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Life-Cycle Analysis and Optimisation of Solar Home Systems

Interim report over 2000 of ENGINE project 74556

F.D.J. Nieuwenhout
J.W. Martens
P.E. Lasschuit
M.C.C. Lafleur
J. Cloin

Preface

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

Abstract

This ENGINE 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 2000 the focus was mainly on the household survey Swaziland and the socio-economic and institutional analysis in South Africa.

Key Words: Solar home system; rural electrification; households

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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, an unfavourable 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 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.

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. Outcomes will be used to formulate recommendations for modifying charge regulators and the user-interface and for sizing of the different components. This activity is planned to be started in March 2001.

2) Survey
Information from the monitoring activity is 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 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) Institutional analysis
The objective of this part of the overall project is to analyse how SHS markets operate and how they can be made more sustainable. In this respect, not only market institutions will be analysed but also the role government may play. Based on the institutional analysis, an identification of market barriers will be made as well as recommendations on how the performance of SHS markets may be improved by addressing these barriers.

5) 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. These activities are planned for 2002.

1.3 Project progress in 2000

Planning
Realisation of the planned activities in 2000 was influenced by the fact that final permission for the activities in 2000 was received only on August 3. Therefore only one-third of the year could be used productively. Due to the ordering time of the data loggers of two months, these became available only in December. Installation of the data loggers in Indonesia is planned to take place in March 2001. Luckily, the household survey in Swaziland and the institutional analysis focussing on South Africa were not affected by the late permission. This report over 2000 therefore focuses on the institutional analysis and the household survey.

Institutional analysis
Based on an extensive literature search, a general analysis was made of the different actors who play a role in the deployment of solar home systems. Outcomes are described in chapter 2. This has been worked out in more detail for the specific case of South Africa in chapter 3. For South Africa, a complete description of the organisations that are professionally involved in solar photovoltaics is provided. Many of these have been visited by team members, and key people have been interviewed. Due to other on-going projects, South Africa was chosen for the institutional analysis in 2000. For next year, this will be expanded to include also other countries, especially Indonesia, where also a household survey will take place.

Household survey
A household survey has been conducted among 170 households in Swaziland. They were visited by a technician who asked questions with the help of a questionnaire, checked the

operational status of the system and conducted repairs when necessary. Outcomes of the survey have been related to the level of technical problems.

Monitoring module

Ten Sentry data loggers were bought and customised for monitoring in Indonesia, starting March 2001.

2. INPUT FOR THE INSTITUTIONAL ANALYSIS

2.1 Introduction

Solar home systems have the potential to be widely used for rural electrification in developing countries. About 2 billion people are currently not connected to an electricity grid, and solar home systems would be a good alternative for these households. In spite of this promising prospective, wide scale application is not taking place yet.

The objective of this part of the overall project "Life Cycle Analysis of Solar Home Systems " is to investigate background material for the institutional analysis of SHS markets[1]. With regard to the literature, there is little information available discussing the functioning of SHS markets in developing countries and considering the wide range of institutions involved. The purpose of this research is to carry out an extensive exploration of institutions involved in SHS markets in the analysed countries and analyse the following questions:

- How are SHS markets organised?
- What institutions are involved in the SHS market?
- How does the government interfere in the SHS market?

After having answered these descriptive questions, the analysis will become more normative:

- What does a sustainable SHS market look like?
- What type of interference is desired to promote sustainable SHS markets?
- What is the best way to interfere?

For each country, the market strategy, conditions and role of the different institutes will be analysed. This will give insight in which strategy fits best under which circumstances. At the same time it will clarify the barriers that hinder the market penetration of SHS in the country.

Once it is known that some serious barriers occur, it can be decided to address these:

1. by technological improvements of the solar home systems more suited to the specific needs of the end-users (for example by improving the price/quality ratio, which is still a major barrier). This is beyond the scope of this part of the project;
2. by changing the market strategy; more specific, by adapting one of the aspects mentioned below;
3. by improvements of the country specific conditions. The country analysis will clarify what functions of institutions need to be strengthened to create the right conditions for a PV market. This will lead to actor specific recommendations with regard to capacity building.
4. barriers that cannot be addressed without structural alterations, which are beyond the scope of a programme of co-operation. An example is an unstable economy with civil war risks.

In this chapter, a preliminary survey has been made of the role of the government (2.2) and the organisation of the market (2.3).

[1] **Definition of "institutions"** (Van de Klundert (1999), who follows North (1990: p.4): ""any form of constraint that human beings devise to shape human interactions". This includes all sorts of rules to which economic transactions are subject divided into formal rules (constitutions, laws, property and rights) and informal rules (habits, taboos, moral standards)."

2.2 The role of the government

The role of the government is treated by explaining the government objectives behind rural electrification, the role of the government in stimulating SHS markets and what options the government has for stimulating SHS dissemination.

2.2.1 Rural electrification

In many countries, rural electrification is considered to be an important component of the national development initiatives especially as a means to promote development in rural areas. There are quite a number of social and economic benefits assigned to electrification. Annecke provides an overview of benefits associated with rural electrification (Annecke, 1998: p. 3), including:

- Improved quality of life and living standards;
- Improved education through the availability of light;
- Improved health conditions in households;
- Improved communications
- Reduced crime
- Improved rural/urban balances

It is important to recognise that the relation of rural electrification to economic development is not straightforward. There are a number of other conditions which have to be met in order for rural electrification to result in net economic benefits for rural areas (these conditions were identified by the World Bank in 1975 (Annecke, 1998). Electrification may contribute to economic development provided that:

- The quality of infrastructure, particularly of road is reasonably good;
- There is evidence of growth of output from agriculture;
- There is evidence of a growing number of productive uses in farms and agro-industries;
- There are a large number of villages, not too widely scattered;
- Income and living standards are improving;
- There are plans for developing the area.

Connection to the grid

An important factor influencing the choice for a SHS is grid connection. Grid power comes in general at lower cost to the user, with no restriction on capacity. This facilitates the use of more appliances with higher capacity and is therefore the preferred option. The point is not whether end-users prefer SHSs above grid-electricity, but how long they are willing to wait for the grid connection.

The probability of being connected to the grid, is an important factor in people's willingness to buy SHS. Any information on when the grid will arrive to their households is therefore important to them. It should be noted that knowing the planned grid extension alone, might not be sufficient. The promise of grid extension is often used in election campaigns to win voters, while reality may be different. This will negatively affect potential customers of SHS. In Sri Lanka, for example, people are often promised access to electricity, and although they are sceptical of these promises, they are still reluctant to invest in a PV system based on the lingering hope of being connected to the grid (Miller and Hope, 1999: p.98).

Transparency on grid extension plans is therefore important. In case transparency on grid extension is difficult to retrieve, buy-back schemes could be offered to customers, in which they receive the depreciated value of the module in case grid extension happens within 2 or 3 years after purchase of the SHS. The financial burden of such a system is likely to be minimal, and it may soothe concerned potential customers (Miller and Hope, 1999: p.99).

The reliability of the grid is important. A survey in Kenya revealed that 34% of PV-owning households would keep their SHS even if grid connection were an option (Van der Plas and Hankins, 1998: p.302).

2.2.2 Setting up sustainable PV markets: is it feasible?

Renewable energy is one of the most cost-effective options in providing electricity to remote areas (see for example Ariza Lopez et al., 1997; Garrad Hassan, 2000). From these renewable energy technologies, SHS are among the most expensive when judged on a cost/kWh-basis. But SHS can become cost-effective when it deals with poor customers who can afford only small electricity consumption levels and who are living in dispersed manner in remote areas. As opposed to grid-extension, SHS are small and modular and do not involve a natural monopoly. The natural way to propagate them is therefore through markets.

In order to have a viable business environment for SHSs to attract long term commitment of private sector, there must be profit at each step of the value chain. The concept of the value chain implies that the activities within the value chain are inter-linked. A failure in any one part of the chain will affect the profitability in the whole sector (Philips and Browne, 1998). In judging the profitability of the sales, there are four main elements underlying a profitable cash-flow: high profit margins, low risk profile of sales, high volumes, continued sales over time.

Martinot et al. (2000) argue that the government plays a crucial role in ensuring this profitability:
"We question whether purely private delivery models, by themselves, are able to achieve the widespread market penetration in poorer countries that will satisfy bot global environmental and development objectives (Martinot, et al, 2000).

However, support of government for SHS markets is a difficult process. Literature provides examples where government interference was for example:

- *Counterproductive* - Subsidies on SHS provided by the governments or donors have undercut existing private SHS suppliers, which were not eligible to the subsidy, thus affecting the sustainability of the SHS market. This happened for example with the GEF project in Zimbabwe (Philips and Browne, 1998).

- *Ineffective* - In India entrepreneurial development programmes were offered by IREDA to develop a SHS market infrastructure, but no business developed from these programmes (Miller and Hope, 2000).

- *Too technical*, devoted to teaching how to design and install PV systems. Miller and Hope (2000), indicate that the local entrepreneurs could have been benefited tremendously from assistance to increase unit gross margins through the identification of alternative component suppliers.

The same applies for the GEF whose experience in creating sustainable market environments for SHS companies has been mixed. On basis of the review of the GEF solar PV portfolio, Martinot et al. (2000) suggest, that the following ten emerging lessons can be drawn:

1. Viable business models must be demonstrated to sustain market development for solar PV
2. Delivery/business models development, evolution and testing require time and flexibility
3. Institutional arrangements for project implementation can greatly influence the value of the project in terms of demonstrating viable business models and thus achieving sustainability.
4. Projects must explicitly recognise and account for the high transaction costs associated with marketing, service, and credit collection in rural areas;

5. Consumer credit can be effectively provided by micro-finance organisations with close ties to the local communities if such organisations already have a strong history and cultural niche in a specific country;
6. Project have not produced adequate experience on the viability of dealer supplied credit under a sales model, and no project in the portfolio appears set to provide such experience;
7. Rural electrification policies and planning have a major influence on project outcome and sustainability, and must be explicitly addressed in project design and implementation.
8. Establishing reasonable equipment standards and certification procedures for solar home systems components that ensure quality service while maintaining affordability is not difficult, and few technical problems have been encountered with systems.
9. Substantial implementation experience is still needed before success of the fee-for-service approach can be judged;
10. Post project sustainability of market gains achieved during projects has not yet been demonstrated in any GEF project; it is too early in the evolution of the portfolio.

Investment climate

Another issue affecting the sustainability of SHS markets is the general investment climate in a country. Investment climate in a country include a variety of issues such as:
- Development of financial sector
- Legal institutions (contract rights)
- Safety
- Political stability
- Compliance with international agreements (WTO; IPR, TRIP)
- Import tariffs, duties
- red tape
- government deregulation
- strong investment programme

The SHSs market is one of the most difficult markets for private enterprises, since they are often in unstable economies and target poor household. Philips and Browne (1998) provide an overview of the macroeconomic and microeconomic risks a SHS entrepreneur is facing:
- politically driven changes in fuel subsidies before an election;
- the unanticipated extension of the grid (or just the promise thereof) into the operating territory of the company;
- the imposition of additional trade barriers (for example, import duties) on imported components;
- the deterioration of capital markets which impedes access to critically important growth capital to reach breakeven;
- the loss of needed technical assistance because of some dispute between a host country and a donor country;
- the launching of a subsidised solar PV program in the same market territory.

In addition, the entrepreneur will face the microeconomic business risks associated with any new business and new industry, namely (Philips and Browne, 1998):
- improper system design or product quality;
- poor cost accounting;
- failure to package the sale to include needed after-sales servicing;
- loss of technicians to competing industries after these technicians have already been trained.

2.2.3 SHS Policy

In the most common approach, described by the World Bank as the open market approach, there is a roughly unrestricted market in which SHS dealers and developers can conduct direct sales

In case there is an SHS policy there are two general approaches for government to stimulate the dissemination of SHSs (Philips and Browne, 1998):

- ***Commercial market approach***. In this approach, the SHS policy consists of stimulating private market structures by addressing existing market barriers and providing financial incentives;
- ***Dispersed area concession approach.*** In the dispersed area concession approach, a private electric utility, rural electric cooperative, or other institution enters into a contractual agreement with the government concession for providing SHS electricity services to the rural population.

The open market approach can be distinguished in active SHS policy and absence of a SHS policy, resulting in the following classification of SHS government policies:
The first choice is:

- A SHS policy is not part of rural electrification policy
- A SHS policy is part of rural electrification policy

Resulting in the following categories of government policies:

1 Non-grid rural electrification policy – SHS is integral part of the national rural electrification: concession approach. This approach often includes the FFS approach

2 SHS market stimulation to cover the areas that will not be reached by the national rural electrification plans

2 No explicit SHS policy

These different government policies combines with the three dominant retail strategies: cash sales, credit and Fee-for-service produces the combination of delivery mechanisms as shown in figure 2.1. In the remainder of this section the concession approach versus the market development approach are explained.

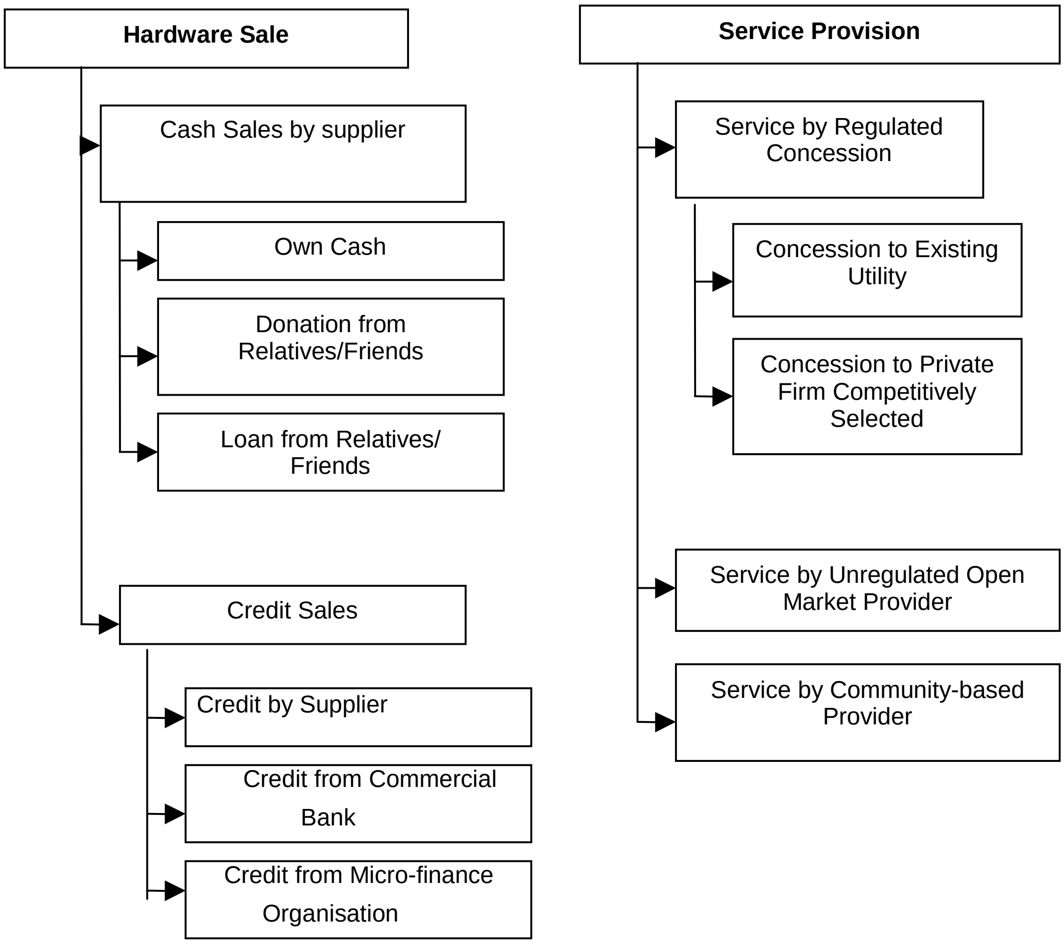


Figure 2. 1 Overview of delivery mechanisms of SHS (Source: Martinot et al., 2000)

2.2.4 Concession approach

Concessions normally include the provision of energy services, the Fee-For-Service approach. In the FFS approach, an energy service company provides solar electricity for a monthly fee to rural households like utilities do for grid-connected electricity. Although the system is based in the house of the customer, the system will be owned and maintained by the energy-service company. The concessionaire will have to invest in setting up a rural infrastructure to implement the activities, but will also have the monopoly right to supply energy services in his area. International experience with the FFS approach reveals that in almost all of the countries where the FFS approach is applied, the energy-services company will be regulated by government and awarded monopoly status for specific geographic regions (Martinot et al., 2000).

In general, consumers are better off if the providers of services compete for their attention. Econ (2000) lists four arguments why competition may be inappropriate with regard to SHSs delivery to rural households:

- There may be some natural monopoly elements to this industry (i.e. costs may decrease significantly with the number of systems installed). This is especially related to market infrastructure, such as rural retail outlets and back-up and maintenance services, which may involve considerable fixed and sunk costs. Efficiency would be improved if only one company supplies these services.
- People are used to electricity being provided by a single public utility and competition may be confusing to rural consumers.

- The FFS concept to poor rural household is a high-risk undertaking. Allowing competition may increase the perceived risks to the point that investors are unwilling to enter the market.
- Another reason is to avoid "cherry-picking", i.e. certain companies only focusing on the more profitable customers and leaving out the poorer. By granting monopoly licenses, the concessionaires can cross-subsidise less profitable customers with the revenues of the more profitable.

ECON (2000) argues that the third and fourth reason have merit and provide a rationale for granting monopoly rights. For the first two reasons it is not obvious why rural SHS markets would be different than other markets.

Martinot and Reiche (2000) provide 6 case studies of concession approaches in developing countries.

Government concession models in other countries (Martinot and Reiche, 2000):

	FFS or sales	**monopoly**	**Private sector /utility**	**Subsidy**	**Bundling with other services**	**Period [year]**	**Govt institutions involved**
Argentina	FFS	All households	utilities, private sector	Yes	In 1 province (water)	15	Provinces,
Benin and Togo	FFS	Open	Private sector	Yes	No	15	Public agency (newly established)
Cape Verde	FFS/ sales			Yes	Water	10	
Peru	FFS		CBOs	Yes	No	-	Minstry of Energy and Mines
Bolivia	FFS/ sales		Local utility	Yes	No	-	

2.2.5 Market development strategies

In order to establish a viable SHS market, Philips and Browne (1998) indicate that three criteria have to be fulfilled to meet those for successful SHS markets:

- There must be potential demand for off-grid resources because, there is insufficient grid access, unreliable grid or grid extension is prohibitively expensive.
- Second, the rural population should be readily accessible within a region so that the systems can be serviced cost-effectively. (One of the problems encountered in Indonesia has been that in some areas, populations are so dispersed that there is no cost-effective way to properly service the systems.)
- Finally, it helps to have a majority of the population in the cash economy with an income level that supports the minimum payments required by a custom financing vehicle. If a country is so poor, or if enough of a country's residents simply have insufficient cash income, then unsubsidised SHS sales—even with a consumer financing program—are infeasible.

A SHS retailer can generate cash flow from the SHS market through direct cash sales from higher income households, shops, small-scale businesses and using financial mechanisms to reach middle and lower income households. "A company's ability to generate revenues from the cash market may only last a few years in a given location before that sales territory becomes saturated. Thus, while direct sales facilitates the penetration of a broader market, this approach has limitations that can only be overcome by alternative financing mechanisms." (Philips and Browne, 1998)

Credit

"Performing microfinance networks exist in many of the markets for financed SHS packages—thus, a marriage between an SHS distribution industry and microfinance networks seems to be the logical way of creating a customised finance vehicle that will help achieve broader market-based SHS penetration." "The answer is that microfinance networks are not yet uniformly in place in most countries, or if they are, they do not lend themselves to PV financing."

Setting up microfinance:

- "Only a few examples can be cited to illustrate a successful marriage between established microfinance organisations and the SHS industry. The best known cases operating on a meaningful scale are the Grameen Bank in Bangladesh and Genesis in Guatemala. The Grameen Bank, which has financed 376 PV installations, provides loans for 2 years at 8% interest, and requires a 25% down payment; risk is reduced by marketing the PV loans to clients who have already borrowed and successfully serviced loans from Grameen in the past. Genesis, which has financed 86 installations, provides 3-year loans at 15%; a local electric utility is now competing with Genesis by offering a slightly lower interest rate." (Philips and Browne, 1998)

Experts in the microfinance industry suggest that difficulties in marrying microfinance and SHS industries centre around three concerns Philips and Browne, 1998):

- ***Loan amounts***: Microfinance organisations typically prefer to start small with their borrowers—perhaps extending an initial loan of only $100—to establish credit at this level with a borrower who has no formal credit record. Thus, the existing customer practices of many microfinancing organisations would not allow them to make an initial SHS loan of $500 (Philips and Browne, 1998).

- ***Loan maturities:*** The repayment maturities for their microloans of most microfinance organisations is around 6 months to 2 years (Philips and Browne, 1998). This is too short to get the monthly repayment costs to a low level, especially when combined with commercial interest rates.

- ***Credit philosophies:*** Many, if not most, microfinance organisations operate credit mechanisms that depend on peer responsibility rather than collateral security (Philips and Browne, 1998). The success of the model depends greatly on cultural factors (see Nieuwenhout et al., 2000)

- ***Insufficient collateral***. The value of repossessed solar modules covers close to 50%, of the credit amount, because it does not include the other costs of sales commissions, installation and balance of system (Philips and Browne, 1998). This limits the option of extending credit on the basis of the PV-module as collateral.

2.3 Market structure

What type of companies are active in the SHS market? In this section, it is analysed what models for SHS companies can be found in the literature. These type of companies will be categorised in order to determine the supply chain of the SHS market, following the general model: production, wholesale, retail, end-user. Besides an indication is made of what the relation is of SHS market with other PV markets.

2.3.1 SHS suppliers

Utilities

National electric utilities are in theory the first candidate for dissemination of SHSs to remote areas as rural electrification is often one of their key priorities. However, they often do not consider SHS electrification in their technology portfolio as their knowledge base, including managerial and technical practices, is based on grid extension (Miller and Hope, 2000). Dealing with huge conventional energy projects and transmission and distribution lines, requires completely other skills than selling consumer products such as SHSs. This barrier could be overcome, however, by creating a special subdivision (or separate business unit) dedicated to SHS dissemination.

Utilities in developing countries are often in a deplorable financial situation. Therefore, the ability to invest in rural electrification as such is limited. To take even more risk by embarking on a SHS adventures is even less attractive to them, given that the potential clients for SHSs are poor rural end-users.

Local SHS retail companies

"Introduction of SHS will rely on a distribution and marketing infrastructure, while its proper functioning will require an installation and servicing infrastructure" (Miller and Hope, 2000). Local SHS companies are companies specialised in the sales of SHSs by establishing such market infrastructure. The requirements to operate such a SHS business, run by local entrepreneurs, need not be extensive, it could consist of a small shop, technicians, motor bikes and a tool kit (Miller and Hope, 2000).

Philips and Browne (1998) list the following activities as the key activities for managing a local SHS retail company:

ESCO

An energy service company (ESCO) sells the energy service but retains ownership of the system indefinitely. The energy service company can be a private or public utility, a co-operative, NGO, or a private company. The consumer pays a fixed monthly fee for the service or pays for the amount of energy consumed. Financing and servicing of the SHS is carried out by the ESCO (Nieuwenhout et al, 2000).

PV system dealers

In India there existed a significant supply network of private and public sector PV companies, which were suppliers of modules and complete systems to Government PV programmes as well as industrial applications of PV (Miller and Hope, 2000).

Private PV system dealers who wish to participate in such programs submit bids for the sales of PV systems to the host government. They often must first go through a pre-qualification process to certify that they are not "fly-by-night" operators. For example, their products must meet the program's technical specifications. Also, they must provide warrantees and show that they are able to service their PV systems. In some cases, a portion of the PV system purchase payment is withheld from the dealer and is escrowed until the warranty expires, thus ensuring the dealer honours the warranty." (Philips and Browne, 1998).

2.3.2 Business models for the SHS market

Kuyvenhoven (1999) classifies companies according to the business model they follow. In this respect he identifies three SHS market models in South Africa: The project model, the system house model and the complementary model.

The project model: Adopted by business leaders (multilateral development organisations, PV-manufacturers (large multinationals) and governments). (…) This model is characterised by its top-down character. Limited in geographic coverage and time, large-scale projects are developed in order to fulfil a variety of (conflicting) goals: infrastructure development, profit from economies of scale and (product-) demonstration/testing.
Because of the large role business leaders play, also other initiatives in the PV sector are focused on this model. For example, standardisation plays an important role as a co-ordination mechanism, resulting in a focus on pre-selected, extensive-design PV-applications. As a result, grants and subsidies are used and credit structures are developed causing an even stronger focus on product standardisation and thus project development.

The system house model: This model holds the middle between the top-down and bottom-up models due to the fact that the central actors, the system engineering houses, are situated relatively 'close' to the end-user.
Because of the flexible character and the relatively weak distribution capacity (small geographical coverage) of the central actors, the model can be characterised by its focus on engineering. This can be either product engineering whereby high margin products are engineered for niche markets, or project engineering whereby the business leaders are followed.

The complementary model: In this bottom-up model, the distribution capacity of complementary traders plays a dominant role. Traders of, for example, batteries or televisions can clearly recognise end-user needs and fulfil them in the best possible way, due to their broad experience with the distribution of such products in rural areas.
PV market development profits from this broad experience of complementary traders. The sales of complementary products can stimulate the sales of ready-made PV-products that need little technical back-up, and vice versa, In addition, PV market development can profit from the existing logistic infrastructure of complementary traders so that a high level of local involvement can be reached."

Table 2.1 - Sustainability of the business models
The sustainability of the three models (Source: Kuyvenhoven, 1999)

Project model	Sustainability within the project model is achieved if the free market follows on project development.
Engineering model	Engineering houses contribute to sustainable PV market development by offering the product differentiation
Complementary model	PV market development can benefit from the combines use of PV and complementary product, the use of existing logistic infrastructure and high local involvement.

2.3.3 Supply chain of the SHS market

The components for the construction of the supply chain are the activities that can be identified in the SHS market. As can be found from the references above, relatively little information could be found on the market structure of the SHS market. Most literature deals with retail strategies of SHS and focus on the introduction of financing mechanisms. Based on these theories, and taking the general structure of a supply chain as reference, the following tasks can be identified, which are schematically presented in figure 2.2:

- Component production
- System design

- Wholesale
- Retail

Component producers

They produce components of the SHS such as panel, battery and BOS. A classification has been made into the following type of suppliers of PV panels on the PV market in a particular country:

1. PV Importers
2. Agents/daughter companies from PV manufacturers
3. Local PV-panel assembly companies
4. Local SHS companies

Using any of the following combinations

1. Import SHS
2. Local assembly:

- Import components: Panels, cells, panel components, BOS
- Purchase locally produced components: Panels, panel components, BOS

Wholesale:

National and/or regional distribution of SHSs to retailers. In the SHS market there are in principle three channels for distributing SHSs:

1. Set up own retail channel to reach end-users
2. Provide panels via existing distribution channels of complementary businesses (battery dealers, audio/hifi dealers, local hardware shops)
3. Tenders for rural household electrification projects.

System design:

The system house is the type of company who designs the solar home system to be sold to end-users choosing system, and finding the panel and other BOS.

Retail:

This is the company, which holds direct interface with the end-user and where the end-user will go to purchase his system. This could be a subsidiary of the national utility, a specialised local SHS company or an established rural business serving the same target group.

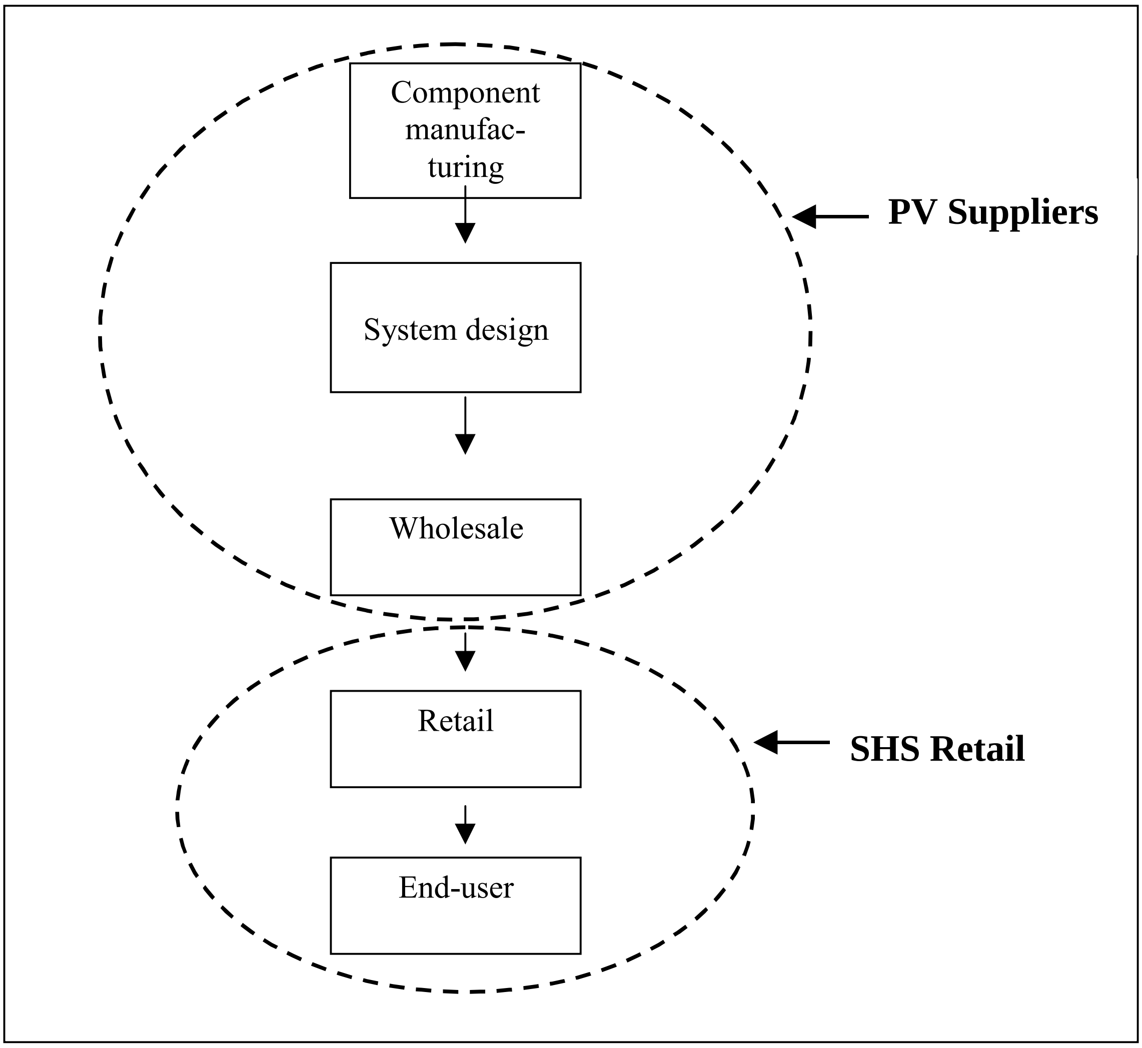


Figure 2.2 – Supply Chain of SHS market

2.3.4 Other PV markets

Complementary PV markets

Besides rural households, there are a number of other markets for PV suppliers. Figure 2.3 shows potential PV markets such as telecommunications, rural schools, clinics and other public facilities, Agricultural water pumping (irrigation), and other PV applications.

It is beyond the scope of this research to focus in detail on the market characteristics of the other PV sub-markets. Relevant aspects encountered in the analysis will be mentioned, especially when they include obvious links to the rural household strategy of these companies.

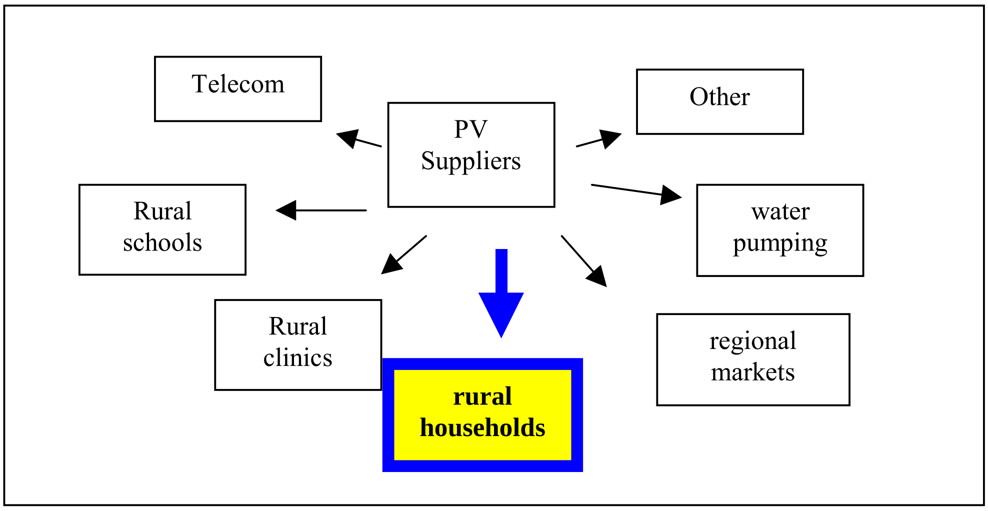


Figure 2.3 Domestic markets for PV suppliers

Synergy between SHS and other solar PV markets

Although all PV systems make use of solar electricity PV Solar Home Systems are a specialised product compared to other PV systems. The scale on which solar PV systems are applied is often much larger, imposing different technical requirements on the system design and operation. Core competencies such as technical skills and delivery of larger 'one-of-a-kind' projects are therefore more likely to be important than smaller, more homogenous products such as SHSs. Besides, the type of customers for such applications are private companies or government institutions, which have more purchasing power behind them than rural households. Instead of mass consumer marketing aimed at addressing the financial barriers, other solar PV products require more business-to-business marketing approach and familiarity with government tenders.

Apart from these differences, the fact hat companies are doing more solar PV products indicate that there are certain synergies between the products. Potential synergies of SHS with other solar PV systems could be:

- **Same components**: The core of the systems, harnessing solar energy through PV panels is the same for all products. Their engagement in the SHS market can be explained because the product they sell is similar to a solar home system (PV panels, batteries, charge controllers, inverters, electric wiring);

- **Similarity in knowledge** required to produce systems – even though the product and the customer may be different, the knowledge required to produce it or market it could be similar;

- **Economies of scale** – Expanding activities over more markets can create economies of scale. Reduction of fixed costs, rebates in component purchasing;

- **Target groups** – Products that are sold to an overlap in target group, in the case of SHS market this means remote rural communities.

- **Similar distribution channels** – Synergy in marketing efforts and transport can be obtained if the same distribution channels can be used.

3. COUNTRY STUDY SOUTH AFRICA

Institutional analysis

In recent years there has been increased attention from governments in developing countries, donor agencies and international organisations to stimulate the development of markets to promote the dissemination of SHSs to end-users. New and innovative approaches have been developed both by private sector operators and public sector institutions to overcome the multiple barriers hindering end-users to purchase SHSs. Numerous projects have been implemented to test and demonstrate these new business concepts championed by the Global Environment Facility (GEF). Despite all these efforts, the results of such co-ordinated market development are mixed (Martinot, 2000). Although projects often succeeded in establishing increased sales of SHSs under the project, they did not build up sustainable structures to allow the continuation of the sales after the project had finished.

With regard to the literature, there is little information available that considers the complete functioning of SHS markets in developing countries and considers the wide range of institutions involved. The purpose of this study is to carry out an extensive exploration of institutions involved in SHS markets in the analysed countries and analyse the following questions:

- How are SHS markets organised?
- What institutions are involved in the SHS market?
- How does the government interfere in the SHS market?

After having answered these descriptive questions, the analysis will become more normative in nature:

- What does a sustainable SHS market look like?
- What are what type of interference is desired to promote sustainable SHS markets?
- What is the best way to interfere?

In this part of the research, the focus is on the descriptive analysis and the case of South Africa is described. At the end, preliminary conclusions are drawn with regard to the normative questions. In the next phase of the research, after having done a similar research in Indonesia, the normative questions will be addressed as part of an international comparison.

Research set-up

As a basis for this institutional analysis a database has been compiled of organisations in South Africa, who are professionally involved in solar PV (See table 3.1). The basis of this database consist of the SESSA member list (47 members), plus an additional number of organisations encountered through personal contacts and literature making in total 72 institutions. It would be too much to claim that the database contains an exhaustive list of PV institutions in South Africa, but it gives a good indication of the organisations active in the field and the activities they carry out. Besides the use of the database, also in-depth interviews have been conducted with a selection of 24 stakeholders from the database.

Table 3.1 – Organisations professionally involved in PV

Total number of institutions in the data base	73
SESSA Member	47
Universities/ research institutes	11
Consultants	7
NGOs	4
Companies	43
GoSA	3
Banks	2
International Organisations	3

The structure of this chapter

The objective of this chapter is to describe the institutional aspects of the SHS market in South Africa and analyse how the institutional arrangements contribute to a sustainable market for SHS.

1. What is the role of the government in the SHS market? (see section 3.2)
2. What type of companies are active in the SHS market? (see section 3.3.1)
3. What is the relation between SHS and other solar PV markets? (see section 3.3.2)
4. What delivery mechanisms exist for SHS in SA? (see section 3.4.1 to 3.4.3)
5. What SHS product strategy are used in the various strategies? (see section 3.4.4)
6. What is the most sustainable retail strategy for SHS in South Africa (see section 3.5)

Figure 3.1 shows a schematic overview of the PV market in South Africa. From top to bottom the supply chain of the SHS market is given, starting with component manufacturing, SHS companies taking care of system design and wholesale; and retail. The numbers in figure 3.1 are the numbers of the above questions. Their position in the figure reflects which part of the supply chain the question targets. By trying to answer each of the questions, a different part of the SHS market will be covered. Question 1 addresses the role of the government (left in the picture). Question 2, the solar PV industry is targeted, question 3 addresses the markets for other PV application in South Africa, question 4 addresses the retail channels and 5 addresses the products, the SHS.

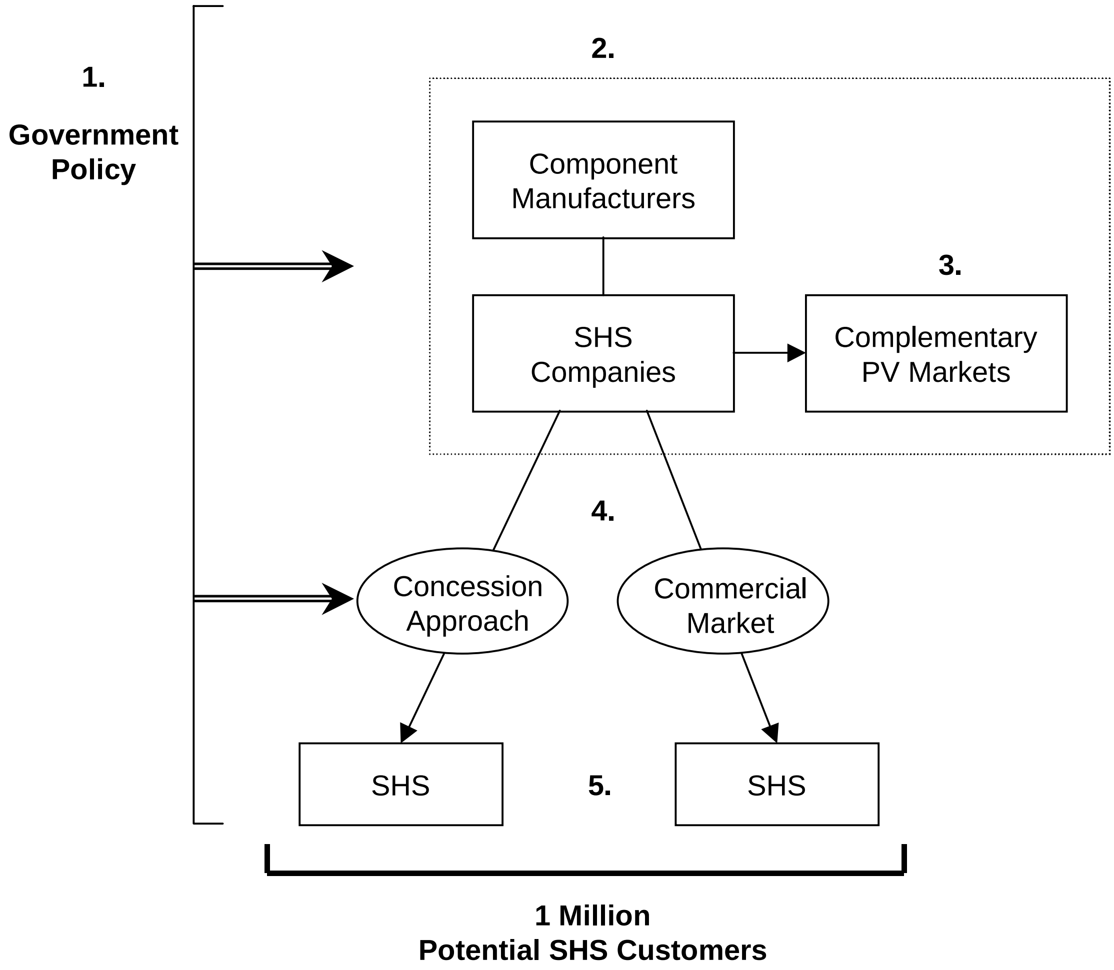


Figure 3.1 – Overview SHS market South Africa

3.1 Government policy in South Africa related to PV

In this section the role of government policy on SHS in South Africa will be analysed by addressing three major components: rural electrification policy (3.2.1), the Non-Grid Rural Electrification Programme (3.2.2) and other relevant government policies (3.2.3).

3.1.1 Rural electrification policy

Electrification of households is one of the core objectives of the Reconstruction and Development Programme adopted by the Government of South Africa in 1994. Regarding electricity, the RDP set an accelerated electrification programme to provide electricity for an additional 2.5 million households by the year 2000, thereby increasing the electrification level to about 72 per cent of all households (double the number in 1994). Both grid and non-grid power sources were to be employed.

In 1998, the Government released the White Paper on Energy Policy. The Paper is aimed at clarifying government policy regarding the supply and consumption of energy, but it does not attempt to deal with implementation strategies, as they are part of the core functions of the Department of Minerals and Energy (DME). The White Paper's objective is to constitute a formal framework for the operation of the energy sector within the broad national strategy.

DME considers electrification as the most important policy objective of the White Paper in the electricity sub-sector. This criterion is consistent with the broader socio-economic targets of the RDP and with the important electrification process led by Eskom since 1991, mainly through grid-connections. The White Paper recognises the role of SHS and other renewable energy technologies in providing energy services to remote rural communities.

Of the total 43 million or so people living in South Africa, most people live in urban areas. Of the urban households, 80% of the households are connected to the grid. While in rural areas, more than half the population is not electrified. This high connection rate in urban areas coupled with the high urbanisation rate (53%) results that two out of three households in South Africa are connected to the grid.

Table 3.2 – Grid electrification in South Africa

	Rural	Urban	Total
Population	20,009,245	23,045,062	43,054,307
Houses	3,873,988	5,752,528	9,626,516
Houses electrified	1,793,193	4,585,185	6,378,378
Houses not electrified	2,080,795	1,167,343	3,248,138
% electrified	46.3%	79.7%	66.3%
% not electrified	53.7%	20.3%	33.7%

Source: DME, 2000 (adapted from Thom, 2000)

ESKOM's electrification Programme

In 1992, Eskom, the national utility, has launched the campaign "Electricity for all" and embarked upon an ambitious programme to electrify South Africa. Despite an impressive record of Eskom connecting people to the grid, it is estimated that still 3.3 million households are not connected to the grid and that 2.1 million of these will not receive grid electricity in the near future.

Eskom is the main contributor to electrification, both through direct investment and grants to municipalities for electrification projects. Within the RDP, in 1994 Eskom committed itself to electrify 1,750,000 houses by year 2000 and claims to have met and exceeded this target in 1999. Recently Eskom set itself a three-year target of a further 600,000 connections, giving more attention to rural areas.

The upcoming restructuring of the electricity industry and the creation of the National Electrification Fund, will eventually cause Eskom to withdraw from directly funding and implementing electrification.

However, given Eskom's central role in meeting RDP's targets, it is expected that the utility will continue to pursue electrification during the transition period, financed by subsidies coming from the electrification fund rather than by internal cross-subsidies.

As electrification in urban areas is reaching saturation, a bigger share of resources will be available for rural electrification.

Table 3.3 – Electrification connection since 1994

	1994	1995	1996	1997	1998	1999
Eskom	254,383	313,179	307,047	274,345	280,977	293,006
Local government	164,535	150,454	137,534	213,768	136,074	144,043
Farm workers	16,838	15,134	9,414	11,198	10,375	6,241
Total	435,756	478,767	453,995	499,311	427,426	443,290
RDP targets	350,000	400,000	450,000	450,000	450,000	450,000

* Expected connections in 2000 are 350,000
(Source: Kotzé 2000, as in Thom et al., 2000)

3.1.2 Non-grid rural electrification

The South African Government, Department of Minerals and Energy (DME) has developed a mechanism to provide electricity and power to those communities that are not planned to be connected to the electricity grid. In 1999, a process was started in which private companies will be awarded concessions to supply energy services to rural households beyond the reach of the national grid by means of the fee-for-service (FFS) approach.

The objective of this concession pilot programme in South Africa is to electrify 300,000 households in five years, divided over 50,000 per concessionaire. The energy service companies could in principle deploy any technology they think is the most appropriate to deliver the energy services to the end-users. With regard to South Africa, in most cases the concessionaires will use solar PV systems, given the low ability to pay of the end-users, the dispersed nature of the households and the lack of institutional end-users.

In order to create a level playing field for renewable energy technologies, the concessionaires will receive the same subsidy as ESKOM per established connection, which is Rand 3000. Based on a SHS price[2] of about R.3500-4000 this is about 75% subsidy of the initial hardware. At the moment, there will not be a subsidy on the tariffs of SHS, but DME may consider this once experience shows that the current tariffs of around R. 45 per month are too high.

Important stakeholders
A number of key players are involved in the concession approach. They are:
- DME
- NER
- Concedantes which monitor the operation of the concessionaires
- The private consortiums forming concessionaires

Concedantes
Eskom and the Durban Electricity Authority, the licensed electricity distributors in the relevant areas, will function as concedantes in this whole process. The role of concedantes is to monitor the implementation of the concessions to ensure that the services are delivered as per the contract. Another role of the concedante is to ensure that the necessary planning takes place that will allow the integration of the grid and off-grid electrification activities. (Banks et al., 2000).

[2] One Rand equals about 0.147 Euro in 2001

National Electricity Regulator

The national Electricity Regulator is the national regulating body of the electricity supply industry. The NER is amongst others responsible for issuing licenses for electricity distribution. NER has also been mandated by DME to regulate the implementation of the Non-grid Electrification Programme.

NER is the regulating body for this concession programme, handing out the subsidy for the systems installed to the concessionaire. NER is responsible for identifying target areas for concessions, licensing of concessionaires, controlling of prices, setting service standards, settlement of disputes, and monitoring and evaluation of the programme (NER, 2000). This latter role is overlapping with the role of the concedante has been taken up by NER to prevent ESKOM getting insight into commercially sensitive information from competitors (Banks et al., 2000).

At the DME People's Power Workshop at the end of September, DME revealed that the concession contracts with the concessionaires will be signed very soon, and that the implementation is expected to start early 2001.

Institutional structure of the National Electrification Programme

Figure 3.2 summarise the institutional set-up of the rural electrification programme, including both grid and non-grid. DME is the responsible Government Department, NER (and the future National Electricity Fund) is responsible for the regulatory framework and the funding for either grid electrification through ESKOM or local utilities (after the electricity restructuring the Regional Electricity Distributors, or non-grid electrification through the concessionaires.

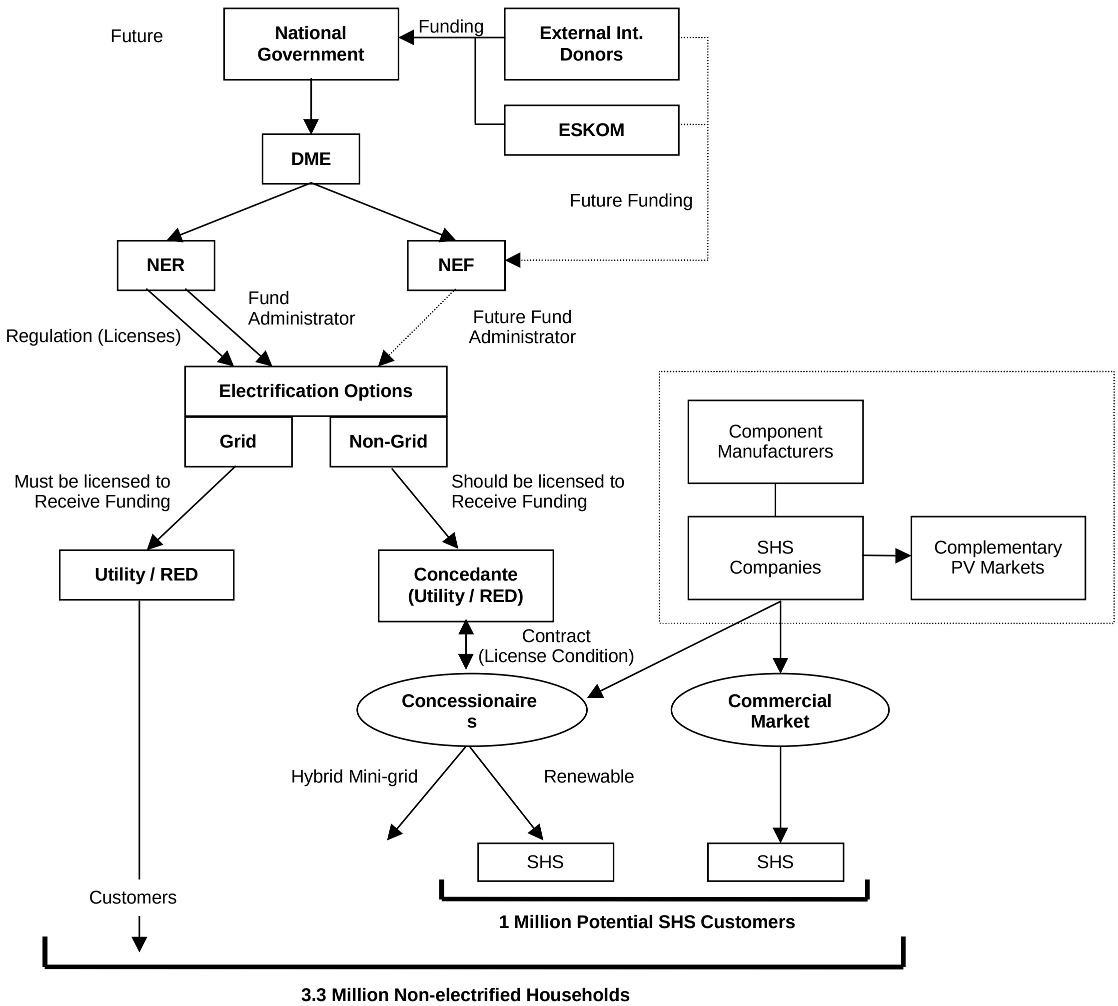


Figure 3.2 – Institutions involved in the rural electrification Programme (Source: NER, 2000)

3.1.3 Other relevant government policies

The objective of this section is to examine what other government policies affect the SHS market.

Import tariffs

Currently, there are no import tariffs on solar PV panels or solar cells. However, other components required to produce solar panels locally are taxed, creating a less favourable environment for local production of solar PV panels.

Technology policy

Reviewing recent publications with regard to SHS in South Africa revealed that 10 research institutes/universities in South Africa are involved in or promoting research into SHS, including:

- CSIR, Pretoria
- Energy Development and Research Centre, University of Capetown
- Port Elizabeth Technikon
- SOLCEN (NGO), Pretoria
- University of Durban Westville

- University of Natal
- University of Port Elizabeth
- University of Pretoria
- University of Stellenbosch
- Vista University, Port Elizabeth

In a recent study, the National Research and Foresight Project of the Department of Arts, Culture, Science and Technology has made recommendations for R&D challenges in the energy sector. The Mission of the Foresight study was to identify future opportunities for economic and social development and its results serve as an important input for the allocation of the R&D investments of the DACTS science budget (Foresight, 2000). Within the energy sector study, SHSs were identified as a key area for research and technology development and the study recommends amongst other to:

- Promote / establish centres of academic excellence in this area;
- Support initiatives to develop low-cost energy storage for PV technology;
- Monitor technology and application progress in other developing countries;
- Investigate applications for PV energy – rural households, low cost appliances.

Rural development

Apart from an increase in welfare, SHS may also contribute to economic development. In other countries, the introduction of lighting has enabled people embarking upon new income generation activities such as:

- Sewing machines running directly on solar PV during the day and run on batteries during the night;
- Poultry farming by lighting henhouses during the evening ;
- Video. People running a video and colour TV with their SHS were found organising video evenings for the village and making money out if it (Uganda);
- Cottage industry, i.e. all types of small work which can be done during night in the house.

Considering that energy issues have important links to development, it is important that energy provision is integrated in other development initiatives. Recently the Integrated Development Planning (IDP) tool has been launched by the Department of Provincial and Local Government (DLGP). IDP is the tool for reorganising local government and setting strategic frameworks for project delivery. The objectives if the IDP is to become a means of mediating between national, provincial objectives and local priorities (Patel, 2000). The IDP will enable local communities to set their development priorities and make informed choices. As far as energy needs are concerned, ESKOM (or future REDs) and the concessionaires could assist with the provision of the energy supply to address those needs. In order to facilitate this process, it is recognised by DPLG that municipalities will require technical assistance to identify and elaborate appropriate energy programmes (Patel, 2000).

3.1.4 Concluding remarks on the role of the government

The government of South Africa interferes with the SHS market in two important ways:

- South Africa has a very strong grid extension programme to rural areas and providing good quality grid, while the government and ESKOM have made political statements about electricity for all. This situation has created high expectations in rural areas on being connected to the grid as well as the level of quality of services. This affects the SHS market in two ways: Potential SHS customers have unrealistic expectations of being connected to the grid and they expect level of electricity services, which can not be provided by SHSs (such as cooking and refrigeration).
- The government has embarked upon a very ambitious programme to provide 300,000 households in the next five years with SHSs. By designing their programme they

strongly influence the structure of the SHS market, the actors involved in SHS dissemination as well as what strategies companies can pursue.

3.2 Solar PV industry in South Africa

The production and distribution of SHS to their customers is a type of business, which is dominated by private sector companies. Despite the ambitious plans of the government to create a mass rural SHS market through the concession programme, the market for SHS in South Africa has until sofar operated under commercial circumstances. A large part of our research has been dedicated in understanding how this market has been organised and what companies play a role in this market. The major questions this section aims to address are what type of companies are active in the SHS market? (see section 3.3.1); and what is the relation between SHS and other PV markets? (see section 3.3.2). The section ends with a typology of companies active in the South African SHS market.

3.2.1 PV market structure

As mentioned in Chapter 2, the upper part of the supply chain for SHSs has for a great deal an overlap with the supply chain of other solar PV systems.

In accordance with the structure in Chapter 2 the supply chain of the PV market was divided into four type of main activities companies undertake in the SHS sector undertake:

- Component manufacturing - Subdivided into PV, battery and BOS;
- System integration - designing and integrating the Solar Home Systems;
- Wholesale –The national/regional distribution of SHSs to retailers;
- Retail –The level where customers will purchase SHSs.

In accordance with these activities, the companies active in the solar PV industry in South Africa have been classified according to the following typology, which are described below:

- Component manufacturers
- PV suppliers
- SHS suppliers
- Retailers

PV component manufacturers

The most important group of component manufacturers is the solar PV panel producers. These panel producers import components like solar cells and other critical components . There is currently on production of solar cells in South Africa. . This is generally restricted to highly industrialised countries (with the exception of India and China, although ideas have been launched to investigate the possibilities of solar cell production in South Africa (see Leitch and Van der Linde, 1995).

There are is currently five manufacturers involved in the production of PV panels.. Besides the local products, most international brands can be found in South Africa. See table 3.4 for an overview of PV panels available in South Africa.

Table 3.4 - PV panels available in South Africa

	Poly or mono crystalline (international)	Poly or mono crystalline (domestic)	Amorphous Silicon (international)
Panels	• BP • Solarex • Shell • Siemens • Kyocera • Isofoton	• Liselo (Midrand) • Tenesa (Cape Town) • M-Solar (Pretoria) • Sun Corp* • Solar fabric*	• FEE (NAPS) • Unisolar (USA) • Intersolar (UK) • Konchar (Croatia) • Panels coming from China

*The existence of these companies needs to be verified

Other component manufacturers

In South Africa there are two battery producers, which are also involved in the production of solar batteries, which range from simple upgraded car batteries to highly efficient solar batteries mainly manufactured for high-tech expensive applications. Both producers have about an equal market share of the solar battery market. There are also imported batteries available on the market, but local batteries dominate the market. Eleven companies have been found who are involved in the production of various BOS components. Since BOS consists of wide variety of components with multiple purposes, it is likely that more companies are involved than are listed here.

Table 3.5 – South African component manufacturers

- PV panel assembly	5
- Battery	2
- BOS	8

PV systems suppliers

PV systems suppliers are companies that are mainly focused on designing and selling off-grid PV systems for all type of PV systems, not only SHSs, and not necessarily incorporating SHSs. They can be subdivided into companies mainly focused on serving specialised markets (for instance solar water pumping or telecom) and companies who will target all sorts of PV appliances. This latter group are more likely to be involved in the SHS market, either through an occasional demand or by winning a tender.

Vertical integration between the companies is mostly centred around PV suppliers:

- PV system suppliers exist who are daughter companies of foreign PV panel producers or are Local PV panel producer also supplies PV systems;
- PV system suppliers also produce one or more BOS components of their system;
- PV system suppliers who are official PV importers for a foreign panel producer.
- PV system suppliers who purchase components "in the market", i.e. either domestic or foreign, as long as it is the most suitable;
- Pure wholesalers: PV systems suppliers who import complete systems from abroad and sells them through their own retail channels
- PV systems suppliers who integrate component manufacturing, system design with an own retail channel.

SHS suppliers
SHS suppliers are a subset of PV system suppliers whose core activity is selling SHS but may serve other markets occasionally. In the commercial market, these companies distinguish themselves from PV suppliers through their explicit retail strategy for SHSs.

Concession holders
Concession holders are a special sub-type of SHS companies who have entered a contractual agreement with the government to provide solar power in a certain area, for a given subsidy and given set of requirements. In the context of South Africa, is their retail infrastructure heavily focused on the given area, and their product strategy by the requirements of the government.

SHS retailers
Companies who are focused on sales of SHSs. Section 3.4.3 explains more of the different type of companies involved.

Table 3.6a - Companies present in South Africa involved in PV

Total	34
Component production	21
PV Systems suppliers	27
Wholesale	24

Table 3.6b - Companies involved in SHS

Total	19
SHS design & manufacturing	17
SHS wholesale	12
SHS retail	12

The division of companies over the various activities can be found in Table 3.6a and 3.6b. Table 3.6a include all companies dealing with solar PV, both PV manufacturers and PV systems suppliers, table 3.6b includes all companies that are involved in selling SHS, which is slightly more than half of the PV companies. In summary, one can conclude that the PV-panel market in South Africa seems to be highly developed with local production capacity of SHSs, PV panels and BOS.

3.2.2 Other solar PV markets

An important element in understanding the companies active in the SHS market is to realise that SHS is often not the core activity of these companies. Besides household electricity, there are many other applications in remote areas with low electricity loads for which PV is a cost-effective solution. As table 3.6b showed, only 19 of the 34 companies are involved in SHS. Besides other PV markets, companies might also be involved in other markets involving PV. The objective of this section is to analyse what other activities SHS companies are engaged in and to what extent that relates to their SHS activities.

Table 3.7 provides an overview of the activities companies implement besides serving the SHS market. Description of activities are subdivided in two categories: “Other PV activities” meaning non – SHS activities and “Other activities” meaning non-PV related activities[3].

[3] With respect to (subsidiaries of) foreign companies included, this aspect is limited to the activities of the solar/off grid activities in South Africa.

Table 3.7 – Other Activities of SHS companies

Other PV activities	- Telecom - Solar water pumps - Regional markets - Clinics - Schools - General tendering for any type of PV activity - Game lodges - Security lights - Farm houses
Other activities	- Water pumping - Battery manufacturing - BOS manufacturing - Other renewable energy/off grid systems - (Solar) consultancy services

Core activities

What the core activity was before the incorporation of PV products and whether any relation could be established between the type of market activities, has been analysed for 19 PV companies. Table 3.8 shows an overview of these core activities.

Table 3.8

	Number	Type of core market
SHS supplier with SHS as core market	9	SHS*
core market of other SHS suppliers	4	• Water pumping • Battery manufacturing • PV tenders • Off-grid energy services
Core markets of other PV companies not involved in SHS market	6	• Battery sales • Battery manufacturing • Solar water pumping (2x) • Schools • Telecom
Total	19	

** This includes the 6 concessionaires under the non-grid rural electrification programme. Although most consist of a consortium of partners with other activities, the project company responsible for the project activities have been considered and not the individual consortium members.*

It is important to note that the distinction between the companies is not rigid. The interviews among the different type of companies revealed that all companies are watching the developments in the SHSs market and are thinking on ways to target this market.

Synergy between SHS and other solar PV markets

As the overview in table 3.9 shows, clinics and schools have the biggest synergy with SHSs, closely followed by farm houses, security lights and solar water pumps. Looking at the companies in the database, no clear pattern of SHS linked to other activities could be found. The main conclusion of this overview is that from the 11 companies (excluding the concessionaires), only 1 is a single SHS company, and 10 focus on more than 3 markets, while a majority (7) focuses on 4 or more markets. It was found that most companies do include schools and clinics within their markets.

Table 3.9 - Synergy between SHS and other Solar PV markets

	Product	System Knowledge	Economies of scale	Target group	Distribution channels
Telecom		●	●		
Solar water pumps			●	●	●
Clinics	●	●	●	●	●
Schools	●	●	●	●	●
Game lodges	●	●			
Game parks		●			
Security lights	●	●			●
Farm houses	●	●			●

Table 3.10 - Overlap in product strategy

Market served: SHS and	# of companies
• Telcom, Solar pumps, commercial off-grid lighting, schools&clinics, Non-PV	2
• Solar pumps, commercial off-grid lighting, schools&clinics, Non-PV	1
• Commercial off-grid lighting, schools&clinics, Non-PV	3
• Solar pumps, commercial off-grid lighting, schools&clinics	1
• Commercial off-grid lighting, non-pv	2
• Solar pumps, non-pv	1
• Only SHS	1
Total	11

Synergy with other activities

Synergy between other products and PV system products include the following:

- Water pumping – vertical integration with solar water pumping
- Battery manufacturing – The market for solar PV systems is a downstream market for batteries
- BOS manufacturing - The market for solar PV systems is a downstream market for batteries
- Other renewable energy/off grid systems – same target group
- (Solar) consultancy services – application of same knowledge gained

3.2.3 Conclusions

There is a large variety of companies active in the solar PV market in South Africa. The following typology was developed to categorise the different companies encountered:
- PV panel manufacturers
- Battery manufacturers
- BOS manufacturers
- PV system suppliers
- SHS suppliers
- Retailers
- Concessionaires

  In the commercial market there is not one company, which looks like another, they all share common characteristics, but differ on other aspects. One has therefore to be careful with the use of the name "solar company". Only the project companies of the concessionaires are likely to show strong similarities due to the uniformity in the concession approach.

1. Considering the production of different SHS components, one may conclude that there is sufficient capacity in South Africa to produce SHSs. The availability of many foreign products shows that the SHS is developing and that South African products can handle international competition. This is also supported by the fact that most South African companies export to neighbouring countries.

2. PV system suppliers seem an important level for the SHS market in South Africa. It is the level where products are designed, where adjustments to end-user needs takes place, where marketing was co-ordinated (brand name, initiating promotion strategies). This is consistent with other consumer good markets where suppliers are the dominant parties. The logic behind this is that suppliers are specialists, focusing on the product. On the other hand, retailers are generalists offering a wide variety of products and hence cannot afford to know details.

3. There are strong relations between other solar PV markets and the SHS commercial market. Only 3 of the 12 SHS suppliers had companies SHS as core activity, and most companies were active on 3 or more solar PV markets.

3.3 Retail strategies in the SHS market

In the previous sections, the Non-Grid Electrification Programme of the government has been discussed as well as the type of companies involved in the production of SHSs in South Africa. In this section, the delivery mechanisms used to bring SHSs to the end-users are further examined.

The delivery mechanisms for SHS are among the most crucial part of the SHS business. SHS are aimed at a very difficult market, poor remote end-users, who often have little awareness of the product. This contains several difficult issues to overcome, including reaching the customers, raising awareness on SHSs and addressing the issue of lack of finance. Another issue important for retailers is after sales services. Replacement of components, such as the batteries, simple repair to the systems, etc. will occur during the use of the system. Experiences in other countries have shown that lack of maintenance infrastructure, or insufficiently trained technicians often lead to early abandonment of the SHS and a bad reputation for the solar market as a consequence (see Nieuwenhout et al., 2000).

Based on these aspects the following questions will be addressed:
1. What delivery mechanisms exist for SHS in RSA?
2. What SHS product strategy is used in the various strategies?
3. What after-sales services are provided?
4. What is the most sustainable retail strategy for SHS in South Africa?

The delivery channels to end-users can be distinguished in three categories: non-commercial demonstration projects, concession approach and commercial markets (see section 3.4.1, 3.4.2 and 3.4.3).

3.3.1 Demonstration projects

Outside commercial channels or the Non-Grid Electrification Programme, government bodies, donors or NGOs provide funding to purchase systems for households, which are often purchased through tender procedures. Companies involved in this type of SHS delivery are PV companies also involved in other type of tenders (see section 3.4.2). They are typically one of a kind projects and as such they can hardly be qualified as a retail strategy for SHS as the driving actor is not the company but the donor. A number of non-grid electrification pilot projects have been implemented in South Africa (see table 3.11). These include

Table 3.11 – demonstration SHS projects in South Africa (Source:Thom et. al., 2000)

Project area	Description	SHS installed	Support	System size
Kwabaza	the provision of an integrated energy package at KwaBhaza by ESKOM and Total;	140	R1500/shs Finance	49 W_p
Maphephethe	A private commercial non-subsidised SHS dissemination pilot at Maphephethe;	60	Project development Loan	55 W_p
Folovhodwe	A joint project between the Bavarian government and the DME at Folovhodwe in the Northern Province.			
Free State farm workers programme	A District Council initiative to supply farm workers with SHS in the Free State Province;	1800	R2000 – 2500/shs	50W_p (estimate)

3.3.2 The concession programme

In this section we will describe the main characteristics of the concession approach. We will discuss brief characteristics such as the monopoly structure, the fee-for service concept, and the product requirements. As the Programme is not yet operating, there is no factual evidence of how the system will work. Nevertheless, the Shell – Eskom enterprise JV has been operating under the FFS concept and lessons can be learned from that.

Concessionaires

In late 1999 the successful bidders and their target areas were announced. The concessions and areas are (NER, 2000):
- Northern Province: Sekhukune and Nebo regions: NUON-RAPS JV.
- Northern Province: Mutale, Shingwedzi and/or Levuvu districts: Solar Vision and partners.

- KwaZulu Natal: Lubombo area: BP ESKOM Emtatweni JV. (BP has recently withdrawn from this JV)
- KwaZulu Natal: Tugela Ferry, Nqutu, Nkandla Districts: EDF/Total consortium.
- Eastern Cape: Flagstaff area: Shell ESKOM JV.
- Eastern Cape: Northern part of Transkei: Renewable Energy Africa and Partners.

An additional concession will probably be soon awarded, after DME has received R100 million (DM 31 million) from the German Government through KfW. However, the private sector party responsible for the implementation of the concession has not yet been identified.

Fee for service

In the FFS approach, an energy service company provides solar electricity for a monthly fee to rural households like utilities do for grid-connected electricity. Although the system is based in the house of the customer, the system will be owned and maintained by the energy-service company. The commitment for the concessionaire under the NGEP will include investing in a rural infrastructure to implement the activities, installing 50,000 systems in the next five years per concessionaire, servicing for the next 20 years the systems installed, submitting business plans to the NER for approval, having the electricity tariffs monitored by the NER. In reward, the concessionaires will have the monopoly right to supply energy services in his area, at least for the first five years, and receive a subsidy of around R.3000 per system, which is an estimated 80% of the system costs.

Eskom-Shell Joint Venture (source: Thom et. al. 2000)
In 1999 a JV between Eskom and Shell was initiated in Bipha in the Eastern Cape Province. The intention was to work towards economies of scale and eventually supply 50 000 households with SHS's. The first 6 000 had been installed by March 2000 and the project halted to allow for technical, financial and customer satisfaction evaluations. These have been completed, various improvements, modifications and adjustments made and Phase 2 was due to start in October 2000 with the electrification of a further 12 000 households.

The system consists of:

- a controller
- a pre-payment card reader
- a 50 Wp PV panel
- a 100 Ah lead acid battery
- 4 lights
- cabling and switches.

A fee-for-service approach is being used in this JV: an installation fee of R150 is charged initially, and a service fee of R47 is paid on a monthly basis, while ownership remains with the JV. Customers outside the immediate project area are being charged R75 per month.

A new feature of these systems is a security device designed by Conlog and fitted at the point of manufacture as a deterrent to tampering and theft, both of which have been serious concerns in the schools non-grid electrification programme. The systems is capable of powering four hours of lights and four hours of television daily.

The main reason why a monopolistic license or concession has been chosen is that the FFS concept to poor rural household is a high risk undertaking. Allowing competition may increase the perceived risks to the point that investors are unwilling to enter the market. Another reason is to avoid "cherry-picking", i.e. certain companies only focusing on the more profitable customers and leaving out the poorer. By granting monopoly licenses, the concessionaires can cross-subsidise less profitable customers with the revenues of the more profitable (NER, 2000; ECON, 2000).

Fee for service as carried under the concession programme will follow the model of the Shell-ESKOM Joint Venture (see Text box). The advantages of the concept are summed up in (Nieuwenhout et al., 2000, p.39):

> "It lowers the up-front costs for the end-user, allows for bulk purchases of the hardware and hence reductions in capital costs and it allow for 'controlled and qualified' installation and maintenance, thus improving the technical performance of the systems."

There are however, also some risks included:

Affordability and payment discipline - The fee-for-service system requires a strong payment discipline from the end-user, which may prohibit a certain end-users from benefiting from the system. Experiments with a fixed rate per month (15 R.) for a 2.5 A grid connection by ESKOM were abandoned because of the negative responses in these communities to this "flat-rate tariff" (Thom et al., 2000). Experience in other countries with financing schemes for SHS showed that payment discipline is an important problem (Nieuwenhout, et al., 2000). Experience in Uganda showed that payment discipline deteriorated after 1 year.

Social impact – Thom et al. (2000) argue that the monthly fee of R. 50 will not be affordable to a large percentage of rural households and that a large-scale subsidised programme like the Non-Grid Electrification Programme will only benefit the more affluent households in rural areas.

Ownership - All commercial market PV companies interviewed expressed their view that they did not believe in a set-up, where the user is not the owner of the system. There are two reasons behind ownership: 1) households prefer to own the system, and 2) ownership is clearer incentive for the household to learn about operation and maintenance of the system. The first point has been confirmed in a customer survey in Maphephethe. There, 70% of the respondents expressed their preference of owning a SHS above renting one, while only 16% wanted to rent a system (Green, 1999).

Solution: more flexibility?

The current system sets standards for the systems to provide and the operational requirements. More flexibility in the performance of the system may be required in order to be successful and meet the above risks. Such flexibility could include:

- Smaller systems – If smaller systems with lower monthly payment services are allowed to offer, also poorer households can be reached. If the financial situation of the household improves over time, the contract could be upgraded to a larger system.
- Handing over of ownership after a x amount of years servicing. This proposition could also include separation of the service contract. Separate service contracts could also allow flexible payment arrangements, such as payments per service instead of per month.

3.3.3 Retail strategies in the commercial PV market

What delivery mechanisms are used by in the commercial SHS market to market and distribute SHSs? The fact that many of the companies interviewed considered information on this subject confidential and did no want to disclose detailed information, illustrates the importance of this aspect in the strategy of SHS.

Commercial SHS sales

Banks et al. (2000) estimate that total sales of SHSs in South Africa through the cash market amounts up to 50,000 systems since the start of commercial SHS activities. This amounts to less than 1% of the initially un-electrified community. This seems however a conservative measure. Stassen and Holm (1996) estimated an installed capacity in 1994 of 40,000 systems. Based on the figures in Stassen and Holm (1996) a yearly average installation of 12,000 SHS can be estimated, resulting in a total of 70 - 80,000 systems in South Africa in 2000. Based on unverified accounts from our field survey among SHS companies, the yearly sold figures would also mount up to 12,000 – 15,000 systems a year. This does not look impressive compared to the target group for SHS, it only covers 0.5% (see Stassen and Holm, 1996; Banks et al., 2000). Compared to other SHS markets in the world, however, the figure of 50,000 to 80,000 systems puts South Africa in the top ten of SHS markets in the world (compare with Nieuwenhout et al., 2000, p.16).

Commercial retail channels for cash sales

An interesting finding is that all companies in this category distributed their systems through urban centres, not via rural distribution networks. Arguments mentioned by companies as of why:

- Maintaining a rural network for SHS delivery was clearly seen as too expensive for the low margins on PV systems.
- SHS belong to a category of products, durable consumer products, for which customers spend a lot of money and for which they are willing to travel as opposed to convenience goods. Customers also purchase their television, radio and other electrical appliances in urban centres, so why not SHSs?
- SHS are often donated to rural end-users by urban relatives, earning a higher cash income than their rural family. There thus exists an urban client base for SHS even though they are not the end-users.

The commercial retail channels for cash sales can be subdivided in:

- Sales from own workshop
- Integrated retail channel
- Strategic alliances
- Independent retail channels

Sales from own workshop:

This is a limited strategy: low costs low results. It is mostly applied by PV companies for whom the SHS market is not their core market. Thus they will serve the upmarket SHS clients with specific design requirements.

Integrated retail channels

PV companies who have their own existing retail channels can use them for SHS as well. In South Africa, this was found for the battery producers.

Strategic alliances

Complementary outlets to small shops in urban centres with exclusive right for delivering solar products

1. Complementary approach by delivering to major chain groups: Makro, Dion, Game, etc.

Independent distribution channels:

This is a retail channel in which no contractual relation exists between retailer and wholesaler and where the retailer supplies different type of SHS on a more or less regular basis. The scope of this research was too limited to do an extensive research to existing retail channels in South Africa. Hence little information was retrieved on independent distributors. The two examples we heard of, illustrated that this channel especially focuses on low price, low quality target group.

- Supermarkets – Supermarkets operate in the segment of low margin, low quality, with the implication of low interest sales.
- Mine worker concession stores - A concession store is a store at a mineworkers compound that hold the monopoly right to sell to the mineworkers. These stores also sell PV panels

which mineworkers can acquire for their families in rural areas. This channel was brought up as an example of how PV has got a bad name in South Africa. Since the concession stores have monopoly right to sell to the mineworkers and the buyers are not the ultimate end-users, they can get away with selling low quality products.

Credit

South Africa has relatively little experience with micro-credit for SHSs. Credit is used to purchase furniture and fridges. As one of the respondents noted, however, these are products with high margins for the retailers, which limits their relevance for SHS. Their higher margins can facilitate the credit provision. Also, existing financial retail channels are not geared towards facilitating loans for PV considering their high interest rates.

The general view of interviewed companies is that credit would help the market, but is very difficult to organise. It will only work if it is organised on a commercial basis, but hardly any experience so far. Two of the interviewed companies mentioned experience with credit. The first mentioned of an experience with a pilot project, which failed. The second company was more successful and has been using credit for a long time and experienced little problems. The company installs the system (to know the location of the customer), and the consumer has to pay 50% deposit, and the remaining amount in a 12 months period with a commercial interest rate of 26[4]%. If the customer does not meet its commitment, than the company will take away the panel (about 50% of the cost). Usually people start paying again then. Especially the lower income customers ask for credit.

3.3.4 Product strategy

The objective of this section is to identify what product strategies are followed by the SHS companies in South Africa, and analyse the pros and cons of each strategy.

It was beyond the scope of this research to make a detailed study of the SHS available on the market. The systems found are grouped into two categories:
1. End-user responsible for designing his own system. Companies provide two sort of products:
- Battery chargers
- Solar kits exclusive battery
2. SHS company provides an integrated systems based on the needs of the end-user

Battery chargers

A battery charger is a panel with two clamps to recharge a battery. The target group for this product is customers who use the electricity services from a car battery and who have to travel to charge their battery. In this situation the end-user designs his own system which often consists of a car battery, a 12-14 W_p panel and some wiring.

Solar kits exclusive battery

A solar kit does not only include the panel, but also comes with lights, wiring and possible charge controller, battery box, inverter. It is not an integrated system yet, since the customer will still be responsible for the design of his system, is free to expand or reduce it according to his wishes and needs to bring his own battery. The size of solar kits varies greatly between 12 – 50 W_p.

These two type of products have the advantage that they better adapt to the needs and ability to pay of the customer. The backside is that their quality is very much dependent on the knowledge of the end-user in dealing with the system. Unawareness with solar products may lead to the

[4] At an average inflation of 15 %; i.e. the real interest rate is 11%

purchasing of poor quality panels and other components. Lack of knowledge of the product may result in bad installation, operation and maintenance of the system.

Integrated SHS

In an integrated system, the system is designed (and often installed) by the SHS company based on the wishes of the customer. Due to the involvement of the company, the quality of the system is likely to be better. Such systems are less likely to be under-designed, use better quality components and are better installed. Backside of it is that such systems are often more expensive than battery chargers or solar kits. Another disadvantage is that customers often require flexibility of their system to adjust to new circumstances and may try to adjust their system, by changing applications, wiring, etc. If this is not properly done, the quality of the system is compromised. The size of integrated systems ranges from 30 – 50W_p and bigger.

Four companies were interviewed who actively sell SHS through the commercial venues. Three of them follow the small system route, in which they offer either panels or battery charging or a solar kit (panels plus additional components). Most systems are in the range of 12 – 14 W, one company also offer larger systems (50 – 70W_p). The company which provided integrated systems sold larger systems (55 – 110 W_p), but also claimed to aim at low and middle income rural households. It was also the only company which provided credit to its consumers.

In short, companies face the challenge of providing small, cheaper systems, which compromise on the performance of the system, or more expensive systems which promise a better quality. It should be noted that no evidence exist from international comparisons that the quality of smaller systems is less than the quality of larger systems.

After sales strategy

Under the concession approach an extensive after-sales strategy is involved through the service contract under the system. Among the interviewed companies in the commercial market there were no extensive after sales service to customers other than component guarantees.

3.3.5 Commercial versus concession

In this section, a comparison between commercial market approach and the FFS concept has been made (see table 3.12). Each of the aspects are discussed below.

Table 3.12 – comparison of FFs with commercial market in South Africa

Sustainability criteria	FFS	Commercial market
Commercial viability	No: requires subsidy	Yes
Outreach potential in the short term	High	Low/uncertain
Addressing financing barrier	+ Upfront capital cost - payment discipline	No Smaller systems (a little through credit)
Delivery channel	Rural	Urban outlets provide systems for neighbouring rural areas
SHS size	Fixed	Small, but in general flexible
Product quality	High	Low
End-user education of system use	Overcome by provision of service contract in combination with design of system which excludes interference	No
After sales strategy	Extensive service contract	Only component guarantee

Commercial viability

Under the current circumstances in South Africa, where the majority of the households is expecting a subsidised grid connecting a fee-for-service system is not a commercially viable operation without subsidy. None of the companies interviewed (both concessionaires and commercial operators) believed that FFS could be operated viably without government subsidies. The commercial viability of the concession programme is therefore dependent on the subsidy of the government and other favourable conditions made in the concession. The pilot phase will teach us whether it is sufficient to operate in a commercially viable manner.

The sustainability of government subsidies will largely depend on the strength and reliability of the government. Government subsidies are normally not regarded as sustainable. On the other hand, (cross) subsidies are common in the electricity sector in many countries. In the case of South Africa, the funds for the concession subsidies in the pilot phase have been allocated by DME in the government, their long term nature as well as the fact that their funding is covered through the extra levy on electricity makes the Programme quite sustainable.

Outreach potential

Both channels choose different retail networks to the end-users. Given the target set for the concessionaires (60,000 systems per year), the concession programme is likely to be more effective in delivering on a large scale than the commercial market channels. Through the latter, a similar amount has been delivered in the past 15 years. However, one has to take into account that if the same amount of money to support market channels in their operations (through awareness raising, support in providing credit, open up shops deeper in rural areas), their scale of operations might increase considerably.

Urban or rural delivery channels

An interesting outcome of this study is that commercial channels all choose their sales points in urban centres, not in rural areas. As mentioned above, important reasons for doing so is that rural network for SHS sales is too expensive, SHS is a durable consumer good for which distance is not so much a priority in the purchase, and a large customer base is located around urban areas.

It should be noted that they can do this because they do not provide extensive after sales services to their customers. That is one of the main reasons why presence in the rural areas is chosen in the concession programme.

Addressing the financing barrier

Addressing the finance barrier is an important way to increase the market for SHS as this is most heard barrier for not purchasing SHSs. The concession addresses this barrier through the FFS concept by spreading the expenses over the lifetime of the product. The disadvantage of this is that customers end-up with long term financial commitments, which may not suit their income pattern (which is often irregular and can not sustain a high debt burden). Thom et al. (2000) mention that the tariff level as envisaged under the concession programme is beyond the reach of poorer households.

The commercial market addresses this barrier by making use of the modularity of PV and provide smaller systems against cheaper prices. With the availability of more cash customers can scale their system up. The disadvantage of this system is that customers go for the cheapest options available and may end up with bad quality. In other countries, the modular approach through commercial venues has resulted in high successes (Nieuwenhout, et al., 2000). Especially the availability of car batteries seems to be important for this market as customers get tired of carrying the battery to and from the charging station (Nieuwenhout et al, 2000). During our interviews we have a reported (on unverified account) that there are currently 8 million batteries being charged in South Africa.

Addressing end-user education to use system

In the commercial market, the end-user is responsible for the design, use and lay-out of his system. This has the great advantage that he can tailor this to his own needs, add attributes which he feels relevant and adjust it when necessary. The bad side of this approach is that it requires quite some understanding of the design, the installation and the use of the system. The lack of this understanding on the part of the end-user, is often cited as the main cause of system failures and the bad reputation of SHSs.

This situation could be sustainable in a developed market. Market incentives will then cause self-cleansing mechanisms. Bad reputation will eradicate bad quality systems in favour of good ones. In such a situation, end-users are more educated on the system and where the infrastructure exists in terms of workshops to ask advice and buy spare parts.

The problem of poor use and maintenance is one of the fundamentals of the FFS concept. The reaction to this problem was the need for an extensive service contract to the end-users and hence the emergence of the FFS concept. FFS operators address the problem by providing higher quality systems, installing systems themselves and design the system in such a way that the end-user cannot interfere with it. The disadvantage of this approach is that its involves expensive service contracts and loss of flexibility on the part of the end-user.

3.4 Conclusions & recommendation South Africa

There is little information available which considers the complete functioning of SHS markets in developing countries and considers the wide range of institutions involved. The SHS market is currently in transition from a commercial market to a market dominated by SHS concessions. There are no hard conclusions to be drawn on either of this model. The commercial market has never really had a chance to prove itself, while the Non-Grid Electrification Programme still has to prove its success. In more detail the market is characterised by the following aspects:

- The state has a large influence on the market for SHS by its ambitious rural electrification programme and promises of "electricity for all".
- The commercial market has not been successful in providing electricity solutions to a large part of the rural population
- The uncontrolled operation of the commercial market has resulted in the appearance of low quality systems leading to a bad reputation of SHSs;
- The potential of the commercial market to deliver has never really been tested since it never received explicit support in terms of market development, awareness raising and it suffered from high expectation on grid-connection
- South Africa does have a number of active PV and SHS companies. Support for developing SHS dissemination could have been possible by supporting these companies in developing delivery mechanisms. The analysis also shows a strong integration of the SHS market with other PV markets. In terms of market stimulation, this relation has to be born in mind. Opportunities and threats in other segments of the PV market do affect the sustainability of actors in commercial market.
- The influence of the State on the SHS market will become even greater by the concession programme
- The main threats to the off-grid electrification programmes are the high payment disciplines it requires, the risk that the Programme only reaches out to richer families in rural areas and leaves out the poorer families

Preliminary policy recommendations based on this analysis are restricted to the SHS market:

Integrate institutional PV projects in IDP process

To enhance the ownership and participation of local communities, PV projects should involve communities from the start of the project in order to make sure that PV projects meet local development priorities. This could be done by integrating the planning of PV projects into the newly established Integrated Development Planning process at the district council level. Useful lessons can be learned from organisations who have experience with community participation such as the Mvula trust.

Launch integrated PV follow up programme

Improve operation and maintenance of installed systems are key to improve the public acceptance of PV systems. Key components of such programmes are training of solar technicians, creating awareness amongst end-users to enable them to make informed choices are key components of such programme.

Although part of such components can be found in individual programmes, it is key for the image of PV that such issues are addressed during in integrated programme. Morris (2000) launched the idea to set up a big maintenance campaign to provide after-sales services to all the pilot projects, that did not incorporate such services as well as the clinics and schools programmes. The idea was that before starting a new pilot project, first clean up the old ones.

Such a programme can at the same time be combined with training local technicians, and raising awareness on the potential of PV among end-users, and train end-users on how to properly use and maintain PV systems. A potential way to implement such a programme would be under the sector specific education support programme. It could also be linked to the PV infrastructure which will be put up by the concessionaires. Stakeholders to be involved in this programme are the concessionaires, PV suppliers, ESKOM, DTI, DME, DoH.

Create a sustainable business environment for PV

The SHS market for rural households is highly integrated with other PV markets. There are few suppliers, international and local, who concentrate solely on the households markets. Government agencies and para-statals together are responsible for a large demand for PV panels. They could use this market power to co-ordinate and distribute their demand more evenly over time. This will allow the South African market for PV better anticipate demand and hence provide their customers with better services and lower prices.

4. ANALYSIS OF HOUSEHOLD SURVEY IN SWAZILAND

4.1 Survey Methodology

4.1.1 Monitoring of Solar Home Systems in Swaziland

The analysis presented here reflects the first phase of a Solar Home System (SHS) monitoring study in Swaziland. The main aim of this monitoring activity is to get insight into the technical performance of systems, the user behaviour and user satisfaction and possible relationships between performance and user behaviour. This should ultimately result in recommendations for optimisation of system design.
In this first phase technical inspections and interviews with users of 170 SHS in various part of the Swaziland have been conducted. In the next phase a) data loggers will be installed at selected households to accurately monitor performance and use b) a similar survey will be conducted in Indonesia.

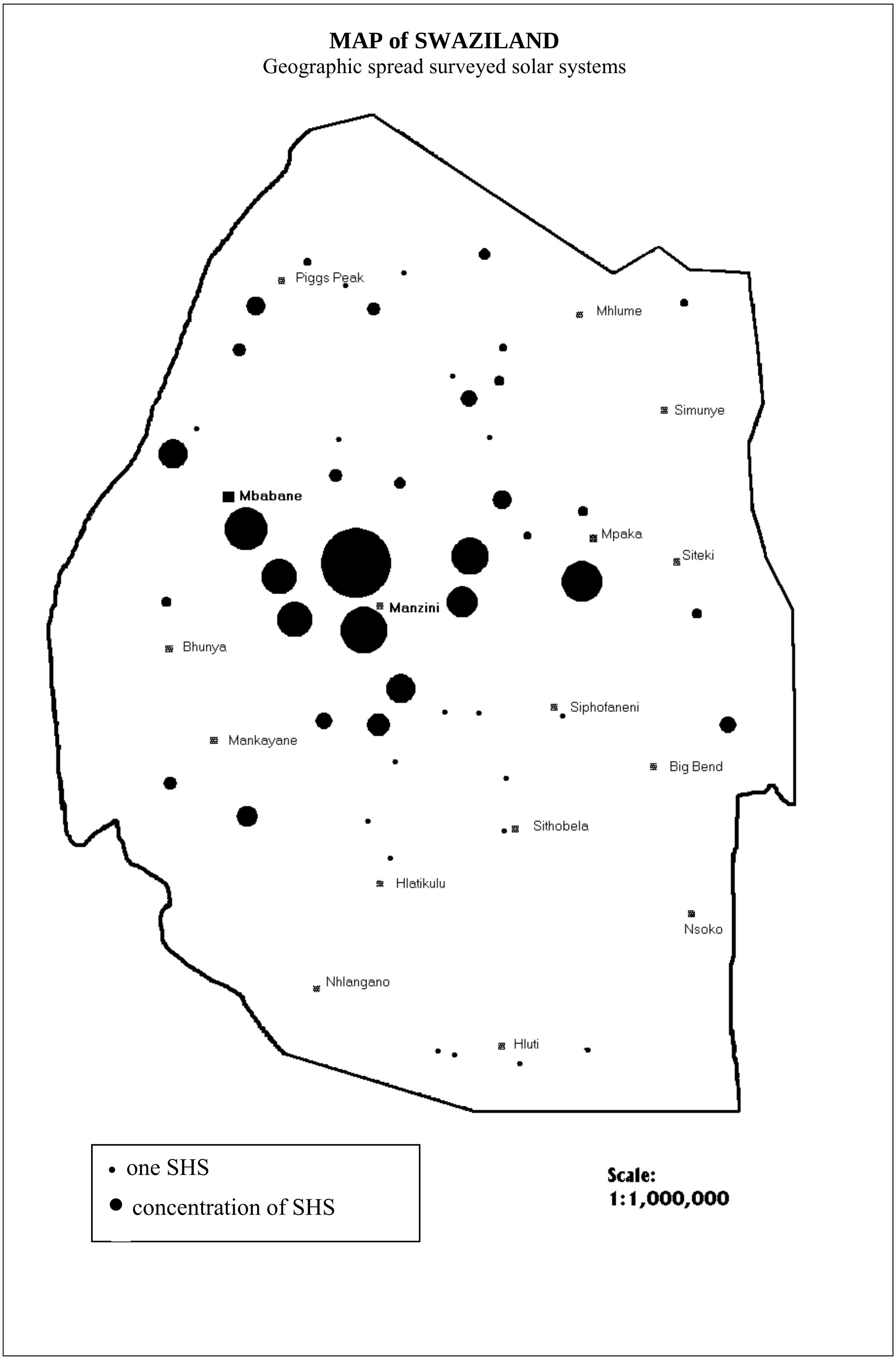
4.1.2 Methodology

To collect technical information, supported with related end-user data, a standard technical data sheet and questionnaire was developed, tested and used in the survey (see Annex 1 for questionnaire format). The data was augmented with data about the customers obtained from the supplier (questionnaire with basic info completed with every sale, financial accounts).
After analysis of the data several questions did not generate accurate responses, due to misinterpretation or sensitivity of questions. For the following survey in Indonesia it is therefore recommended to use a revised list of questions conform the example included in Annex 2.

For the sample selection use have been made of the information of the two main solar energy dealers in Swaziland, viz. Swazitronix and Solar International. These two retailer account for about 80% of the installed SHS capacity in Swaziland. The sample has further been limited by a focus on those systems that were sold on a credit basis. Only for these systems detailed customer information existed. This focus has resulted in a relative over representation of larger systems (40-106 W_p).

The actual inspections and interviews have been carried out by a solar technician. The technician has been accompanied on various occasions by ECN staff. The visits took place from May till October 2000.
The geographical spread of the inspected systems is presented in figure 4.1.

FIG.4.1: geographical spread of surveyed households



Given the remote locations of many of the systems and the lack of means of communication, visits were carried out unannounced. As a result repeated visits were often required to gain access to the system. In some cases where neither the head, wife of head or grown up children were at home, only a technical inspection of the system has been carried out. In a few cases access was denied. In total about 200 users have been visited, of which only 170 could actually be accessed. After entering and cleaning of data 164 useable cases remained that have been used for the analysis. The analysis has been carried out using SSPS+.

The results of the survey are presented below. First an overview is given of the technical performance of the systems. Next the results of the socio-economic analyses are presented. Lastly, the interrelationships between technical performance and user behaviour are examined.

4.2 Technical Analysis

4.2.1 Overview system specification

The average capacity of the solar home systems in the survey is 44 W_p, with the smallest being 10 W_p and the largest 106 W_p. The oldest system dates back to 1992. The average age of the SHS is 2.6 years, with the newest system being 6 months, and the oldest 8.2 years.

Performance of systems

performance	% of systems
good	73
working, but not optimal*	17
not working at all	10

note: sub-optimal performance implies that the system still generates output, but lower than it should. Main reasons for sub-optimal performance are old batteries, faulty regulators, shaded or broken panels.

The most common appliances powered by a SHS are: lights (94%), televisions (70%), hifi sets 42%, radios 21%.

Below a detailed overview is given of the performance of the single components of the SHS.

4.2.2 Solar panels

The average panel[5] size was 41.4 W_p. The largest panel size is 75W_p and the smallest 10 W_p. Most system (92%) consisted of one panel only, 7% of 2 panels and 1 system consisted of 3 panels. The average installed system capacity is 44.3 W_p (N=154).

[5] Please note that the differences with the numbers provided in paragraph 4.2.1 are due to the fact that paragraph 4.2.1 deals with complete systems, and a small percentage of these consist of more than one module.

Table 4.1 reflects the different panel brands, type and size encountered in the survey.

Brand	**Frequency (%)**	**Type**	**Size (W_p)**
Shell	83	poly crystalline	40
Siemens	14	poly and mono crystalline	20, 36, 40, 50, 53, 55, 75
Helios	2	mono crystalline	40, 53, 55
M-Solar	1	mono crystalline	10
Solar Africa	1	amorphous	12

To get insight in the actual performance of the panels 3 measurements were carried out:

- Charging current (Ic) Measures the actual current, which depends among others on the charge state of the battery
- Short circuit current (Isc)
  The Isc is the current measured in full sunlight at the leads of the panel, without any load. When the sun is at a straight angle to the module, it is the maximum current that module is capable of producing.
- Open circuit voltage (Voc)
  The Voc is the voltage measured in full sunlight at the leads of the panel, without any load connected. It is the maximum voltage the panel can produce under sunny circumstances.

Given that a) each type of panel has its own characteristic, and b) measurements are influenced by the weather conditions and cell temperature, no general conclusions can be drawn from aggregating the outcome of all panels. To get more meaningful results, an analysis has been carried out for Shell solar panels of the same capacity 40W_p on a sunny day, with measurement taken between 11.00 am to 3.00 pm. The results have been compared to the specific manufacturer specifications in table 4.2.

Table 4.2 Performance of Shell 40 W_p solar panels:

	average survey	Manufacturer Specs
charging current [A]	1.20	not applicable
short circuit current [A]	1.50	2.7
open circuit voltage [V]	18.8	20.3

In figures 4.2 and 4.3 the distribution of short circuit current and open circuit voltage are presented for part of the modules. Measurements took place during cloudless days, between 11.00 h and 15.00 h. However, without actual insolation measurements these figures are very difficult to interpret. There are a number of reasons for the low (0-1A) values of the short circuit current in figure 4.2. Besides degradation of the modules, these low values are more likely caused by a combination of dust on the modules, shadowing and sub-optimal orientation. It is recommended that for similar measurements in the future, a portable insolation measurement device is used.

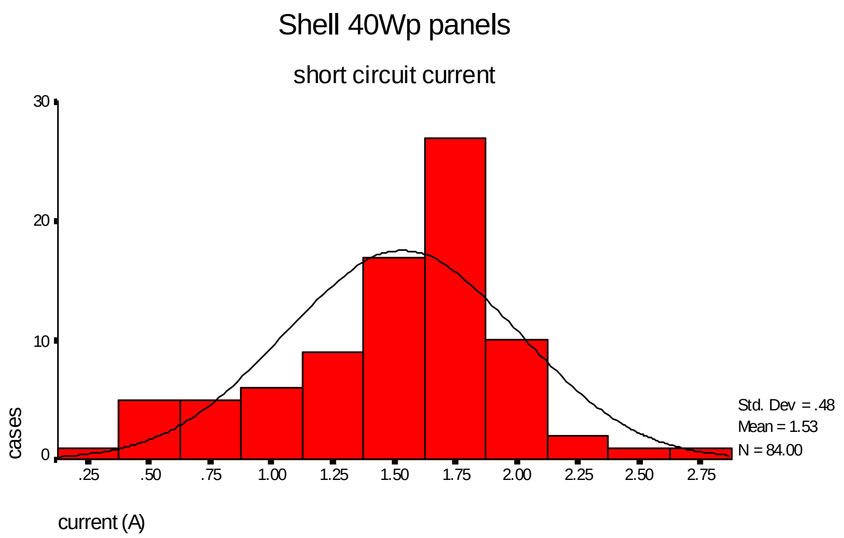


Figure 4.2 Distribution[6] of the short circuit current for 84 modules in the sample.

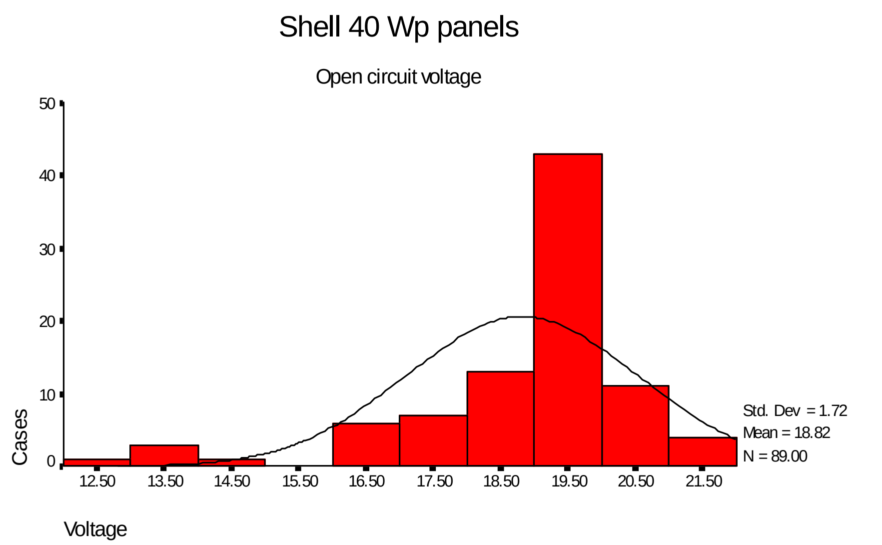


Figure 4.3 Distribution of the open circuit voltage

Looking at the physical state of the panels, the following picture emerges:

Table 4.3 Differences between Shell modules and the complete sample in %

	All	Shell sample only
Surface - clean (%) - slightly dusty (%) - dirty (%)	 82 17 1	 79 20 1
Loose connections (%)	3	0
Shaded parts (%)	5	2
Signs of Breakage (%)	1	0
Signs of UV damage (%)	3	5
Signs of corrosion (%)	1	0
Tilt (degrees)	26 (range 10-60)	24.5 (0-45)

[6] A Gaussian distribution curve was fitted to the data, although there is no reason to expect this to be gausssian.

4.2.3 Batteries

There are various type of batteries that can be used with a solar system, ranging from ordinary car batteries to highly specialised deep cycle batteries which in theory can last up to 10 years. Below the types of batteries are shown that were encountered in the survey.

Table 4.4 Battery types encountered in the survey.

Type of battery	Common brand names	Frequency (%)	Av. capacity (Ahr)
Automotive (lead acid)	Bosch, Willard	19	61
Modified/Portable (lead acid)	Raylite, Willard, Exide	72	94
Maintenance Free (lead calcium)	Delco, GNB, Champion	8	102
PV flooded deep cycle (lead acid)	BP solar bloc	1	108

Table 4.5 Overall battery conditions in the survey sample :

condition	frequency (%)
worn out	16
low electrolyte level	10
loose connections	14
corroded terminals	7

In 54% of the cases the battery has been replaced at least once, whereas another 16% indicated that the battery actually needed to be replaced. Most of the worn out batteries were still being used, but 3% of the systems were used without a battery. In most cases the replacement of a battery was postponed due to lack of the money.

The majority (92%) of those who replaced the battery, had to do so only once. The average age of the SHS that had the battery replaced once is 2.8 years. According to the respondents their first battery lasted for 17 months on average. The remaining 8% had the battery replaced twice, and the average age of these SHS is 5.8 years. For these 8%, the average battery life is estimated to be about 2.3 years.

	% respondents	lifetime battery
battery replaced	54	17 months
battery never replaced	30	24 months
battery have to be replaced	16	27 months

To calculate the average battery lifetime based on the figures in the table above, one has to assume a lifetime of those batteries that were never replaced. Assuming 30 months for this 30%, results in a total average battery lifetime of 22 months for those solar homes systems which had their battery replaced once. Combining this with the figure of 2.3 years for the those who replaced the battery more than once, we arrive at a best estimate of the average battery lifetime of two years.

It is interesting to note that there is a tendency for people to replace their modified battery (which is generally provided as 'a standard' when buying a complete solar home system), with cheaper automotive batteries.

Table 4.6 Battery use in two groups: one still using the original battery and the other where battery replacement took place [battery type as % of the households in the group]

Type of battery	Group using original battery (% users)	Group who replaced battery (% users)
automotive battery	6	32
modified battery	89	55
maintenance free	5	13

To assess the state of the battery to measurements have been carried out:

- Voltage with panel and load disconnected;
- Voltage after connecting a standard load.

Measurement of the voltage with disconnected panel and load took place 5 minutes after disconnecting
In the table below the voltage is used as a proxy for the state of charge.

Table 4.7 Battery voltage after load test:

Open circuit Voltage	State of charge (%)	% batteries	% batteries (cumulative)
12.74 +	100	3	3
12.73 - 12.41	99- 75	5	8
12.40 - 12.00	74 - 40	12	20
11.99 -11.64	39 -10	36	56
< 11.64	9-0	45	100

The table shows that only 20% of the batteries had a charge state of 40% or more at the time of the inspection. Given an average charging current of 1.2 amps, an average remaining charging time of about 4 hours, this would imply 35% of the battery with a charge state of 40% or more at the end of the day.

The figures suggest that people tend to drain their battery as much as they can while hardly allowing the battery to fully charge up.

4.2.4 Other System Components

Battery Charge Unit

Only 3% of the systems had no battery control unit (BCU) installed. Common BCU brands are Omnilite, Shell (R&S), Neste/Naps, PDI, Solsum, AMP. The average capacity of the BCU was 9 Amp (N=148), ranging from 5 to 20 Amp. Almost all BCU's had a low and high voltage disconnect and one or more charge indicator lights, ranging from 1 to 5.

About 6% of the systems had more than one BCU. This was the case when the respondent had 2 or more panels. Based on practical experience the strategy had been adopted to separate kits for specific application rather than installing one large system. In most cases one kit is used for lighting and one for television. By doing so, people can e.g. drain the battery for watching television, while still having some power for lighting. Although it means an increase in cost, it was generally preferred by the users.

Of all the BCU installed, 90% were actually used, 6% were bypassed and 4% was faulty.
The BCU problems encountered in the survey are blown transistors, units struck by lighting or simply not charging for unknown reasons.

Inverters
The use of inverters is not very common. Only 8% of the SHS had an inverter installed. Common brands are: Franklin, Nikki, TES, Top Solar, Solar Africa and Spectrum. The average capacity of the inverters was about 200W ranging from 100-300. Average Wattage of the connected appliances was 94 Watt. Inverters were mainly used to power a colour television (10 cases). In one case it was used for a hifi set and in another case to charge a cell phone. None of the inverters were faulty during inspection, but many can only operate properly far below their rated power capacity.

Lights
Almost all of the SHS (94%) were powering lights. PL lights were more common than fluorescent tubes, respectively 87% and 13%. The average wattage of PL lights was 9W and fluorescent tubes 15W.
Overall 37% of the SHS had one or more non-functional light. The noticed light problems are: a blown ballast (65%), faulty tube (26%), incorrect wiring (4%), a faulty switch (4%), blown fuse (2%). In 14% of the cases, the ballast was infested with insects and blown.

4.2.5 Failure rate of SHS components

Below an overview is given of the failure rate of SHS components over the total lifetime of the SHS. Contrary to the above information, which is only a snap shot at the time of the technical survey, the latter is based on information obtained from the users and provide insight of the component performance in time.

The table shows that 75% of the systems have or had to replace at least one faulty component. This figure ranges from 51% in the first 2 years to 100% if the system is older than 4 years.

Table 4.8: Solar home system component failures

Component	Age of solar system				
	0-2 year (n=36) %	2-3 years (n=75) %	3-4 year (n=17) %	4-8 years (n=9) %	All %
PV panel	8	5	6	22	7
BCU	6	4	6	11	5
Battery	19 (31)*	64 (9)	71 (12)	100	55 (15)
Lights	27	35	71	44	39
1 or more components	51	79	94	100	75

*) the figures between brackets reflect the number of batteries that are still in use, but only function marginally and need to be replaced.

The way obsolete components are dealt with largely influences the 'environmental friendliness' of a SHS.
The battery, given its short lifetime, has the largest environmental impact. The battery accounts for 88% of the total energy required to produce a solar systems[7]. The production of the battery accounts for 80% of the total material used and in the final phase of the life cycle the battery accounts for the largest share in solid waste. Many of the battery material can be recycled, but clearly this depends on effective collection and recycle mechanisms.
The survey findings show that in 42% of the cases obsolete batteries find their way back to the supplier, which generally means that the battery is returned to the manufacturer and recycled. In 40% of the cases the old battery is either kept in or around the house. Sometimes they are being used as support of benches and tables. In 18% of the case, the batteries were thrown away

[7] With a 2-year lifetime of the battery and no recycling of lead assumed. Source: J.R Ybema et al., Towards a streamlined CDM process for solar home systems, Emission reductions from implemented systems and development of standardised baselines, ECN report ECN-C—00-109

together with the normal rubbish. In most rural places there is no rubbish collection service, which means that batteries are either buried or burned.
Another interesting finding is that more PV panels have been replaced than battery charge regulators. In total, 7% of the users had to replace their panels, compared to 5% who replaced their charge regulator. These figures are relatively independent of the age of the system. It suggests that these failures are not primarily wear because of old age. There must be other reasons such as manufacturing faults or user mishandling of the equipment. Based on user feed back in the solar shop, lightning and vandalism both play a role in the occurrence of faulty panels. Other possible causes include lightning, UV damage and corrosion.

4.3 Socio-economic Analysis

4.3.1 Socio-economic background users

The average households size of the SHS users in the survey was 7, ranging from 2 to 11. The vast majority (88%) had a least one member of the family in paid employment and many households had more than one income source (see table 4.9). Based on the perception of the interviewer, 15% of the households could be classified as high income earners, 63% as middle and 22% as low.

Table 4.9: Household income sources

income source	**respondents %**	**common types**
paid employment	88	teachers, soldiers, policemen, civil servants, drivers.
agriculture	65	maize, cotton
home based activities	22	sewing, knitting, beer brewing, selling cakes, fruits, veggies, shylock
own business	9	shop, garage
pension	9	n.a.
remittances	2	n.a.

Similar to findings in Kenya and Zimbabwe (see WB,1999), the survey in Swaziland indicates that solar systems are primarily bought by people, who would like to overcome the drudgery of charging car batteries. 78% of the SHS owners were using a car battery before, mainly for television and to a lesser extend for hifi's and radio's. About 4% of the respondents were using a generator before.

4.3.2 Finance of Solar system

The survey has been focused on systems that were obtained on credit terms. In total 90% bought their system on credit terms and 10% on cash terms. No experiences with rental services exist in Swaziland yet.
Of those who bought their system on credit, 46% has paid off their loan at the time of the interview, 43% is still paying and 5% has stopped paying because they are not happy with their system and 5% was not sure whether the loan had been fully repaid or not. Of those who were still paying off their loan the average outstanding balance was 40% of the loan amount . Of those who paid off their loan the average credit period was 16 months. Down-payments ranged from 15 to 50% and interest rates were around 22%, which was slightly above prime interest rates. The average purchase price of a complete system, including installation service was US$ 504 or US$ 11.60 per W_p. If people were to buy another SHS, the most preferred finance mode

was credit (72%), followed by cash (23%), whereas 5% indicated they would never buy a SHS again.

4.3.3 Maintenance and repair of SHS

In many SHS implementation projects, the maintenance of a SHS is often a major bottleneck for optimal performance of the solar home system. The main reasons for neglect of maintenance and repairs is that a) SHS are donated and people don't feel responsible b) lack of knowledge among end users and c) people simply do not have the money to replace faulty components.

The survey showed that 17% of the system were performing sub-optimal and 10% of the SHS were not performing at all. In those case where the SHS was completely down, the causes are mainly related to the battery (see table 4.10):

Table 4.10 Causes of failures of non-performing solar home systems

cause	no. of cases
battery completely worn out	8
panel not charging	3
panel stolen	1
panel broken	1
charge regulator faulty	1
grid connection and SHS taken down	1
moved to other house and SHS not connected yet	1

In most cases the reasons why the problems have not been solved is the lack of money. In one case e.g. where the SHS battery was worn out, the battery was taken out of the car in the evening and connected to the lights and television. In two cases the battery has been replaced twice in a relative short period of time and people were just not prepared to invest in a third battery. In one case vandalism (stone throwing) resulted in a broken panel. Theft seems to be an important issue when buying a solar home system. The general perception is that solar panels get easily stolen. Looking at solar systems installed for public utilities, such as water pumping, clinics, schools, railways etc. the incident of theft is indeed very high: a recent study showed a theft rate of about one third of the installed capacity. For private systems the incidence of theft is generally lower though. In the survey one case of theft was encountered. Nevertheless, 19% of the respondents indicated to know about a case of theft cases, whereas 6% indicated to know of or had experienced a failed theft attempt.

Looking at the systems that were working sub-optimally, again the battery seems to be the major cause of technical problems as can be seen in table 4.11

Table 4.11 Technical problems with solar home systems that operate sub-optimally.

cause	no. of cases
Battery worn out	16
Shaded panel	3
charger controller faulty	4
all lights faulty	1
panel broken	1

Regular maintenance of the solar system by the user is assumed to improve system performance.
With the exception of two, none of the users received a manual when they bought their system. However 94% received a verbal explanation on the use and maintenance requirements of the system by the installer or solar energy dealer. In 57% of the cases the explanation was given to

the head of the household, in 33% of the case to the wife, in 10% of the case to the children. No relationship could be established between the technical status of the system and recipient the explanations.

Below general maintenance activities are set against the actual status of the components.

Table 4.12 Maintenance levels

maintenance	% respondents
cleaning of panels	59
cleaning of battery terminals	49
checking electrolyte level of battery	62

Again there is no relationship between those who carried out maintenance activities and the status of the panel or battery. The main factor determining the status of the battery is likely to be the intensity of use. In the technical section it was already established that the charge state of most batteries was rather low. This suggests that people drain their battery to the maximum and do not allow the battery to fully charge up.
Looking at intensity of use people were asked how long they were running their appliances. With most people using the system for television and lighting the following common use pattern was established:

- television: 2 hours 45 minutes (average 20W) and
- lighting: 2.3 lights, 3 hours. (average 9W).

This would imply an electricity use of almost 120 Wh, which corresponds to the calculated electricity availability. The average panel size of 44 W_p should in theory be sufficient to produce the required output provided suitable weather conditions. A 44 W_p panel @ 5kWh/m^2/day could generate 220 Wh per day. If corrected for system losses of 50% (Vervaart and Nieuwenhout , 2000), there should still be 110 Wh available to the user.
There is an inconsistency between the generally bad condition of the battery and the fact that the supply and demand of electricity balance. What can be concluded from the above is that a) respondents have underestimated their use b) the weather has been bad for a number of days before the household visits took place c) the quality of the batteries is just poor. In phase two of this study, with the use of data loggers more detailed information will be obtained on this issue.

Overall, some 65% of the users indicated to appreciate more guidance on the use and maintenance of their system. Not surprisingly, those who didn't need more guidance on the use and maintenance all had properly working SHS.

4.3.4 User satisfaction

Most users (89%) indicated to be satisfied with their system. Especially the improvement in lighting was appreciated. Nevertheless, 47% indicated to have insufficient power to do all the things they wanted. More and longer lighting, longer television watching and connection of a fridge were the most preferred expansion options.
The appreciation for a SHS can also be derived from the fact that 95% of the people would recommend a SHS to somebody else.

Besides improved lighting, other positive impacts of SHS are day time extension, and savings on energy expenditures.
About 80% of the users indicated to go to bed later than before due to better lighting. The extra time was primarily used watching television (75%), studying or reading (44%), household activities (9%). Only 3% used the time productively.

Although no data has been collected on the magnitude of the savings on energy expenditures, 91% of the respondents indicated that their monthly energy expenditures have been reduced. The biggest financial impact is probably due to savings on charging car batteries and dry-cell batteries for hifisets. In both cases the substitution rate is more or less 100%. Looking at lighting, 44% indicated to have substituted all conventional lights (primarily candles and to a lesser extent paraffin lamps) by their solar lights, 14% sometimes use other lights, and 42% always use conventional lights in addition to their solar lights.

Based on previous research (Lasschuit,1994;1997) a rough estimate is given below of the actual savings in terms of candles/paraffin and batteries.
On average a non-electrified rural household uses 22 dry-cell batteries per year for radio and/or hifi sets. Car batteries, which are mainly used for television, are being charged twice a month on average and one candle is used per day (generally two or three candles are lit, but not fully used in one evening).Given the above substitution rate for lighting the average annual savings on conventional fuels would amount to some 225 candles or 23 litre of paraffin. For those who use the SHS for television (74%) the saving on car battery charges amount to 24 charges a year plus related transport cost. For hifi systems the savings would be about 2 dry cell batteries (PM9 or PM10) a month and for radio the average saving would amount to about 2 batteries (RR20) per month.
On the question what people would do if the grid would become available 68% indicated to apply for a connection and keep on using their SHS, 27% would not apply for a grid connection, 4% would apply and sell the SHS, and 1% was already connected to the grid.

Almost half the people didn't expect the grid to come to their area within their lifetime, 30% had heard of electrification plans and expected the grid to come soon, 17% had heard about electrification plans but expected it to take quite some time and in 4% of the cases the area was already connected.

4.3 CONCLUSION

This survey focused on the technical performance of solar home system in Swaziland and user satisfaction. A total of 170 system were inspected and augmented with a standard questionnaire to be completed by the end-users.
SHS are being used for lighting (94%), television (70%), hifi-sets (42%) and radio's (21%). AC/DC inverters are used by 8% mainly to power a colour television.

Of the total number of SHS 73% performed fine, 17% performed sub-optimally and 10% was not working at all. The major cause of sub-optimal or non-performance is related to the battery. The average life time of the battery is generally short (about 2 years). This means a substantial investment cost over the lifetime of SHS, one which is much higher than the solar panel itself. Many people postpone the replacement of the battery due to lack of money. Once a battery is disposed of, only 42% find their way back to the manufacturer for recycling purposes.
Lights are also subject to technical problems: 37% of the systems inspected had one or more faulty lights. Common technical faults are blown ballasts and faulty tubes. The impact on both the total system performance and replacement costs are limited though.

Looking at the background of the users, 88% had at least one family member in paid employment. In many cases, additional income is obtained from agriculture products, remittances, pensions or home based activities. In none of the cases the solar systems is used directly for productive purposes.

The majority (90%) of the users had obtained their system on credit. Due to technical problems 5% of the users had stopped repaying their loan.

The main reason why people buy a solar system is to overcome the drudgery of charging batteries: 78% already had a car battery - which was mainly used for television - prior to buying a solar system.

Maintenance of the SHS is generally limited to regularly checking of the electrolyte level of the battery and cleaning of the panel every now and then. Most panels in the survey were clean or only slightly dusty.

The majority of users (89%) is satisfied with the performance of their system. The most often mentioned virtue of a SHS is improved lighting. Other benefits are day time extension and savings on energy expenditures.

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5. ANNEX 1. SURVEY QUESTIONNAIRE SWAZILAND

Solar Energy Questionnaire: Section 1 to be completed by Technician **(version: Sept. 2000)**

Questionnaire no. : ....
D. Location: ....

A. Client reference no.: ....
E. Date of visit :_____/_____/2000

B. Client name:..............................
F.Time of visit: ....

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1 Indicate prevailing weather conditions during system inspection:
  a. clear
  b. cloudy
  c. complete overcast

2. Indicate type and state of **batteries:**

	battery 1	battery 2	battery 3
a. brand name			
b. type: automotive (A) portable/TV (T) deep cycle (S) maintenance free (M)	 A T S M	 A T S M	 A T S M
c. no of batteries per type			
d. capacity (Ah)			
e. state of charge (V)			
f. charge after load test (V)			
g. electrolyte level	low/normal	low/normal	low/normal
h. state of terminals	corroded/clean	corroded/clean	corroded/clean
i. loose wires/connection	yes/no	yes/no	yes/no

3. Indicate type of wire that has been used:
  a. from battery to charge regulator: mm2
  b. from regulator to panel: mm2
  c. from battery/charge regulator to appliances: mm2

4. Indicate type and state of charge controller (BCU)

	BCU 1	BCU 2	BCU3
a. brand name			
b. rating (Amps)			
c. no. per type			
d. high voltage disconnect			
e. low voltage disconnect			
f. no of charge indicator lights			
g. used (U) bypassed (B) faulty (F)	U B F	U B F	U B F

4h. Describe problem if BCU is faulty:

5. Indicate type and state of inverter

	INV 1	INV2	INV3
a. brand name			
b. rating (Watts)			
c. no. inverters per type			
d. total Watts connected			
e. state of inverter	OK / faulty	OK / faulty	OK / faulty

6. Indicate number of appliances connected to solar system and indicate whether or not used through inverter (DC/DC or AC/DC):

Appliance	**no inverter**	**DC/DC inverter**	**AC/DC inverter**
a. B/W television			
b. Colour television			
c. Hifi			
d. Radio			
e. Lights			
f. Refrigerator			
g. Other indicate			

7. Indicate type and status of lights:

appliance	**fluorescent tubes**	**PL**	**other**
a. brand			
b. rating (Watts)			
c. number installed per type			
d. number faulty per type			
e. infested by insects			

7f. If one or more lights are faulty, indicate problem..
....

8. Specify type and state of **solar panel(s):**

	solar panel 1	solar panel 2	solar panel 3
a. brand name			
b. type (amorphous, mono, poly crystalline**)**			
c. no. of panels per type			
d. rated peak power (W_p)			
e. charging current (A)			
f. short circuit current (A)			
g. open circuit Voltage (V)			
h. tilt of panel (degrees)			
i. orientation (degrees)			
j. panels shaded	yes / no	yes / no	yes / no
k. panels dirty	clean/dirty/ slightly dusty	clean/dirty/ slightly dusty	clean/dirty/ slightly dusty
l. loose wires/connections	yes / no	yes / no	yes / no
m. signs of corrosion	yes / no	yes / no	yes / no
n. sings of breakage	yes / no	yes / no	yes / no
o. sings of UV damage	yes / no	yes / no	yes / no

9. Other remarks on system status/ performance:

Solar Energy Questionnaire Section 2: Questions to be completed by end user

10. How did you get to know of solar energy?
    a. radio
    b. television
    c. newspaper
    d. local energy dealer
    e. friends/relatives with solar system
    f. nearby school/clinic which is powered by a solar system
    g. demonstrations (trade fair, community meeting etc.)
    h. other.....................
    i. don't know

11. How do you normally get to know about new developments, products, event etc?
    a. radio
    b. television
    c. newspaper
    d. community meetings
    e. talks (neighbours, in shop)
    f. visits to nearby cities
    g. other.....................
    h. don't know

12. Did you consider any other electricity options before purchasing a solar system?
    a. yes
    b. no *(go to question 14)*

    13. If yes, can you indicate which other electricity options you considered?
        a. Grid (SEB) connection
        b. Generator
        c. Wind turbine
        d. Other.............................

14. Why did you decide to buy a solar system?
    indicate...

15. Do you know the brand name of your current solar panel?
    a. yes
    b. no *(go to question 18)*

    16. What were the main reasons to choose for this type and this brand of panel?
    a. reliable brand name
    b. only one available in shop
    c. cheap
    d. no specific reason
    e. other...

    17. Can you mention any other brand names?
    a. yes, indicate...
    b. no

18. When did you buy this solar panel? year:....................../month.................

19. Did you buy the battery at the same time as your solar panel?
    a. yes
    b. no, already had a battery before buying the panel
    c. no, bought the battery after buying the panel

20. Did you buy your present battery from the same supplier as the one of the solar panel?
    a. yes

b. no, indicate other supplier..

21. Did you buy the lights at the same time as your solar panel?
    a. yes
    b. no, bought lights before buying the panel
    c. no, bought lights after buying the panel

22. Did you buy your present lights from the same supplier as the one of the solar panel?
    a. yes
    b. no, indicate other supplier..

Finance of system

23. Who of your family raised the issue of buying a solar system for the first time?
    a. husband
    b. wife
    c. children
    d. all
    e. don't know

24. How did you pay for your system?
    a. cash
    b. credit *(go to question 26.1)*
    c. rental *(go to question 27.1)*
    d. donation *(go to question 28.1)*

25.1 What did you pay for your solar system?

a. price of complete kit:		E
b. price of components:	panel:	E
	battery:	E
	regulator:	E
	cabling:	E
	lights:	E

25.2 Who paid for the solar system?
    a. husband
    b. wife
    c. children
    d. others...
    e. don't know

26.1 If credit, who provided the credit?
    a. solar system supplier (name:..)
    b. bank (name:..)
    c. credit & savings organisation (name:..)
    d. family/friends
    e. others, indicate...

26.2 Can you indicate the terms and conditions of the loan?

a. cash price of systems:	E......................
b. amount of deposit:	E.....................
c. interest rate:	..................%
d. monthly instalment:	E....................
e. repayment period:	no. months........................_______

26.3 If credit, are you still paying your monthly instalments?
    a. yes, still paying
    b. no, paid off the loan in full
    c. no, loan not fully repaid but not happy with the system.
    d. no, loan not fully repaid but have no money

e. don't know

(go to question 28)

27.1 If rental, whom do you rent the system from?
Name rental company:..................................

27.2 If rental, how is the rental being charged?
a. per time period: indicate day, week, month, season, year
b. per rate of consumption

27.3 If rental, what is the amount of the rent?
Amount: E.....................

27.4 How do you pay the rental fee?
a. rent is being collected from home
b. pay rent/buy token at nearby outlet
c. pay rent/buy token to rental company in town
d. other.............................

27.5 If rental how often is your system being checked by a technician?
number of visits so for:...........................

(go to question 29)

28. If donated, who donated the system?
a. Government (name programme/project...)
b. Aid organisation
c. Relatives
d. Others...................................
e. Don't know

---

29. Have your monthly energy expenditures been reduced after you started to use your solar system?
a. yes
b. no

30. Have other community members shown an interest in your solar system?
a. yes
b. no *(go to question 33)*

31. If yes, why do you think they haven't bought one yet?
....
....

32. If you could buy another system what would be your preferred way of finance:
a. cash
b. credit
c. rental
d. don't know

33. Which electric appliances did you already use before the solar system was installed?
a. electric lamp
b. B/W television
c. Colour television
d. radio
e. hi-fi
f. refrigerator
g. other.........................

34. How were these appliances powered before you had a solar system?

a. electric lamp				
b. B/W television				
c. Colour television				
d. radio				
e. hi-fi				
f. refrigerator				
g. other............				

Usage of appliances

35. Can you indicate when and for how long your appliances are normally switched on per day?

	period of the day	**number of hours per day**
a. lights	morning, afternoon, evening	
b. radio	morning, afternoon, evening	
c. hifi	morning, afternoon, evening	
d. television	morning, afternoon, evening	

Repairs

36. Can you indicate the components of your solar systems that are/have been faulty?
   a. panel
   b. regulator
   c. battery
   d. inverter
   e. lights

37. Do you know the reason(s) of the problem?
   a. poor quality of components
   b. poor quality of installations/service
   c. not enough guidance and information on the use/operation
   d. theft
   e. vandalism
   f. lightning
   g. other, indicate..................................
   h. don't know

38. How was the problem solved?
   a. problem have been solved by yourself
   b. problem have been solved by technician
   c. problem has not been solved *(go to question 42)*
   d. don't know

39. How much did you have to pay for the replacements/repairs?
   Amount: E............................

40. If a technician repaired the fault how long did it take between reporting fault and visit of technician?
   number of days:...............

41. If any of the components were replaced, what did you do with the faulty components?
   a. were taken back by supplier/technician
   b. threw them away
   c. still keep them somewhere in the house
   d. other, indicate...

(go to question 43)

42. Why has the problem not been solved?
   a. no money to pay for repairs/replacements
   b. still waiting for technician to come
   c. don't know who to contact
   d. other...

Maintenance

43. Did you receive a manual when you bought the solar system?
   a. yes
   b. no *(go to question 46)*

44. Did you read the manual
   a. yes
   b. no *(go to question 46)*

45. Did you consider the manual useful
   a. yes
   b. no

46. Did the technician/supplier inform you on the maintenance requirements of the system?
   a. yes, explained it to the head of the household
   b. yes, explained it to the wife of the head
   c. yes, explained it to the children of the head
   d. no, did not explain

47.Would you like to get more information on maintenance and operations of your system?
   a. yes
   b. no

48. Did you ever clean the solar panel?
   a. yes
   b. no

49. Did you ever clean the battery terminals?
   a. yes
   b. no

50. Did you ever check the electrolyte level of the battery?
   a. yes
   b. no

51. Did you ever topped up the battery with water?
   a. yes
   b. no

52. If yes, what kind of water did you use?
   a. water straight from the tap
   b. boiled water
   c. distilled water
   d. other...

53. Did you ever have to replace the battery?
   a. yes
   b. no, but have to do it soon
   c. no.

54. If yes, how long did the previous battery last? ________ months.

55. From whom did you buy the new battery?
   a. from Solar International/Swazitronix
   b. from another battery supplier
   c. other....................................

56. What did you do with the old battery?
   a. returned it to the supplier
   b. kept it
   c. threw it away

User satisfaction

57. Are you happy with your system?
   a. yes
   b. no

58. Can you indicate why you are happy/not happy?
..
....

59. Is the amount of electricity produced by your system enough for all the appliances you would like to
   use?
   a. yes
   b. no

60. If no, for which appliances can't you use the system?
indicate*...*
....

61. Do you know of any plans to electrify this area?
   a. yes, SEB is planning to electrify this area soon
   b. yes, there are plans to electrify this area by it may take a long time
   c. no. there are no plans to electrify this area

62. What would you do if grid electricity would become available in your area?
   a. get a grid connection and keep the solar system *(go to question 64)*
   b. get a grid connection and sell the solar system (*go to question 64*)
   c. don't apply for an electricity connection

63. Why wouldn't you apply for an electricity connection?
   a. can not afford it
   b. unreliable service
   c. don't need more power than I have at present

64. Would you recommend a solar system to other people?
   a. yes
   b. no

65. Do you think your solar system has improved the safety around your house?
   a. yes
   b. no
   c. don't know

66. Have you or has somebody you know ever had a panel stolen?
   a. yes, panel got stolen
   b. no, but there was a failed theft attempt
   c. no

67. Do you or other household members stay up longer since your solar system has been installed?

a. yes
b. no

68. What do you do with the extra time?

a. perform household duties
b. watch television
c. socialise with family or friends
d. make homework
e. read
f. perform income generating activities
g. other..

Income level

69. Hoe many household members live here?
- no. of adults:...................
- no of children:.................

70. How many of them only stay here throughout the week?
- no. of adults:...................
- no of children:.................

71. How many household members are employed?
- no. employed....................

72. Can you indicate the type of employment
....
....

73. Does the household receive an income from one of the following sources:

a. agricultural products
b. home based income generating activities, indicate..
c. pension
d. remittances
e. other.............................
f. don't know

74. Which of the following cattle does the household have?

a. cattle (no................)
b. goats (no................)
c. chickens (no................)
d. other, indicate............................

75. If household has any other remarks please indicate …….

Observation:

Indicate your perception of the income level of the household
- rich
- middle income
- low income

6. ANNEX 2. PROPOSED SURVEY QUESTIONNAIRE INDONESIA

Solar Energy Questionnaire: Section 1 to be completed by Technician

0a Questionnaire no. : .... 0e. Date of visit :_____/_____/2000

0b Name of Interviewee.: .... 0f. Time of visit: ....

0c Location :....................................

Indicate prevailing weather conditions during system inspection:
- d. clear
- e. cloudy
- f. complete overcast

2. Indicate type and state of **batteries:**

	battery 1	battery 2	battery 3
a. brand name			
b. type: automotive (A) portable/TV (T) deep cycle (S) maintenance free (M)	 A T S M	 A T S M	 A T S M
c. capacity (Ah)			
d. state of charge (V)			
e. charge after load test (V)			
f. electrolyte level	normal/corroded	normal/corroded	normal/corroded
g. state of terminals	clean/corroded	clean/corroded	clean/corroded
h. loose wires/connections	yes/no	yes/no	yes/no

3. Indicate size of **wire** that has been used:
   a. between battery and charge regulator: mm2
   b. between battery/regulator and panel mm2
   c. between battery/regulator and appliances: mm2

4. What is the maximum length of the wires between the battery/regulator and one of the appliances: ....meter.

5. Indicate type and state of charge controller (BCU)

	BCU 1	BCU 2	BCU3
a. brand name			
b. rating (Amps)			
c. high voltage disconnect			
d. low voltage disconnect			
e. number of charge indicator lights			
f. used (U) bypassed (B) faulty (F)	U B F	U B F	U B F

5g. Describe problem if BCU is faulty:

6. Indicate type and state of inverter:

	INV 1	INV2	INV3
a. brand name			
b. rating (Watts)			
c. total Watts connected			
d. state	OK / faulty	OK / faulty	OK / faulty

7. Indicate number of appliances connected to solar system and indicate whether or not used via inverter (DC/DC or DC/AC):

appliance	**without inverter**	**with DC/DC inverter**	**with DC/AC inverter**
a. Lights			
b. B/W television			
c. Colour television			
d. Hifi			
e. Radio			
f. Other, indicate			

8. Specify type and status of lights:

	FL	**PL**	**other**
a. brands(s) of tubes/bulb			
b. rating (Watts)			
c. manufacturer of lamp unit			
d. number installed per type			
e. number faulty per type			
f. infested by insects			

8g. If one or more lights are faulty, indicate problem..
....

9. Specify type and state of **solar panel(s):**

	solar panel 1	solar panel 2	solar panel 3
a. brand name			
b. type: (amorphus, mono-, poly crystalline)			
c. rated peak power (W_p)			
d. charging current			
e. short circuit current			
f. open circuit current			
g. tilt of panel (degrees)			
h. orientation (degrees)			
i. panel shaded	yes / no	yes / no	yes / no
j. panel dirty	clean/dirty/ slightly dusty	clean/dirty/ slightly dusty	clean/dirty/ slightly dusty
k. loose wires/connection	yes / no	yes / no	yes / no
l. signs of corrosion	yes / no	yes / no	yes / no
m. signs of breakage	yes / no	yes / no	yes / no
n. signs of UV damage	yes / no	yes / no	yes / no

10. General systems performance:
a. working fine
b. working, but not optimal
c. not working

Remarks: ....
....

Solar Energy Questionnaire: Section 2 to be completed by end-user

11. Are you happy with the performance of your system?
    a. yes
    b. no

12. Why are you happy/not happy with your system?

....
......
....
......

13. Why did you buy a solar system?
    a. no grid available in this area
    b. grid too expensive
    c. grid too unreliable
    d. other,
    indicate..
    e. don't know

14. Are you aware of any plans from Government/utility to electrify this area?
    a. yes
    b. no

15. Did you consider any alternative electricity supply options before buying a solar system
    a. generator
    b. wind turbine
    c. micro-hydro system
    d. other options (indicate...)
    e. no other options considered

16. Have other people you know shown an interest in your systems?
    a. yes
    b. no

17. Would you recommend a solar system to other people?

a. yes
b. no

18.Did you already own a battery before you bought your solar system?
    a. yes
    b. no (go to question 23)

19. How many times per month did you normally charge this battery?
    no. of chargings per month......................

20. How much did it cost to charge a battery?
Rp................. per charge.

21. Are you still using this battery?
    a. yes
    b. no

22. What do/did you used this battery for?
    a. lighting
    b. radio
    c. hifi
    d. B/W television
    e. Colour television
    f. other, indicate...

Finance of solar system

23. When did you obtain your solar system?
date:.......................................(month and year)

24. How did you pay for your system?
   a. cash
   b. credit
   c. rental (go to question 29)
   d. donation (go to question 30)

25 What was the purchase price of the solar system?

26. What was included in the price of your solar system?
   a. solar panel
   b. battery
   c. battery regulator
   d. cables and connecting material
   e. lights
   f. installation
   g. other, indicate....................................

27. Who of this household paid for the solar system?
   a. husband
   b. wife
   c. grown-up children
   d. other

CREDIT

28.1 Who provided the credit?
a. Solar system supplier
b. Bank
c. Credit & Savings Organisation
d. Friend/Relatives
e. others.......................................

28.2 What was the amount of the deposit you had to pay?
Amount deposit:......................

28.3 How long is/was the repayment period?
repayment period (months): ....

28.4 How much is/was your monthly instalment?
Amount of monthly instalment: ....

28.5 Are you still paying your instalments?
a. yes, still paying
b. no, paid off the loan in full
c. no, loan not paid off in full, but not happy with the system
d. no, loan not paid off in full, but no money to pay

(go to question 31)

RENTAL

29.1 Whom do you rent the system from?
Name rental company:...........................

29.2. If rental, how is the rental being charged?
  a. per time: indicate day, week, month, season, year
  b. per rate of consumption (kWh)

29.3. What is the amount of the rental?
Amount of rental:........................

29.4 How do you pay the rental fee?
  a. rent is being collected from home
  b. pay rent at nearby outlet
  c. pay rent to rental company in town
  d. other,...

(go to question 31)

DONATION

30. Who donated the system?
  a. Government
  b. Aid organisation
  c. Relatives
  d. Other,..

Service and Maintenance

31. Who is responsible for maintenance and repairs?
  a. you
  b. supplier, through service contract
  c. rental company
  d. donor
  e. other, indicate.................................
  f. don't know

32. How often has your system been serviced by a technician? no. of visits.............

33. Which of the following system components have ever been faulty?
  a. battery
  b. charge regulator
  c. solar panel
  d. lights
  e. DC/AC inverter
  f. none (go to question 34)

33.1 Do you know the reason(s) why they stopped working?
  a. component(s) worn out
  b. poor quality of installation
  c. theft
  d. vandalism
  e. lightning
  f. other, indicate.........................
  g. don’t know

34. Which of the following system components have ever been replaced?

a. battery *(go to question 35.1)*
b. charge regulator (*go to question 36*) .
c. solar panel *(go to question 36)*
d. lights *(go to question 36)*
e. none

34.1 Why didn't you replace the faulty components?

a. no money to repair/replace components
b. still waiting for technician to come
c. don't know who to contact
d. other, ...

35.1 How often has the battery been replaced?
no. of replacements.........................

35.2 How long did your last battery last?
months.................

35.3 What did you do with the old battery?

a. returned it to the supplier
b. kept it
c. threw it away

36. Did you receive a manual when you bought your solar system?

a. yes
b. no (*go to question 39*)

37. Did you read the manual?

a. yes
b. no (*go to question 39*)

38. Did you consider the manual useful?

a. yes
b. no

39. Did the technician/supplier inform you on the maintenance requirements of the system?

a. yes
b. no (*go to question 41*)

40. To whom did he/she explain the system?

a. household head
b. wife of head
c. children
d. others

41. Did you ever clean the solar panel(s)?

a. yes
b. no

42. Did you ever clean the battery terminals and contacts?

a. yes
b. no

43. Did you ever check the electrolyte level of the battery?

a. yes
b. no

44. Did you ever topped up the battery with water?

a. yes
b. no

45. If yes what kind of water did you use?
   a. water straight from tap/river
   b. boiled water
   c. distilled water

46. Have your monthly energy expenditures been reduced after you started to use your solar system?
   a. yes
   b. no

47. Do you think your solar system has improved the safety in and around the house?
   a. yes
   b. no

48. Do you or other household members stay up longer since your solar system has been installed?
   a. yes
   b. no

49. What do you/they do with the extra time?
   a. perform household duties
   b. watch television
   c. socialise with family or friends
   d. make homework
   e. read
   f. perform income generating activities
   g. other,...

Socio-economic background

50. How many household members live here? no.________

51. How many of these household members are employed? no. _________

52. Can you indicate the type of employment?
....
....
....

53. Does the household receive income from one of the following source:
a. agricultural products
b. home based income generating activities, indicate....................
c. pension
d. remittances
e. other, indicate..................

54. Which of the following livestock does the household own?
a. cattle: (no............)
b. goats: (no............)
c. chickens (no............)
d. other, indicate (no............)

Remarks:
....
....