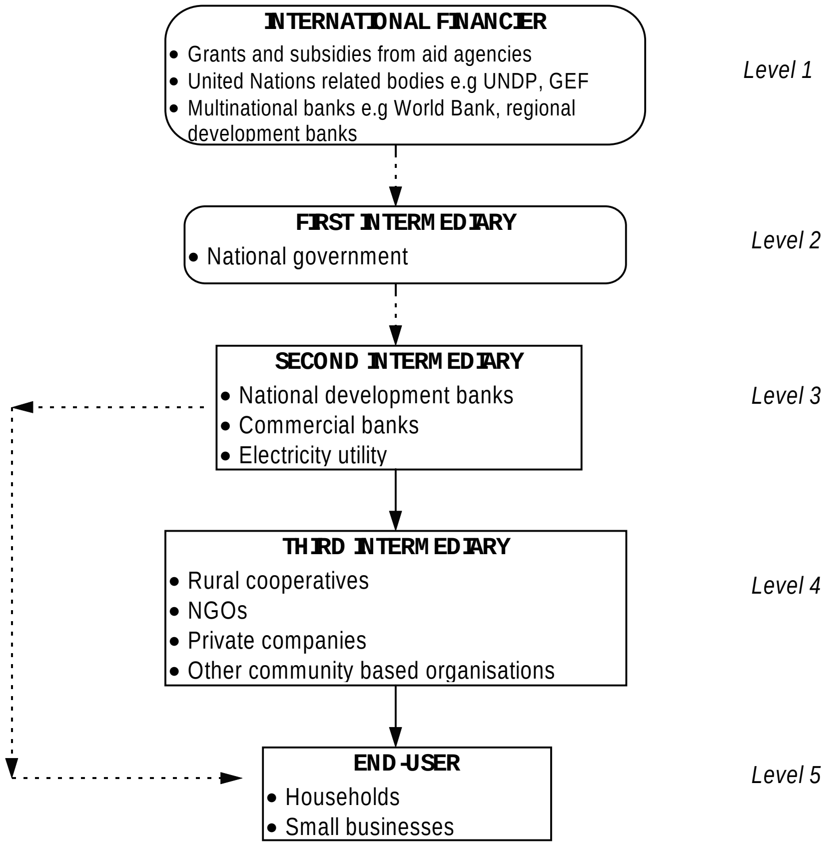


Figure 1 Typical finance delivery chain

The next levels involve intermediaries, whose goal is to see that the Level 1 funds end up with the consumer in Level 5. It's worth noting that the longer this intermediary chain, the more the administrative overheads compile. Often these intermediaries are necessary, or at least perceived to be, for successful PV market development. They fulfil necessary services in the total market structure by creating economies of scale and hedging risk through the bundling of projects.

National governments often intercept the funds as is the case for GEF projects, although this is not always necessary for example, the Solar Development Corporation may skip level two directly into level 3. Actually there is also a possibility of a loop directly from Level one to four, as is with the Solar Investment Fund.

Last in the chain is the consumer himself. Although the literature contains diverse views on the exact details of how funds have to filter down to the consumer, there are also remarkable similarities. These exact details of flow of funds will be called financial mechanisms in this paper. Example of the interactions between the levels is given in the section dealing with institutional arrangements.

Several financial schemes have been developed and applied to overcome the barrier of high initial investment, namely:

- Revolving Loan Fund (RLF) : the concept of RLF is simple. Initially, a fund is made available to finance the SHS programme. The costs of the SHS are paid back in monthly instalments that flow back in to the fund. This money can be used again to finance new SHS programmes.

- Credit Financing: in this financing scheme the consumer deposits a down payment, and then pays the balance in regular payments.
- Leasing schemes: this scheme draws similarities to the system of how grid electricity consumers pay for electricity. The SHS is leased to the consumer for a monthly fee, the utility (or Energy Service Company) will provide O&M services and hand-over the system after a number of years.

5.4 Institutional Arrangements

Institutional arrangements are usually meant to facilitate the processes of the financial mechanism(s), the product delivery mechanism(s), training and the after sales services. For this reason, it is difficult to disentangle finance issues and those that are institutional. The following key players can be identified in this respect:

- the public authorities;
- the utilities; and
- the co-operatives and associations.

Public authorities

The conventional attitude of public authorities that SHS "doesn't work", "its too expensive" is on its own an institutional constraint. This situation is encouragingly changing though and many developing country governments have already included, RE technologies, including SHS in energy policy objectives. The Solar Summit Process, in Harare 1996, gave a much required impetus to the change of attitude of public authorities, resulting in their commitment to " join in the development and implementation of the World Solar Programme 1996-2005"[8]. The declaration made during this summit includes *inter alia* three grave commitments in favour of renewable energies in general, and solar energy in particular. Here commitment two is quoted, which reads: "We commit ourselves to work towards policies and effective mechanisms that will speed up and facilitate the use of solar energy avoiding duplication and administrative delays, and the encouragement of international co-operation, including participation in regional and international bodies, scientific and technical organisations". The other two commitments are of similar seriousness. Much work is ongoing and has already been done towards the fulfilling these commitments. However, there is still a great scope for improvements and this remains a challenge of authorities; to ensure that commitments made are effected and not just remain a mere will.

On the other hand over-enthusiasm on SHS can lead into ill-planned projects yielding disastrous results. The best role of public authorities seems to be one of market catalyst without excessive interventionism.

Public authorities can also play an important role in removing or reforming fiscal and policy regimes, which are in disfavour of alternatives, like SHS. In the Senegal case, authorities waived duties on solar energy equipment, making systems more affordable and promoting the solar business

Utilities

The attitude of utilities towards alternative energy, SHS for example, is changing for the better.

Although not funding the project, the utility is often responsible for quality assurance and standards issues, which is a real achievement. The South African Utility, ESKOM, has been involved with active research and implementation of alternative energies, including solar, since

1991[9]. It has also recently launched an ambitious electrification project, in conjunction with the Renewables division of Shell, which seeks to disseminate 50,000 system on a leasing basis.

The engineering background of utility engineers and technicians, and the infrastructure utilities already possess, could be extremely useful if available also for SHS programmes. In fact utilities with a commitment to rural electrification should find SHS an attractive cost-effective option in many instances. The examples of utilities in many countries that are already active in SHS should serve as a reassurance that it is possible to integrate SHS in electrification programmes.

An interesting example is CRE, perhaps the largest electric co-operative in the world, which has the electrical concession for the state of Santa Cruz in Bolivia. CRE has set up a "solar electric utility" within the co-operative structure. CRE has developed a tariff collection and maintenance system, and has over 1000 customers. Another distribution utility in Bolivia, ELFEC, considered setting up a similar electrification unit to CRE, but later rejected it based on financial analysis[10].

Private sector initiatives
Another venue is the entering of private sector in the provision of electricity services. Such companies are usually referred to as Energy Service Companies (ESCOs) and work as a "Solar Electric Utility" which basically acts like grid electricity utilities. This type of company sells electricity and retains ownership of the SHS. The SEC in Kiribati is one example. The principle advantage of utility-based service is that it can provide electricity at low cost to the consumer. It also transfers the maintenance responsibility from the user, to trained technicians, thus guaranteeing proper care of systems. It however, requires a capable technical and administration infrastructure in the area to be served and often needs access to long term credit at modest rates. The Kiribati experience also highlights the importance of establishing a "critical mass" of demand in the service territory, to improve economic viability (this requirement is also echoed by Kalumlana et al,[11] and Aguilera et al,[12]).

Co-operatives and Associations
Experience in many countries` shows that using existing co-operatives and associations with a good reputation, is more effective than trying to establish new structures. These groups have more on the ground experience, are in better contact with the people and so know the socio-economic situation of their areas quite well.

However, care should be taken to assess the capabilities of their officers, and provide training where necessary. In a successful project in Honduras, Enersol worked with an existing coffee co-operative, COMARCA, after the former had conducted training[13]. This approach can lead to prejudice though towards communities with strong organisation, leaving out potential customers or deserving recipients, in other communities. In cases where using existing associations is not possible, new organisations can be set up. In the Pacific Islands, the Tuvalu Solar Electric Co-operative Society was established after failed attempts to involve the utility[14].

Similarly, NGOs may be very effective in programmes since they are normally familiar with the communities they serve on more than just a monetary basis. NGOs have the further advantage of having established extension networks, which could be used for training and information services. Stone et al[15] reports another institutional possibility; religious missions. The US Renewable Energy Laboratory (NREL) co-financed a project with the Indian government in West Bengal. The Ramakrishna Mission reliably managed the project that is now completed. So reports Stone about the Mission as a project partner, "The Ramakrishna Mission has been perfect in this respect".

Conclusion
Experiences differ from country to country but some conclusions can be drawn for the conditions for successful project design. The best role of public authorities seems to be one of market catalyst without excessive interventionism. Experience in many countries` shows that using existing co-operatives and associations with a good reputation, is more effective than trying to establish new structures.

6. PROPOSED ACTIVITIES FOR 2000

In general, we propose to continue with the activities as described in the proposal, formulated medio 1999 and accepted on July 5th 1999. In this proposal, four activities were stated:

1. monitoring with data loggers;
2. Field survey with questionnaire;
3. Socio-economic and institutional analysis; and
4. Laboratory tests in relation to lifetime aspects of solar home system equipment.

The fourth activity will be postponed to 2001, to benefit from the Novem project: “Ontwikkelen en uitvoeren van levensduurtesten van Solar Home Systemen”, which will be conducted from 1-1-2000 to 31-5-2001.

For 2000 the following activities are planned:

1. The draft survey questionnaire will be expanded with questions relevant to life-cycle analysis and socio-economic aspects;
2. An updated version of the questionnaire will be tested in Swaziland and Indonesia in a few tens of households;
3. Parallel to the pre-survey, data loggers will be installed in rural households in Swaziland and Indonesia;
4. A household survey will be conducted in Swaziland in about 300 households;
5. Analysis of socio-economic impacts and institutional arrangements for SHS-dissemination in South Africa, Indonesia and possibly in Zimbabwe.

ANNEX 1 DRAFT SHS PERFORMANCE QUESTIONNAIRE

A. Location: .... F. Questionnaire no. : ....

B. Enumerator no .... G. Date of interview :..........

C. Name Household ....

D. Interviewee :
1. head
2. wife of head
3. son
4. daughter
5. other.......................
....

E. Number of occupied structures/huts on the homestead (exclude storage, empty huts) no. structures...........................

Specifications Solar system

1. When was your solar system installed?
year.............. month................

2. From whom did you buy the solar system?
Name supplier ....
City, town ....

3. What does your solar system consist of ?

component	**no.**	**type / brand name**	**capacity**
1. Solar panel			Wp
2. Battery		solar bat...................... car bat........................	Ah Ah
3. Battery regulator			
4. Battery box			
5. Inverter DC/DC			Watts
6. Inverter DC/AC			Watts
7. Cabling			
8. Mounting material			
9. Lights		Fl. tube...................... PL tube......................	Watts Watts
10.Light switches		toggle / pull switch	
11.Connection for TV			
12.Connection for Radio			
13.Other___________			

4. Did you buy:
1. a complete solar system at once
2. first bought a battery and at a later stage added a solar panel and other components
3. don't know

5. How was the system paid for?
1. cash
2. credit from the solar supplier
3. loan from the bank, indicate name of bank..........................
4. loan from friends, relatives

5. other, indicate…………………………………………………….

6. Who installed the solar system for you:

1. installed by the supplier
2. installed by a technician (other than the supplier)
3. did the installation yourself

7. What are the solar panels mounted on:

1. roof (grass thatched)
2. roof (corrugated iron)
3. roof (roof tiles)
4. pole next to the house
5. outside wall of the house
6. other..................................

Use of a solar system

8. What do you use the solar system for ?

1. Lighting
2. Radio
3. B&W TV
4. Colour TV
5. VCR
6. Hifi
7. other………………………………..

9. Do you use a battery regulator?

1. do not have a battery regulator (go to question 11)
2. use the regulator all the time
3. bypass the regulator every now and then
4. by passes the regulator all the time
5. don't know

10. Do you regularly look at the indicator lights of your regulator?

1. don't have indicator lights
2. never look at the lights
3. frequently look at the lights
4. don't know

11. Are you happy with the performance of the solar system?

1. yes
2. no, why ....

....

....

12. Are you planning to expand your system soon?

1. yes
2. no

13. What would you do if grid electricity would become available in your area?
1. apply for a grid connection and re-sell the SHS
2. apply for a grid connection and keep the SHS (use both of them)
3. not apply for a grid connection and keep on using the SHS
4. other..

Battery Performance

14. Do you often have a flat battery?
1. almost daily
2. once or twice a week
3. once or twice a month
4. a few times per year
5. never *(go to question 18)*

15. If it is flat, how long does it take the battery (on average) to get charged by the solar panel?
1. charged the following day
2. longer, indicate...

16. Have you ever charged your solar battery other than with the solar panel?
1. yes, at a charging station
2. yes, other ....
3. no *(go to 18)*

17. How often do you charge the battery other than with the solar panel?
1. once or more per week
2. once or twice per month
3. a few times per year
4. once every one to two years

18. Was the battery ever topped-up with water
1. yes, topped-up by you or somebody else in the family
2. yes, topped-up by a technician
3. no *(go to 20)*

19. If yes, what kind of water was used?
1. water from the tap
2. boiled water
3. distilled water
4. don't know

20. Did you ever replace the battery?
1. yes
2. no *(go to 24)*

21. If yes, after how much time did you have to replace the battery?
1. less than 6 month
2. within one year
3. within two years
4. within three years
5. within four years
6. within five years
7. after more than five years

22. From whom did you buy the new battery?
1. from the supplier you bought the solar systems from
2. from another battery supplier
3. other....................................

23. What did you do with the old battery?
1. returned it to the supplier
2. threw it away
3. other..............................

Appliances Performance

(Check question 8 whether lights are being used, if no go to question 28)

24. How many lights are powered by your solar system: no. ……..

25. Did you ever replace one or more tubes/bulbs of you solar lamps
1. yes, no of lights replaced: ....
2. no *(go to 27)*

26. From where did you obtain the replacement tubes/bulbs
1. spare tubes/bulbs were provided by the supplier of the solar system
2. bought it from the supplier of the solar system
3. bought it somewhere else.

27. Are you satisfied with the brightness of the lamps
1. yes
2. no, not bright enough
3. no, too bright

Repair and Maintenance

28. Did you every had a problem with your solar system?
1. yes
2. no

29. If yes, please indicate what kind of problem(s)?

1.	faulty battery
2.	faulty lights
3.	low power output
4.	maintenance is expensive
5.	no spare parts available to repair system
6.	system struck by lighting
7.	theft
8.	vandalism
9.	other, …………………………………….

30. What did you do to solve the problem(s)?
……………………………………………………………………………………………………
…………………………………………………………………………………

31. How often did you call in a technician to check/repair your system in the past 12 months?
no. of times:……………….

32. Did you ever clean the solar panel?
1. yes, did that once
2. yes, do that regularly
3. no, never cleaned it before

6.1.1.1 Information

33. Did you receive a user manual from your supplier?
1. yes
2. no *(go to question 35)*

34. Do you consider the manual useful?
1. yes
2. no, why not...............................

35. Did the installer explain the use of the solar system to you?
1. yes
2. no

36. Would you recommend a solar system to other people?
1. yes, why..
....
2. no, why not..
....

37. Have other people shown an interest in your solar system?
1. yes
2. no

END OF QUESTIONNAIRE

ANNEX 2: DATA LOGGER HARDWARE

At this time there are three options to obtain the required data logger for Solar Home Systems. The possibilities are listed below:

1) Buy a complete unit (commercial of the shelf, COTS).
2) Develop the current prototype to a production ready model.
3) Develop an upgraded version of the current prototype.

While developing the prototype of the data logger we realised the need for further improvements such as the use of more than four channels. At the same time an answer is formed to the question if data loggers available on the market are applicable to suit our needs. In the table 'Comparison table data logger functions' below the functions per data logger are listed.

Comparison table data logger features	Current version of ECN Logger	Upgraded version of ECN logger	Squirrel of Grant	Sentry of Big Ben Electronics
Sample interval	0.1 seconds	0.1 seconds	1 sec - 250 days	1 sec - 250 days
Storage interval	0.1 sec - 24 hour	0.1 sec - 24 hour	1 sec - 250 days	1 sec - 250 days
Average battery voltage	yes	yes	yes	yes
Average module current	yes	yes	internal shunt	external shunt
Average load current	yes	yes	internal shunt	external shunt
Average battery current	yes	yes	internal shunt	external shunt
Memory data retrievel methode	Memory module	Memory module	RS-232/PCMCIA	RS-232
Memory capacity (registrations)	86000	172000	256000	40000
Power supply via solar home system (W)	0.2	0.2	no	no
Battery life included battery	no	no	2 years	5 years
Dimensions hxlxd (mm)	40x100x60	40x100x60	40x150x80	25x104x56

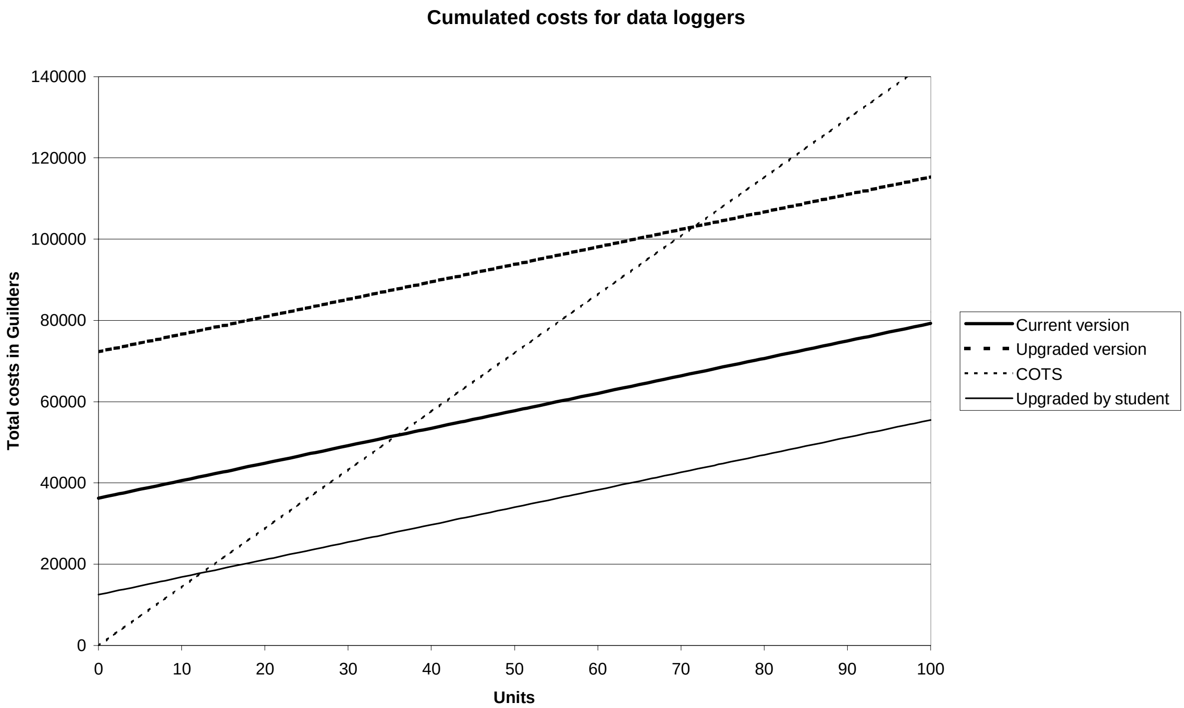
As shown in the table, there are functional differences between commercially available data loggers and 'our' data loggers. When we do not make the requirements regarding dimensions and memory too strict, commercially available data loggers are suitable for our purposes.

In first instance option 2 (Develop the current prototype to a production ready model) and option 3 (Develop an upgraded version of the current prototype) are investigated to estimate the costs per unit. Additional, the costs from COTS (commercial of the shelve) components is under investigation (option 1). The amount of money paid for the COTS components is set to HFL 1440,- based on the quotations of CaTeC for 20 pieces of the Grant 401. It is very likely the price per COTS unit can be further reduced. The cost breakdown for the 'current version' and the 'upgraded version' are listed in the table on the following page.

The figure 'cumulated costs for data loggers' shows the different options in one picture, based on rough cost estimates. From the figure it's clear that a student is (as expected) by far the cheapest, however considering the factor time a student is not the best option. The quickest way to obtain a ready to use data logger is to use COTS components instead. A big advantage is the risk due to the make-the-prototype-production-ready does not exists for COTS components.

For small numbers of ‘sites to monitor’ COTS components will be the quickest and cheapest. For larger quantities it is cheaper when our prototype monitor module is made production ready. The break-even point between COTS and ‘home-made’ units is considering HFL1440,- for COTS approximately 70 units but negotiations are expected to bring the price down to HFL1000,- to HFL1200,-.

Figure Cost comparison of different options for producing or buying data loggers (for cost assumptions, see table on the next page).



Conclusion:

At this time the best way to obtain the required data loggers for monitoring of Solar Home Systems is to buy COTS components. With COTS components the risks are minimised for both financial risk and delivery time risk. If monitoring on larger scale is required (e.g. more then 150 data loggers) continuing development of the upgraded version might be an interesting consideration taking into account the lessons learned from a smaller project with COTS components.

Kosten raming monitor module vervolg

Ontwerp+prototyping	Current version	Upgraded version		Opmerkingen
Prijs per uur (gulden)	180	180	gulden/uur	
Componenten invoeren cad	0	16	uur	
Ontwikkelen/aanpassen ontwerp	40	64	uur	
Schema tekenen	24	24	uur	
Review schema	4	4	uur	
Ontwikkelen/aanpassen software	0	160	uur	
Pcb preplacement	16	16	uur	
Aanmaken shapes	8	8	uur	
Bestukken prototypen	16	16	uur	
Testen protypen	16	16	uur	
Aanmaken bedradings-schema's	8	8	uur	
		+		
Totaal uren	132	332	uur	
TOTAAL KOSTEN MANUREN ONTWIKKELING	23760	59760	gulden	Eventueel stagiair laten uitontwikkel en print ontwerp laten maken
Calibreren en testen per print	1	1		Uur per unit
KOSTEN CALIBRATIE PER PRINT	180	180	gulden	

Produktie kosten			
Uitbesteden bestukken			
EXTERNE PRODUKTIE AANLOOP KOSTEN	7500	gulden	Golf-solderen
KOSTEN EXTERNE PRODUKTIE PER PRINT	25	gulden	
Bestukken print intern			
Per print	4	uur	
AANLOOP KOSTEN INTERNE PRODUKTIE	1500	gulden	
KOSTEN INTERN BESTUKKEN PER PRINT	720	gulden	

Integratie printen in behuizing			
Prijs per uur (gulden)	100	gulden/uur	MTS'er extern
Montage print in kast	3	uur	(In elkaar zetten kast, aansluitkabel (drie per print (aan de ruime kant))
KOSTEN MONTAGE per print	300	gulden	

Onderdelen kosten	Prijs		
PCB			5 weken lead time
AANLOOP KOSTEN PCB PRODUKTIE	5000	gulden	incl. Print ontwerp
Produktie kosten per print	50	gulden	Volgens offerte eerste prototype
Componenten	35	gulden	Schatting Mark F35,00 per print
Behuizing	20	gulden	
TOTAAL KOSTEN ONDERDELEN PER PRINT	105	gulden	

Totaal kosten vervolg huidig ontwerp	Ontwerp	produktie	integratie	pcb+onderdelen	calibratie	Totaal
Machinale produktie						
Vaste kosten	23760	7500		5000	=	36260
Variabele kosten per print		25	300	105	180 =	430
Handmatige produktie						
Vaste kosten	23760	1500		5000	=	30260
Variabele kosten per print		720	300	105	180 =	1125

Totaal kosten vervolg upgraded ontwerp	Ontwerp	produktie	integratie	pcb+onderdelen	calibratie	
Machinale produktie						
Vaste kosten	59760	7500		5000	=	72260

ANNEX 3. REFERENCES

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