August 1999 ECN-I--99-005

# SOLAR HOME SYSTEMS: INSIGHTS FROM DEVELOPING COUNTRIES OF THE WORLD

A literature survey of current issues and topics

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## Abstract
The study presents an overview of the main issues discussed and topics in regards and with relevance to Solar Home Systems. The main issues are grouped and discussed in five topics: financing, institutional arrangements, market opportunities, information and communication, and standards and quality control. Major challenges as far as projects are concerned, whether public or private, are highlighted, in particular regarding aspects of financing and institutional mechanisms. The up-front costs make Solar Home Systems out of reach for the greater number of people who need them most. On the other hand, sourcing private finance for renewable energy technologies in general, and Solar Home Systems in particular has often been very difficult because of the perceived risks. Even if these funds would be available, weak institutional links often undermine project success. However, a handful of success stories exist today and could possibly be replicated elsewhere in the developing world. The subject of information dissemination needs to be revisited and clearly set in perspective. Several countries and organisations have now developed standards and technical norms, but universality and applicability are issues still at hand.

## Acknowledgement
This work was done during an eight week secondment period at the Policy Studies Unit of the Energieonderzoek Centrum Nederland (ECN). The secondment was a partial fulfilment of the requirements for obtaining a Master of Science degree in renewable energies from the University of Oldenburg, Germany. The author wishes to register his heartfelt appreciation to the staff of the Policy Studies Unit, for all the support and assistance rendered during this period. Special thanks goes to Drs. Nico van der Linden, who supervised this work and facilitated the detachment. Many thanks also to the Solar and Wind Energy Unit. This publication is registered at ECN under number 7.7185.

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# 1. INTRODUCTION

The modern solar energy age effectively started in the 1950s, the main thrust being the US space programmes. In 1961 the first 'UN conference on Solar Energy in the Developing World' was held, and later, in 1972, the IEEE - a major actor in photovoltaics (PV) development at that time - held the first PV Specialists Conference to include a session on terrestrial PV (Fitzgerald, 1998). The oil crises of 1973 ignited a search for alternatives in energy production, and so gave a further impetus for the consideration of PV for terrestrial applications. Since then, an avalanche of projects and programmes on PV has been initiated and the pace has been intensified over the last two decades. In developing countries[1], PV is seen primarily as a strategy for the electrification of rural and remote areas. From a global point of view, PV offers a contribution to the attempt to reduce anthropogenic $CO_2$ emissions and other pollutants associated with conventional fuel use. Facing a threat of undesirable climatic change, the world today gives high priority to environmental protection. Agenda 21, chapter 9, of the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992, identified evolution towards greater reliance on environmentally sound energy systems, particularly new and renewable sources of energy, as one of the key future directions (UNDP, 1995). PV naturally falls within this category.

Indeed, studies by different experts are in agreement that even on a complete energy chain basis[2], greenhouse gas emissions (GHG) of PV, including $CO_2$, are by several orders of magnitude lower than the emissions of conventional fossil fuel based generation units (e.g. van de Vate, 1997, Kato et al, 1998). There still exists an appreciable scatter of values of the real emissions of PV and other technologies, mainly due to different assumptions on system boundaries of energy technologies and different accounting methods. In spite of these differences, PV is still ranked among the highest in terms of least full energy chain GHG emissions[3]. Within the main PV technologies themselves, amorphous silicon shows the lowest rate of GHG emissions while mono crystalline silicon cells show the highest.

Governments of developing countries, amidst conflicting economic and social pressures, see PV as an attractive means to address some of the rural energy problems and so improve the quality of life. In this regard, through the years they have increasingly placed high priority on rural electrification. However, it is accepted today that despite the rapid development of national grids, a large population of the rural world will not have access to grid based electricity services, even in the near and medium term. On the other hand, off-grid PV systems can generate adequate electricity for these households, and in many such cases they make economic sense. From the view of the industrialised world, including those of the donor agencies and international funding agencies, the increased use of modern energy carriers in developing countries is important for the alleviation of poverty (World Bank, 1998). Additionally, PV as a renewable energy technology fits into the world's quest for sustainable development. There is also another side to the PV story, which is that industrialised countries see the developing world as a market now and a potentially 'big' market in the future. Shipments in 1997 were just over 110 MW. Some estimates even predict a 500-fold increase in shipments by 2040, meaning that PV would by then be contributing about 1% of the world's electricity (Oswald, 1998). However, nowadays we are aware of the fact that it is wise to be cautious in relying on such estimates.

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1 Developing countries include most countries in Sub Saharan Africa, South and East Asia, the Pacific, Latin America and the Caribbean.

2 This analysis includes mining, energy embodied by materials used in manufacturing, energy used in the entire production process and energy produced during lifetime. Sometimes referred to as 'cradle-to-grave' analysis.

3 It is worth noting that PV is among the least cost effective options for GHG abatement. A discussion on this topic however is beyond the scope of this paper.

Ever since the terrestrial applications of PV began, a plethora of utterly misfired estimates has been made on the decrease in cost with time and future PV production. This, however, gives an idea of the viewpoint of PV.

In response to the two oil crises of the seventies, PV was initially promoted with the reasoning that fossil reserves would soon run out and therefore alternatives should be sought. As a consequence, the logic would go that the price of fossil fuels would rise dramatically, as the resources diminished and mining remaining reserves would become more expensive. However, the fact that we are facing a resource problem is a hot debate by itself. The quantity of proven reserves of oil for example, has increased through the years. The world's reserves to production ratio (R/P) stood at 40.9 by the end of 1997, indicating that the world is assured of adequate conventional oil supply at least for the next 40 years (BP, 1998). A similar picture is painted for natural gas and coal, recording R/Ps of 64.1 and 219 respectively. Given the continuing technological advancement and the fact that more reserves are being unveiled with time, it is a contentious issue whether mankind will ever face fuel shortages. Whatever the case, PV has now and in the past enjoyed promotion due to this scenario of future fossil fuel depletion.

It is no doubt that PV in many cases proved to be economically competitive to conventional energy carriers. In particular small, decentralised units in the form of Solar Home Systems (SHS) have shown to have multiple advantages, namely:

- modularity, which renders them flexible in response to consumer requirements,
- short lead times, which reduces risks and renders them easier for 'quick' deployment,
- suitability for deployment in dispersed dwellings, a common characteristic of developing countries.

Additionally, SHS displaces the need for candles, dry cell batteries and kerosene quite well, showing a better result both economically as environmentally. These are real merits of SHS and part of the reason why so many have been disseminated already. A typical SHS consists of;

- A *PV generator* comprising one or more modules, which may be interconnected to form a DC power unit (typically less than 100W).
- A lead acid *battery*, typically with a capacity of between 40-200Ah.
- A *charge regulator* to prevent excessive overcharges or discharges of the battery, *loads* typically lamps, radio, etc.
- A *support frame* for the PV generator.
- *Accessories*, i.e. cables, connection boxes, switches, fasteners, etc.

Five key issues, in connection with SHS, namely; financing, institutional arrangements, market opportunities, information and communication, and standards and quality control are repeatedly cited in literature today.

This paper seeks to deliberate and possibly evaluate these main issues as reported in literature. The goal is not to reproduce similar works carried out previously, but rather to complement them and perhaps report on new issues and insights. As much as possible, only literature from credible sources was considered and quoted. Sources include project reports, conference proceedings, project proposals, journals, and Internet sources. Interviews were also made both in person and via communication media. Only non-technical aspects of SHS are deliberated in detail.

# 2. FINANCING SOLAR HOME SYSTEMS

## 2.1 Problems in SHS financing

In SHS and renewable energy literature, especially with reference to developing countries, financing is the most discussed topic to date. On this topic, most authors are quick to flag the point that although sustainable energy technologies in general may well be cost-effective from a life cycle analysis basis, they are also more capital-intensive (from the end-user's point of view) than conventional energy sources. This, coupled with the fact that consumers in developing countries often evaluate alternatives primarily on first cost basis rather than on life cycle costs, makes the market diffusion of SHS quite slow.

Unlike conventional energy projects, model projects and success stories in SHS have unfortunately only barely been able to build the necessary confidence in private investors and banks, although this situation is slowly changing. There is a general call for innovation in financial mechanisms pursued in tandem with appropriate delivery mechanisms.

The main constraints and impediments in financing frequently encountered in SHS programmes are:

- *Access to finance*
  This is claimed to be a cardinal prerequisite for SHS projects, and renewable energy projects in general.
- *Cost of finance*
  When financing involves loans, raising and servicing the financial arrangements goes together with certain costs.
- *Perceived risks*
  All projects are exposed to risks, which are often considered high when the project involves relatively new technologies. Avoiding, reducing and sharing risks among key players is essential for success (Tatsis et al*,* 1997).

The above issues bring up three finance-related concerns that stand out as being critical if the SHS industry is to grow successfully, namely (Northrop et al, 1995):

- Consumers need to obtain credit from banks or distributors.
- Suppliers and retailers must be able to secure working capital if they are to be able to in-turn provide credit to their customers.
- Investors need credible financing opportunities to mobilise capital towards the solar industry.

## 2.2 Finance delivery chains

Close inspection of literature reveals three main categories in the finance process arranged in a fixed vertical structure viz.; international financiers, several (institutional) intermediaries who handle the funds, and the end user of the funds. In practice a pattern can be recognised, which further breaks down these categories into five levels of actors, again vertically integrated. These are illustrated by Figure 2.1.

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

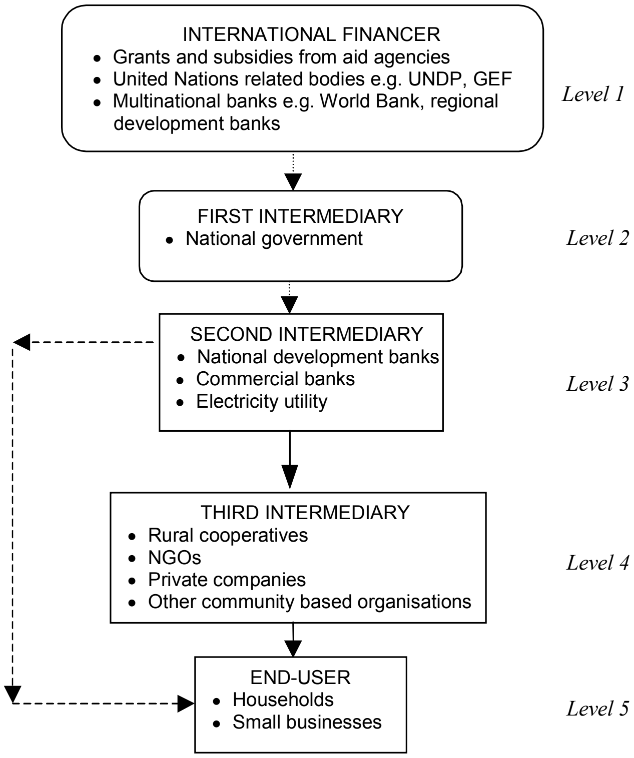


Figure 2.1 *Typical finance delivery chain*

The finance types they provide are:

- *Debt financing*
  This is a financial instrument that provides capital for the purpose of earning interest for the lender[4]. Commonly, in SHS programmes this is some form of concessional loan, meaning that the terms and conditions of the loans deviate somewhat from common commercial terms by including some grant element. Debt finance may be of many forms and variations, as shown in Figure 2.2.
- *Equity financing*
  Level 1 financiers may also be equity (shares of stock) partners in projects. In this case the investor has the right to play an active role in the decision making process of the project. In legal and institutional terms equity finance may assume many forms, including joint ventures. This type of financing is increasingly encountered in SHS literature, for example the Solar Resources Inc[5]. and Philippine companies (CADDET, 1995), ESKOM and Shell Renewables (Shell, 1998). An impressive treatment of this topic is given by inter alia Tatsis (1997).

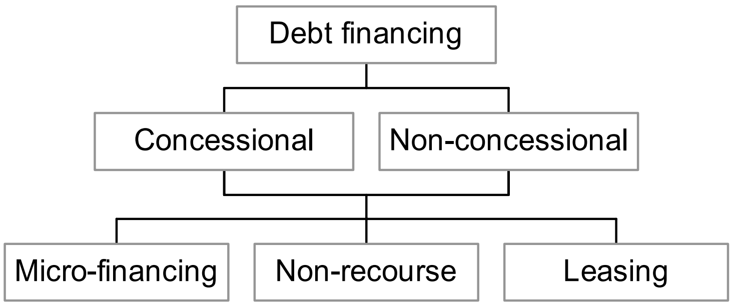


Figure 2.2 *Debt finance*

[4] The underlying objective for debt finance is often market development.
[5] Based in Wilmington, Massachusetts.

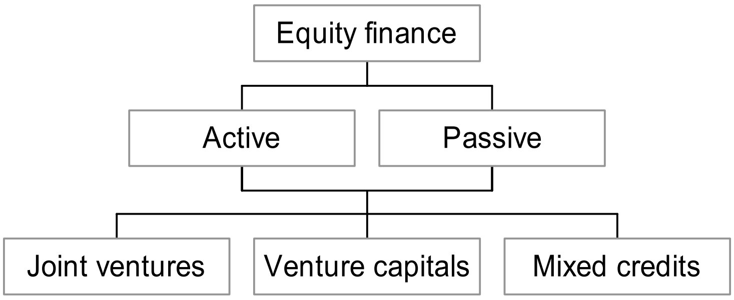


Figure 2.3 *Equity finance*

The next levels involve institutional intermediaries, whose goal is to see that the Level 1 funds reach the consumer in Level 5. It is worth noting that the longer this intermediary chain, the more the administrative overheads compile. Often these intermediaries are necessary, or at least perceived to be, for the project success, but they do worry the Level 1 financier.

National governments often intercept the funds, as is the case for GEF projects, although this is not always necessary. For example, the Solar Development Corporation may skip Level 2 directly into Level 3. There is also a possibility of a loop directly from Level 1 to 4, as is the case with the Solar Investment Fund.

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

## 2.3 Revolving Loan Funds (RLF)

This has been the most exploited financial mechanism to date. It was applied in the GEF project in Zimbabwe, the E&Co project in Guatemala and the Banpres project in Indonesia, to name a few from many. The revolving fund concept is simple, although often the funds do not revolve for a very long time, but rather deplete and sink, and so require recharging.

A simple example to illustrate the RLF concept is a project carried out by the Vietnam Women's Union[6] (VWU) and the Solar Electric Light Fund (SELF) in 1995 (CADDET, 1997). The scheme was organised as shown in Figure 2.4.

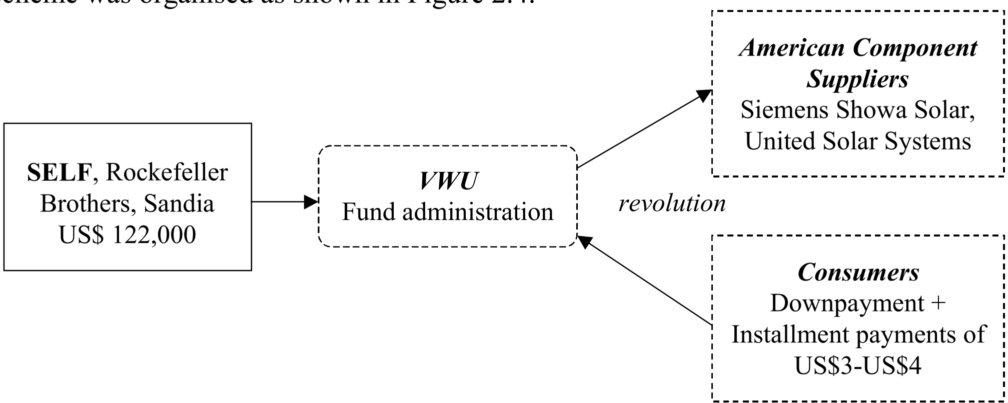


Figure 2.4 *Organisation of project carried out by VWU*

[6] VWU is the largest Women's Union in the world, boasting of about 11 million members.

*The Vietnam-SELF RLF*

In this case the RLF was soon eroded, because no interest was charged and there were also problems with inflation[7]. This poses considerable problems in developing countries, which should be considered with regards to fund sustainability. It is common in literature, as in the foregoing example, that the RLF have a social dimension and some kind of semi-commercial operation. In this case the project is regarded as semi-commercial because it cannot be sustained without financial support for capital costs and overheads. One of the difficult tasks in RLFs is to define and screen recipients. If the demand exceeds the limited funds, it is quite difficult to objectively establish who should benefit, who should be first and who should wait. Although no commotion amongst disgruntled candidates is reported in literature, one can speculate that this is a realistic possibility.

It is a fact that there is no fixed recipe of financial mechanisms that can be universally applied for project success, and that project developers, either for pure commercial or semi-commercial objectives must often innovate on existing possibilities.

## 2.4 Credit Financing

This type of consumer financing helps the end-user to overcome the high first costs, by allowing payments in 'easy terms'. Normally, the consumer deposits a down payment, around 30% for commercial schemes, and then pays the balance in regular payments, typically extending to up to three years. Actually, credit financing for purchasing consumer goods like furniture is common in many parts of the developing world.

The reported experience in credit financing of SHS is impressive so far, with defaulting reported to be lower than for other consumer goods. Figures of 90-100% repayment are very common indeed (inter alia Sudimara, 1995)[8]. The table below captures just some of the many examples to date.

Table 2.1 *Examples of experience in credit financing of SHS*

| | Financing | Down payment [% of cash price] | Annual interest rate [%] | Repayment period max. [months] | Status and comments |
|---|---|---|---|---|---|
| *Swaziland* | | | | | |
| Retailer 1 | Private (International) | 23 | 22 | 36 | • ongoing; • less than 5% defaulting |
| Retailer 2 | Private | 50 | 24 | 12 | • ongoing |
| *Indonesia* | | | | | |
| Banpres project (ca. 1991) | Presidential grant | 5 | 0 | 10 | • intended to be a precursor to a 1m household 50MWp programme |
| Retailer | Private | 30 | 18 | 44 | • ongoing; • 0% default payments (1993-1995) |
| *Zimbabwe* | | | | | |
| GEF project | GEF; government | 15 | | 36 | • 1993-1998 • set out to install 9000 45Wp systems |
| *Kenya* | | | | | |
| Retailer | Private | 25 | 14.5-33 | 24 | • ongoing, very successful credit schemes |

7 SELCO, a company in which SELF has some holdings, in association with VWU, is now implementing a 12,000 SHS program on a commercial basis, funded by the IFC with credit from the Vietnam Bank for Agriculture.

8 Sudimara operates in Indonesia. Information received from fax communication through EAP, UNDP. Hosier et al reported on the GEF project in Zimbabwe, from Imech prospectus (see references).

## 2.5 Leasing Schemes

This kind of financing is newer in SHS projects and is already being experimented with in many countries. Some authors speculate that this is the financial model which best reaches out to the poor. In literature it is commonly referred to as 'fee-for-service', the idea behind being the replication of how grid electricity consumers pay for electricity; in small monthly usage fees. No one is asked to buy a power station, transmission and distribution system up-front if he wishes to have electricity services, and this is exactly what the SHS consumer has been expected to do.

The islands of Kiribati have accumulated a wealth of experience in leasing. In a report delivered at an Asian regional workshop on the Kiribati experience (see table) in 1996, the failure of rural electrification through sale of systems to users was highlighted. With strong advocacy for the leasing concept the following was reported; 'The shift to service provision by a utility type of institution has completely turned around the situation with high user satisfaction and rural households now paying in advance to be put on a waiting list for systems' (Akura, 1996). The table below captures some of the current and continued leasing schemes.

Table 2.2 *Example of leasing schemes*

| | Key players | Financier | End-user payments [US$] | Remarks |
|---|---|---|---|---|
| *South Africa, Eastern Cape* | Shell Solar, ESKOM | Shell Solar, ESKOM | Installation fee: 30<br>Monthly fee: 8 | • began early 1999 and intends to electrify 50,000 homes<br>• uses magnetic card based prepayment<br>• commercial activity<br>• product to be marketed through franchised outlets |
| *Philippines, Visayas region* | Solar Resources Inc., three local companies | AEP (demo.) | Monthly fee: 5.75 | • (1995) 18 system installed for demonstration, 2000 more planned for the following 16 months<br>• projected payback at 8-10 years<br>• electric co-operatives trained to provide maintenance and to collect rental fees |
| *Dominican Republic* | SOLUZ, IEBV | SOLUZ | 'A few $ a month, even less than instalment for credit payments' | • 100% collections since 1994 (to late 1995)<br>• no major maintenance by 10/95 |
| *Kiribati* | SEC, S.P.I.R.E | EU (Lome II) | Installation fee:A$ 50<br>Monthly fee:<br>A$ 10-A$ 50 | • repayments more than 80% on time, and 100% in two months due date 1996 |

Note: 1US$=1.57A$-Australian dollar-(1999)

However, there are risks involved with the leasing schemes, one of which being that effecting disconnection might not be easy in certain socio-political climates. The other is the risk of module theft. One can speculate that since the customer does not own the system, he also is under no obligation to protect it. This should be an important consideration in societies where theft of modules is rife already. Furthermore, the monthly user fees commonly used so far, between US$ 3 to 8 - presumably equal to costs of alternatives e.g. kerosene, candles, dry cell batteries etc. - are likely to be too low for full cost recovery.

## 2.6 SHS Pricing

Figure 2.1 below shows the pricing breakdown of typical complete SHS in various countries. It can be seen that taxes and duties for example add around 12% (Namibia) and 15% (Kenya) to the total system price. Clearly, waiving these taxes and duties would make systems more affordable. Some governments, for example Senegal and Swaziland, have already intervened by removing import tariffs on solar equipment and this has a positive reflection on the system price (Sokona et al, 1994, Lasschuit, 1999). Actually Sokona et al reports that, before reform, taxes and duties in Senegal increased prices by over 60%. A similar story is reported for Uganda. Prior to 1992, taxes on imported systems were at 58%. They have now been eliminated (GEF, 1997).

There may be a myriad of reasons for the price discrepancies between different countries. Besides the effects of duties and taxes, as previously discussed, another effect seems to be the varying length of the distribution chain. In Kenya, consumers are reported to prefer purchasing equipment in Nairobi in order to avoid retailer mark-ups (Osawa, 1998)[9]. Other reasons for variations may be the heavy competition at the market and the quality of components and services provided by retailers.

There is no doubt that manufacturing BOS equipment in-country lowers system prices, improves maintenance and repair capabilities and has other benefits as well, such as job creation. Most developing countries already have industry related to mechanical and electrical engineering, meaning that local fabrication of BOS does not imply as great a technological leap as required in local module manufacture. The investment costs of BOS factories are also significantly lower than those of a module assembly plant, and thus make them within economic reach of many countries. In Bolivia for example, the initial capital costs of a BOS factory was estimated to be of the order of US$ 30,000 and the corresponding capital costs for a module assembly plant around US$ 1.5 million (Uglier, 1996). Many other countries are now manufacturing good quality BOS locally. On the other hand, local module assembly in developing countries is only economically viable in countries with sufficiently large populations to be able to take advantage of economies of scale. It is difficult to hold prices at par or below the international prices if the local market is relatively modest. Zimbabwe has a local company which assembles modules, Solarcomm. However, Solarcomm's module prices are in many cases higher than imported module prices (Bacon, 1998)[10].

Other influences have to do with market sizes and hence the volume of orders. Many suppliers offer price reductions corresponding to the size of the bulk purchase, as is common in business practice. Price reductions of up to US$ 4.75/Wp (F.O.B) are common.

9 Personal communication.

10 Bacon speculates that one reason for this is that the GEF project in Zimbabwe distorted market prices and therefore placed Solarcomm at an unfair disadvantage.

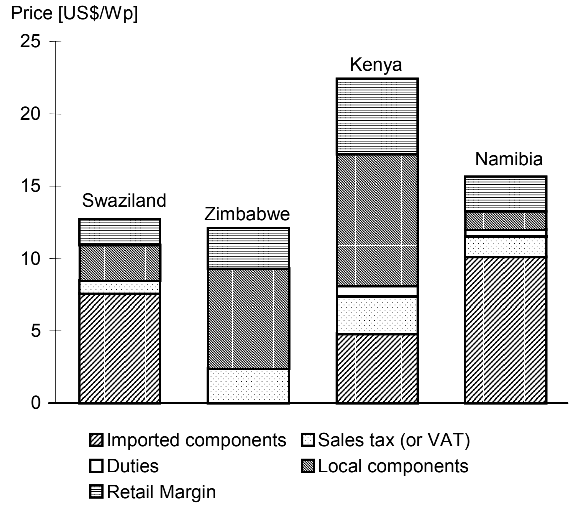


Figure 2.5 *Price structure of SHS in selected countries. Swaziland: 45 Wp, Zimbabwe: 53 Wp, Kenya: 50 Wp, Namibia: 55 Wp c-Si modules. Source: author, through email communications*

Figure 2.6 shows a typical cost share of SHS. There are, of course, variations in magnitude of the percentage from country to country, but the relative component proportions are very similar.

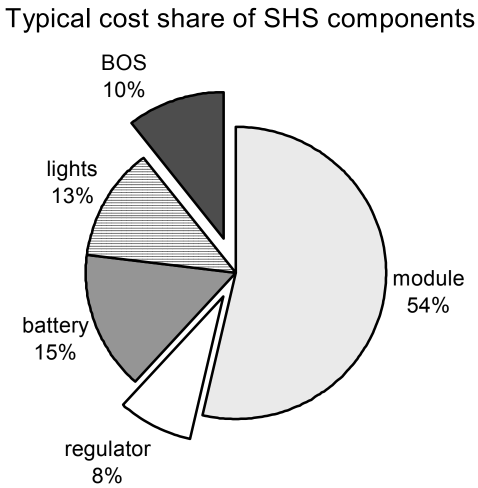


Figure 2.6 *Source: author's estimates from various sources*

As can be seen in Figure 2.6, the module is the most expensive component of the system. For one, the manufacturing of solar cells is a highly energy intensive and intricate industrial process. However, the most important costs are not those of the cells, but rather of their assembly into modules. In 1993, the cost of the module housing (excluding the cells) was around US$ 200/m$^2$ (Trainer, 1995). Estimates by then set the finished module cost at about three to seven times the cost of the cells. Since then, there have not been significant cost reductions. It is clear that the hope to reduce module costs is based on an attempt to reduce the use of glass and perhaps production of frameless modules. However, there has to be a balance between reducing the amount of material and the durability.

## 2.7 Subsidies

Literature attacks the issue of subsidies with varying degrees of ferocity, although there is a general consensus on the need for their elimination, reduction or reform. Subsidies must be targeted, their impact closely monitored and they must have a known sunset.

In rural energy, subsidies are usually well-intentioned and as far as the governments of developing countries are concerned, they serve to meet a number of objectives, which can be classified into five categories. These are not limited to SHS but to rural electrification, or even more generally, improving rural access to energy.

a) *Social equity*
Governments have a social responsibility to improve the quality of life[11] of rural households, especially the poor and women and children in particular (UNDP, 1995). The poor in rural communities cannot, on their own, make an energy transition to modern fuels, due to their low disposable incomes. It seems logical for governments therefore to move in and intervene. 'Poverty and scarcity of energy services go hand in hand, and exist in a synergistic relationship' (UNDP, 1995).
b) *Economic growth*
Energy is a crucial input in productive processes. Historically, demand for electricity has been closely tied to economic growth. While industrialised economies have managed to decouple economic growth from proportional input of energy through improved energy technologies, the traditional view still holds in many developing countries (Sampa, 1995). Rural electrification project documents often specifically mention the promotion of performance of agro-based industries and establishment of a base for small scale industries, as distinct objectives (van de Broek et al, 1997). For SHS, project developers often cite the benefit of women being able to continue with economic activities, e.g. sewing, even after sunset, although it is common that the costs be understated, and the benefits overstated. Viewed from this economic perspective then, governments view subsidies as being justified.
c) *Regional balance in development*
Due to the politicising of social services, water, health services and electricity in particular, governments strive to ensure that all the different regions in a country have equal access to infrastructure. In the rural setting this can be barely achievable now and in the near future without some sort of government assistance. Additionally, rural electrification is also seen as an instrument for inhibiting migration to urban areas (Jansen et al, 1997). Since rural grid electrification projects normally have poor returns on investment, many developing country utilities give them, at best, lukewarm interest. Of course exceptions exist among them, the Mexican utility Comisi∴n Federal de Electricida (CFE), and the South African utility, ESKOM, who reckon; 'Bringing affordable electrical energy to people living in remote rural areas is an important factor in the revival of Africa' (de Beer, 1998).
d) *Market promotion*
The government may subsidise new technologies, which are perceived to contribute to a strategic goal, but also are exotic and therefore need confidence building. SHS are a good example to illustrate this point; by investing in SHS programmes, governments build private sector confidence with the hope that the latter would thereafter take up the business on pure commercial terms. Hence it is conceived that once economies of scale are reached, subsidies can then be eliminated. Some authors view tax credits, exemptions and rebates for producers or retailers as having the same effect as cash subsidies (APEC, 1998).

[11] Measures of the quality of life include life expectancy at birth, sanitation, access to safe water, commercial energy use, prevalence of child malnutrition and adult literacy rate.

e) *Environmental aims*
SHS are perceived to be a 'green' energy technology which, when substituting kerosene, candles and dry cell batteries, can have positive effects on the environment (CADDET, 1995).

Unfortunately, experience has shown that subsidies often do not reach the poor for whom they are intended, defying the above objectives and at worst being counterproductive. However, when used judiciously they can be effective in promoting household PV programmes. They were proved to be more effective and result in more sustainable programmes when used for market conditioning activities, like promotion, quality assurance and similar activities. The use of subsidies to cover operating costs undermines long-term financial sustainability (Cabraal, 1996).

Subsidies come in one of two forms:

- *Direct subsidies* that alter market prices. These may come in many forms, including direct government payments to hold down consumer prices.
- *Indirect subsidies* through fiscal and other means that affect investment decisions. These may include preferential loans and guarantees, tax and duty exemptions etc. If at all necessary, this type of subsidy is believed to yield better results (WEC, 1995).

Traditionally these subsidies have been heavily applied to grid electrification in order to reach the poorer of both rural and urban households. There seems to be consensus today that subsidies for conventional energy constitute a significant restraint to new energy technologies like SHS. The popular phrase is that of 'levelling the playing field' in order for new technologies to participate fairly in the energy market. Actually reducing (or reforming) subsidies provided to conventional fuels is envisaged to have a better effect than directly subsidising SHS or other renewable energy technologies (WEC, 1995).

Even from an equity point of view, indiscrete subsidies are counterproductive and incompatible with the aims of rural electrification, often also creating fiscal burdens for the government (UNDP, 1998). A relatively new concept in subsidy reforms is that of offering 'lifeline rates' up to levels of consumption believed to be needed to support basic human needs; for example up to 50kWh per month, and setting progressively higher tariffs for higher consumption levels. Measures like this, although with potentially fierce political opposition, would not only better reach the poor, but also make new technologies like SHS more attractive.

# 3. MARKET OPPORTUNITIES

## 3.1 The world market

World-wide production of PV cells and modules in 1998, stood at about 120MW. World-wide sales have increased on average at 15% every year during the last decade (Siemens, 1999). The 'big' players in PV manufacture are Siemens Solar, Solarex, Kyocera and two petroleum multinationals, namely BP Solar and Shell Solar. Current silicon cell production requires around 15 ton/MWp of silicon. It seems, therefore, that low cost silicon might be a problem to find in the near future. With this view in mind, many solar commentators believe thin film technology holds the greatest potential for the future. This technology also promises significant cost reductions as compared to, for example, crystalline based technology.

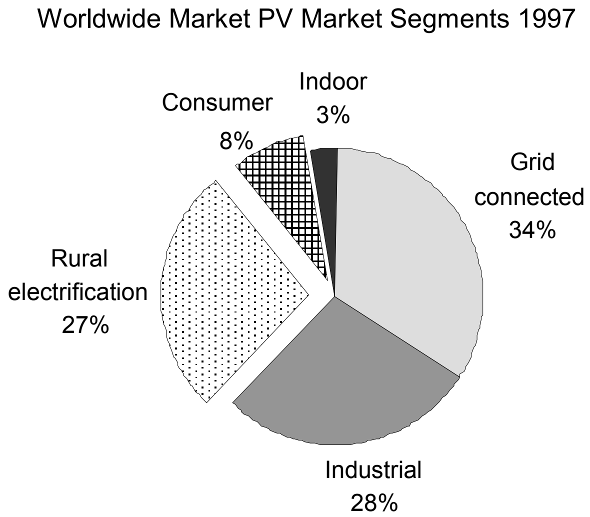


Figure 3.1 *Worldwide Market PV Market Segments 1997. Source: Siemens*

The question of where the market opportunities for SHS are, can be split into subquestions like *where are they cost-effective*, *who can afford them*, and *who is willing to pay for them*. Rural electrification presents the largest market of SHS in developing countries. In practice, three options for rural electrification have been employed: conventional grid electrification, decentralised local grids (usually diesel powered), and stand-alone PV, SHS for example. Estimates for the currently installed stock of SHS point at around 500,000 (Ciscar, 1997). Ciscar (1971) also estimates that around 80,000 SHS are being set up annually, most of them in developing countries.

## 3.2 Rural electrification

In terms of cost-effectiveness of solar PV as compared to alternatives, Markvart suggests the following diagram, Figure 3.2, which he computed for an insulation level of 5.5 kWh/m$^2$ day and based on life-cycle costs.

Based on Figure 3.2, diesel will always be less costly than PV for anything above the smallest of loads i.e. 2-3kWh/day, assuming the current SHS cost of around US$10/Wp. This presents the market niche for SHS. When one is dealing with the typical rural settings; dispersed population and low energy consumption[12], SHS often prove to be the most cost-effective solution.

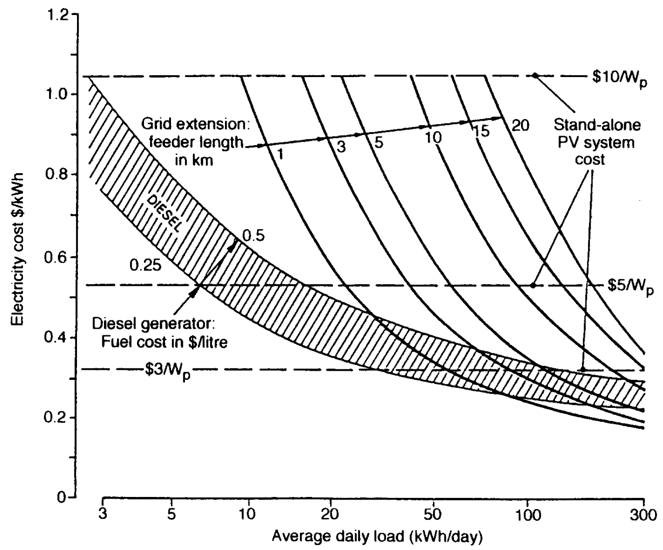


Figure 3.2 *Source: Markvart, 1994*

Furthermore, project developers have argued that SHS displaces kerosene lamps, candles, and dry cell batteries cost-effectively, reducing the monthly energy expenditure currently borne by households (generally between US$ 4-US$ 10). SHS is also attractive for households which currently use car batteries for electricity and must frequently travel to have them recharged, at a cost.

From a commercial point of view, cost calculations based on Markvart's diagram (or similar) should not in any way deter wider marketing of SHS. Lasschuit (1999) reports interesting observations about Swaziland. In this survey, most SHS were found in areas already supplied by the grid[13]. A similar story is reported by Acker et al (1996) in Kenya, who noted that a substantial number of SHS in their survey was located within 5 km from the grid. They conceded however, that their sample might have been biased. Nevertheless, the point is, the market opportunities of SHS are not simply restricted by the (in-) availability of the grid. This may further mean that, although SHS have restrictions in use, i.e. small loads like lighting, small TVs and radios, it is also an attractive product. So the SHS market does not only apply to remote households, but also in peri-urban settlements, where grid reticulation may be weak and the quality of service provided by power utilities low, as is the case in many developing countries.

So, who is buying SHS? Ciscar (1997) reports that out of the 300-400 million households in developing countries, who have no access to electricity, 10% can afford SHS, i.e. 30-40 million households. This percentage is expected to rise to 25-50% if appropriate financing and delivery mechanisms were established. He and many other authors are in the opinion that the SHS market is elastic in response to credit, meaning that the demand for SHS is higher when credit is available, and the more flexible the credit structure, the progressively higher the demand.

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12 A 50Wp SHS can provide between 4 and 6 kWh/month (typical), which sufficient power lighting loads and other small DC appliances.

13 The author of this paper was involved in this survey.

Commentators often paint some kind of pyramidal picture as far as the market is concerned. About 5-10% of non-urban non-electrified households are believed to be able to afford a system for cash. Availing credit would increase this figure by another 10-20% of households to this. A leasing arrangement would further add to this some 20-35% of the households.

Some authors even dare to say that SHS actually reaches even the poorer of the poor. Even without wrangling with definitions, these statements are extreme and almost always untrue. Certainly not when the World Bank estimates that about 1.3 billion people live on $1.50 a day or less (in 1997 US prices) (World Bank, 1998/99).

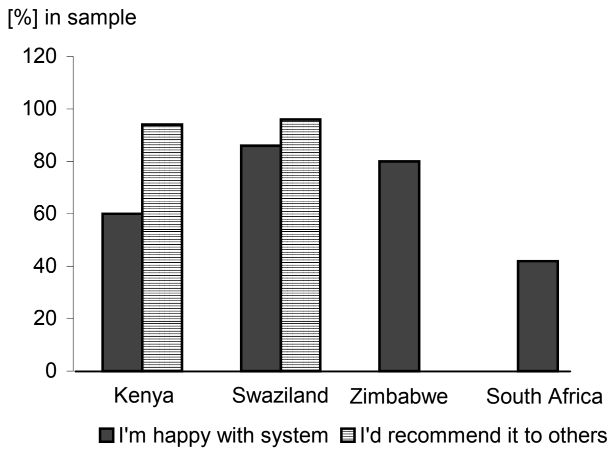


Figure 3.3 *Satisfaction among SHS owners. Zimbabwe: Mainicaland, South Africa: Free State Province. Source: Lasschuit, van der Plas, Cloin, Hochmuth*

Figure 3.3 shows the perception of SHS users about their systems in selected countries. In general, from all the samples, owners are happy with their systems. In Kenya and Swaziland, 94% and 95% respectively of SHS owners would even recommend it to their friends. The South African case, in the Free State, is one where systems were heavily subsidised[14].

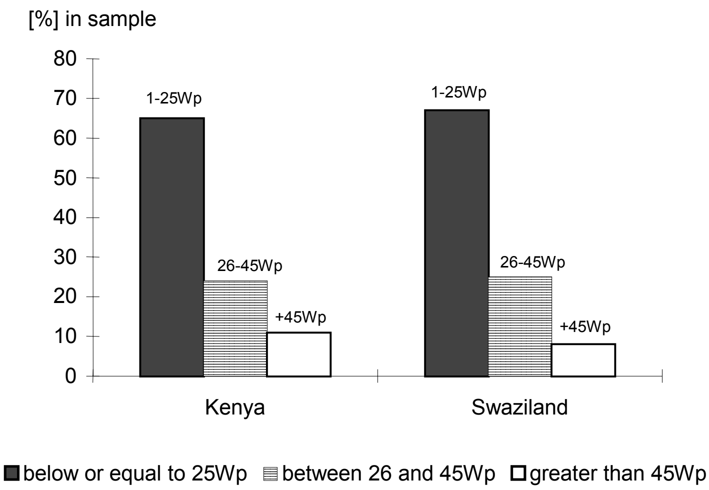


Figure 3.4 *Systems installed by capacity. Source: van der Plas, Lasschuit*

[14] This is not a conjecture to indicate that the low level of happiness was due to the heavy subsidies, although it is an interesting coincidence.

### 3.2.1 Modularity

Figure 3.4 shows that the smaller module range, i.e. less the 26Wp, had the greatest share of the market in Kenya and in Swaziland. Reports from other countries of the developing world give similar indications. The majority of these are the amorphous modules, less than 15Wp, which are normally sold over the counter. Often end-users buy the 12-14Wp amorphous modules to add onto their car battery system, building up the system as finances and opportunities arise (van der Plas, 1997). Sometimes these modules are sold as part of a 'do-it-yourself' package, which also contains (some) BOS and, as the name connotes, the consumer can install by himself.

This highly modular configuration has several advantages, the main one perhaps being the fact that the consumer can pay in cash and so there is no need for any formal consumer financing. The price of a 12Wp amorphous module is around US$ 60-100, which is affordable to a significant number of low income end-users. Connected directly to a (car) battery, this system is simple and affordable. Notwithstanding the weaknesses of this configuration, it is quite a leap from the consumer's point of view, since no (or much fewer) trips to the charging station are necessary anymore and the associated costs of charging (about US$ 1) are thus avoided. From another perspective however, there are also disadvantages to these 'over the counter' sales. These systems are prone to in-optimal use and incorrect installation. A complete system offers the advantage of being well designed for the expected energy requirements, and the installation is of a better quality since it is often done by the retailer. The battery life is also longer, owing to the battery charge regulator protection. It is also a fact that amorphous modules are less efficient compared to crystalline based modules and are susceptible to slight degradation under prolonged exposure to sunlight[15]. Earlier amorphous modules also had poor quality aluminium framing, making the active material susceptible to rapid degradation. This weakness prompted a general impression that amorphous modules are 'bad'[16]. However, as much as bad products exist at the market, there are also good ones, which is the case for crystalline modules. This is not merely arguing a case for amorphous modules, but rather an emphasis on the need to be open-minded and consider amorphous modules especially in smaller systems.

Perhaps it is fitting at this moment to also comment on batteries. So-called solar batteries are already being produced and commercialised in many countries, but still a large number of solar home systems still utilises classical car-type batteries. One can envisage that it is highly likely that, even if the initial installation is made with a solar battery, the replacement in three or four years' time would be a car type battery. The car type batteries are cheaper and are easily available in most countries (if not all) while solar batteries often have to be imported. In many developing countries, they are even manufactured locally. Local production is not only good for economic reasons but it also presents the best possibility to recycle old batteries, thus evading environmental damage.

The main disadvantage of car type batteries is the fact that they offer a smaller usable capacity (say 30%) compared to that of solar batteries (say 70%) and have relatively shorter lifetimes. However, car batteries have been used in some large dissemination projects, for example in the Mexican PV electrification programme (Annex A.1). Huacuz et al (1995) reports on a survey involving car type batteries[17] in SHS in different states of Mexico. Each battery in the sample was inspected on its physical and operational conditions. The survey findings were extremely positive, showing most batteries to be in good condition and performing reasonably well.

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15 Many suppliers now give a five year warranty to amorphous modules. Even after some light degradation the module is expected to still provide, at operating conditions, the rated power minus some specified value (5-10%).

16 For this reason, many (donor) funded projects have sidelined the use of amorphous modules.

17 Their survey included a total of 555 batteries. This is one of the largest SHS battery surveys recorded. All batteries in the sample were less than three years old. The systems had charge controllers.

In short, the obvious advantages of solar batteries being granted, car batteries should not be ruled out. Depending on country to country situations, the net advantages of the use of car batteries might exceed those of solar batteries and so an investigation on such facts should be made.

### 3.2.2 Pre-electrification

The phrase pre-electrification wears different hats. On the one hand, it may simply mean PV electrification implemented as an interim measure, in places unlikely to be grid serviced in the near future. In this sense, there is certainly a market for SHS as deliberated above. On the other hand, sometimes this phrase is also associated with a belief that providing an SHS acquaints households with modern electricity usage, making the transition to grid electricity smoother if and when it arrives. There might be some truth to this but there is still a lack of plausible empirical evidence to support this idea. However, it is a fact that when a system household eventually gets grid connected, only the radio and TV, which are in the strictest sense not part of the system, are likely to be usable. The whole system, including the DC lights, is then rendered almost obsolete, at best being used as a backup to the grid supply. This implies that owning a system today does not help one to 'build up' on appliances as such.

# 4. INSTITUTIONAL ARRANGEMENTS

## 4.1 Introduction

This topic, when discussed, is usually associated with four processes; support of the financial mechanism(s), product delivery mechanism(s), training and after sales service. For this reason, it becomes difficult to disentangle financing issues and institutional issues. Rather than trying to do this, this section will simply outline general experiences with this topic and make reference to the three cases with various forms of institutional arrangements in Annex A.

Three cases of SHS implementation with different institutional arrangements are described in Annex A. The Mexican programme is a wholly endogenous process, with no foreign assistance and high involvement of the electricity utility. The Kiribati experience, which is commercially driven, is based on the leasing concept. Lastly, the Senegal project, a government project with donor financing, selling systems on mainly credit basis.

In general, it can be found from literature that sustainable programmes seek to ensure the programme's continuation by natural mechanisms, i.e. the actors in charge of their real economic role, outside the project. Therefore attempts are made to remove any perceived constraints preventing this natural development.

There is also no 'one-size-fits-all' suitable for every application in every country, but lessons learned from other countries can be extremely useful in tailor making and fine tuning of institutional models for each specific case. In fact, the energy sector and socio-economic situations of developing countries is strikingly similar.

## 4.2 The role of public authorities

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

On the other hand, over-enthusiasm for SHS can lead to ill-planned projects, yielding disastrous results. The best role of public authorities seems to be that of market catalysts without excessive interventionism. The Mexican example shows how the levels of government were only involved as stimulants to the programme, while leaving programme management to implementation agents (Huacuz, 1998).

Public authorities can also play an important role in removing or reforming fiscal and policy regimes, which are in disfavour of alternatives like SHS. In the Senegal case, authorities waived duties on solar energy equipment, making systems more affordable and promoting the solar business (Sokona et al, 1994).

## 4.3 Utilities

The attitude of utilities towards alternative energy, SHS for example, is changing for the better. The Mexican example showed a case of active involvement of the utility. Although the utility is not involved in funding the project, it is responsible for quality assurance and standards issues, which is quite an achievement. The South African Utility, ESKOM, has been involved with active research and implementation of alternative energies, including solar, since 1991 (Shell, 1998). It has also recently launched an ambitious electrification project, in conjunction with the renewables division of Shell, which seeks to disseminate 50,000 systems on a leasing basis.

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

Another possibility is to establish a 'Solar Electric Utility', which basically acts like grid electricity utilities. This utility sells electricity and retains ownership of the SHS. The SEC in Kiribati (Annex A.2) is one example. The principle advantage of utility based service is that it can provide electricity at low cost to the consumer. It also transfers the maintenance responsibility from the user to trained technicians, thus guaranteeing proper care of systems. However, it requires a capable technical and administration infrastructure in the area to be served and often needs access to long term credit at modest rates. The Kiribati experience also highlights the importance of establishing a 'critical mass' of demand in the service territory, to improve economic viability (this requirement is also echoed by Kalumiana et al, 1998 and Aguilera et al, 1996).

Other examples include CRE, perhaps the largest electric co-operative in the world, which has the electrical concession for the state of Santa Cruz in Bolivia. CRE has set up a 'solar electric utility' within the co-operative structure. CRE has developed a tariff collection and maintenance system, and has over 1000 customers. Another distribution utility in Bolivia, ELFEC, considered setting up a similar electrification unit to CRE, but later rejected it based on financial analysis (Smith, 1998).

## 4.4 Co-operatives and Associations

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

Care should be taken to assess the capabilities of their officers, and provide training where necessary. In a successful project in Honduras, Enersol worked with an existing coffee co-operative, COMARCA, after the former had conducted training (CADDET, 1995). However, this approach can lead to prejudice towards communities with a strong organisation, leaving out potential customers or deserving recipients in other communities. In cases where it is not possible to use existing associations, new organisations can be set up. In the Pacific Islands, the Tuvalu Solar Electric Co-operative Society was established after failed attempts to involve the utility (Cabraal, 1996).

Similarly, NGOs may be very effective in programmes since they are normally familiar with the communities they serve on more than just a monetary basis. NGOs have the further advantage of having established extension networks, which could be used for training and information services. Stone et al (1996) reports another institutional possibility; religious missions. The US Renewable Energy Laboratory (NREL) co-financed a project with the Indian government in West Bengal. The Ramakrishna Mission reliably managed the project, which is now completed. Stone reports about the Mission as a project partner, 'The Ramakrishna Mission has been perfect in this respect'.

## 4.5 Maintenance and after sales services

In the case where the user owns the SHS, he should also be trained to give adequate maintenance. Training will be discussed in detail in section 5.5. However, support from the installing organisation is crucial. In Kiribati, this was one of the lessons learned after initial SHS projects flopped (Akura, 1996). With their utility concept, preventive and damage repair maintenance structure was properly planned and effected. The maintenance system must be easily accessible and have sufficiently trained personnel.

Since SHS uses DC components, which may be difficult to source on the part of the user, the after sales structure should ensure adequate stocking. It is best when the installing agent is also responsible for stocking and maintenance. The Senegalese case showed an example of where associations involved with the dissemination process also had the responsibility for stocking essential spares.

# 5. INFORMATION AND COMMUNICATION

## 5.1 Introduction

Knowledge is like light; it illuminates every part of our lives, dispelling uncertainties and inducing attitude change. In order to acquire this, we need information which must be communicated to us. All actors in society, be they public authorities, financial institutions, community organisations and communities, need information to make decisions in their everyday lives. In fact, developing countries - and poor people - differ from the rich not only because they have less capital but also because they have less knowledge (World Bank 98/99).

Looking carefully, one can also see that most of the problems encountered in SHS programs, are consequences of information problems. To quote Hoogenstrijd (1995), 'In some cases decision makers, through lack of knowledge, misunderstanding and from being biased against alternative energy technologies, have held up the wider utilisation of alternative energy technologies'. Households also need information about alternatives and their attributes, information to give them a chance to re-evaluate their beliefs and information on maintenance of their systems.

The subject of information and its communication is broad and beyond the scope of this paper, and here we only discuss in brief some of the essential points of relevance. Many -almost all-project reports reviewed incorporated a component of awareness raising, showing that there is considerable importance attached to this (inter alia*,* Sokona et al, 1994, Huacuz, 1998, Diniz et al, 1998). Although many attach financial and other details in appendices, similar details on information dissemination activities could not be found. For this reason, there seems to be some air of ambiguity and uncertainty in literature surrounding this topic, regarding the contents and often also the target of the communication efforts.

Communicating with the public has four basic goals: to inform, to educate, to handle (potential) conflicts and to enhance decision making (Kant et al*,* 1995). Often these objectives are intertwined and may involve multiple actors and processes. Below we discuss some important considerations on meeting these general goals with different actors.

## 5.2 Informing the decision maker

It should be obvious that political and high level support is important for project thrust and sustainability. Many project developers have recognised this fact and involved political leaders and financial institutions. However, informing or educating these high level actors should be carefully planned and not just sporadic or ad hoc. The government authority needs timely and reliable information to enhance his decision making capability. The authorities have the responsibility to create and maintain a conducive environment for SHS development through policy and fiscal means as already described. However, they often have other commitments and so their timely and regular information is crucial in attracting their support and should not be taken for granted as has often been the case.

## 5.3 Informing the (potential) end-user

Literature encouragingly mentions the end-user more than any other actor in SHS projects and ventures. Many reporters mention demonstrations, for example in Sri Lanka, Gunaratne (1995), cites campaigns on vans that travelled from village to village. CADDETT (1995) reports that a BAHNCAFE Foundation in Honduras installed a demonstration SHS in front of a store on a major rural road. It attracted so much attention that the store owner compiled a list of 50 interested purchasers in no time. Some countries even have dedicated demonstration centres, the Silverton Renewable Energy Demonstration Centre (REDC)[18] in South Africa being one of the many examples. Commonly these are government supported centres and are not financially self-sustainable.

A great deal of information dissemination on radio, TV and other public media targeted at the end user is reported in literature both expressly and implied (Gunaratne, 1995, Foley, 1995, p. 63). Figures 5.1 and 5.2 show two cases where such campaigns were assessed in Kenya and Swaziland. The most notable feature in both cases is the importance of word-of-mouth adverts. Respondents in both surveys, first found out about SHS from their friends, relatives and neighbours. A similar story is reported by Bacon (1998) on Zimbabwe. This brings up two important points.

Firstly, a working system is the best advert. No matter how much effort is put into other information media, if people cannot see that a system works, the efforts will be undermined. Rural communities are cautious about new exotic equipment, information from their friends and neighbours is important to reassure them and this can only be achieved by a system that works.

Secondly, rural people are very oral. Commonly with low literacy levels, a convenient way to express their feelings, is by talking. Rumours and information are passed by word of mouth as women collect water from common water taps, as men play games, in community meetings and so on. Information is assimilated in such informal networks, often spiced up, opinions formed and further disseminated. Social networks like these are very strong and project developers should take them seriously and exploit them where possible.

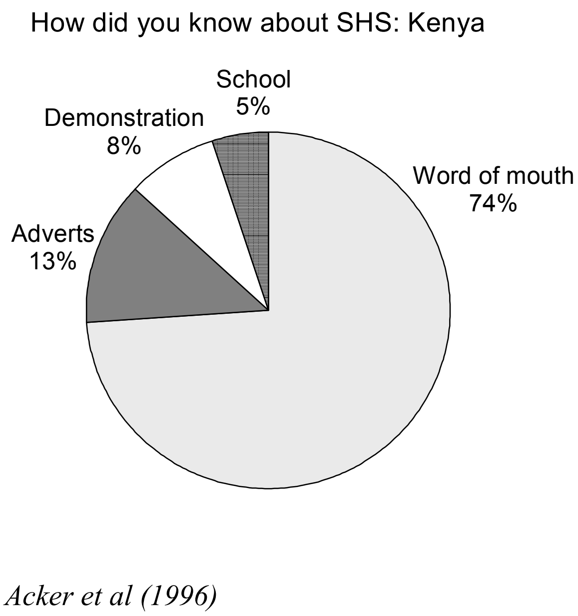


Figure 5.1 *Adapted from Acker et al (1996)*

[18] Established by the Department of Mineral and Energy Affairs, South Africa.

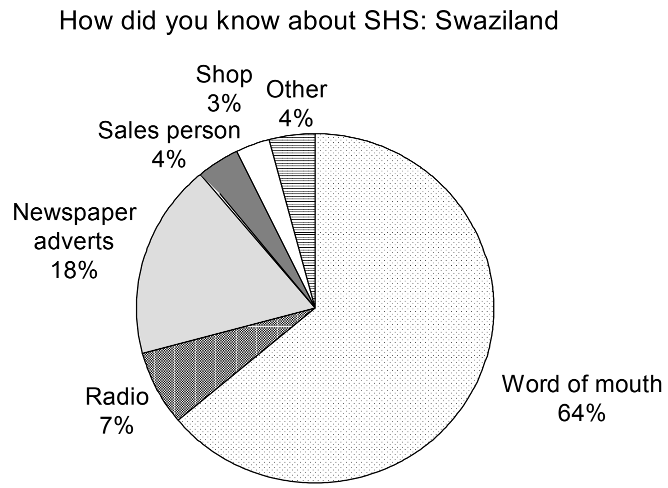


Figure 5.2 *Adapted from Lasschuit (1999)*

One important art which information disseminators should learn is listening. Communication involves both talking and listening. This is a simple fact, which is regretfully overlooked. Officers of aid agencies, governments, and NGOs are often overwhelmed with the fact that people from rural areas (the poor in particular) do not have access to so much knowledge. Therefore, in their eagerness to inform and educate these people, they forget that their listeners have a great deal of knowledge, which they themselves do not have. People know their own needs, priorities and aspirations better than anyone and this information is not immediately obvious to outsiders.

Most rural households, generally over 60%, own a radio (Cloin (1998) reports 70% for Manicaland, Zimbabwe), therefore radio advertisement reaches a good share of the rural households. Other media, like newspapers and TV, should not be ignored either. Many owners of SHS are literate people, therefore newspaper adverts can be very effective. It is important that information dissemination activities be targeted. Only when the specific target group(s) is known can an appropriate medium (or media) be chosen. Moreover, targeting will help to ensure that, at the end of the day, whichever medium is chosen, the message carried is clear, well structured and attention calling.

## 5.4 Evaluating efforts

Again in literature, it could not be established whether information dissemination activities were evaluated, although this is not to mean they were not. Evaluation is a structured procedure designed to produce and analyse data that enables judgements to be made, allowing effective control or improvement of a process. Evaluation involves formulating questions, selecting sampling procedures, collecting and analysing results and finally making judgements on the value of the activity.

Evaluation is best done as an independent activity along and after the project. There are obviously costs associated with this, but this is an important exercise, especially in large projects. There are other opportunities for conducting an evaluation, not necessarily independently. For example, contracts involving SHS purchases can include specific questions regarding the way the customer received information on SHS and perhaps also solicit his opinions on this[19].

[19] This approach is already being used by Solar International, Swaziland.

## 5.5 Training

Reporters are in agreement that training is essential as a communication tool, for widespread use of renewable energy technologies. Training should span all actors in programmes, well up from government decision makers, financial institutions, utilities, trainers, to private sector and end-users. The magnitude and scope of training for each of the actors will vary from project to project, but it still is important that all be involved.

Training has different meanings to different people. In this paper the description of Mrohs (1998) is adopted, an so by training we mean 'the process of attainment of minimum levels of knowledge and skills, so specific tasks, appropriate to achieving desired and agreed upon goals, can be performed to measurable standards'. This entails careful planning and ensuring that the trainer(s) has at least an idea of adult learning theory. Such detailed planning also ensures that the correct trainees are selected for the correct programme. Additionally, training should have an emphasis on the learner 'doing'. In this sense, training is not synonymous with informative or motivational presentations and demonstrations.

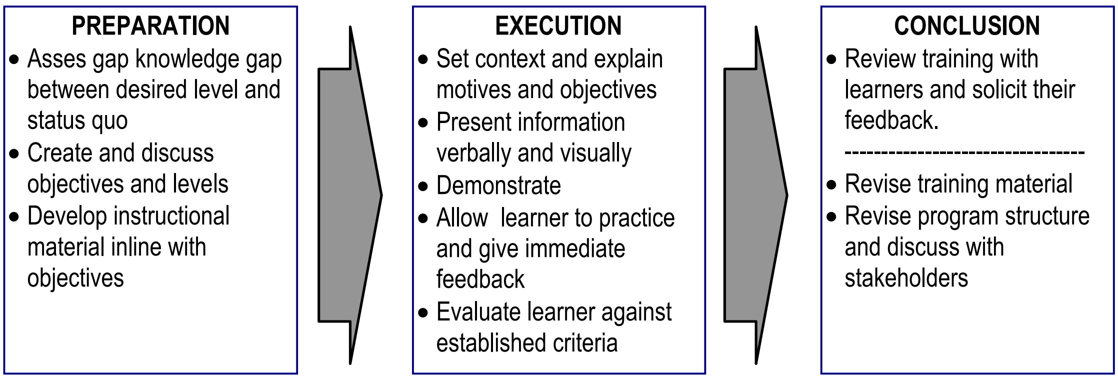


Figure 5.3 *Typical events in training*

Figure 5.3 shows a set of typical events in training. Looking at this sequence, one can see that training should be implemented in a framework seeking to achieve a long term goal, and not just an impromptu need. This may look very complicated and a great deal 'too much theory, hardly applicable on ground', yet it is not. In fact this scheme can be applied from user training, lasting tens of minutes, to high level engineer or project implementation team training lasting days and weeks, albeit with modifications depending on resource constraints. This also implies that even the installer should be trained to train the user.

Again, depending on country situation and resources available, training can also be provided by an existing accredited institution. This, when possible, has several advantages. First, institutions already have training facilities and personnel who are trained to train. Secondly, it ensures equal training of groups of trainees, from different regions and experiences, under identical conditions and with the best time effectiveness.

## 5.6 Training the user

There is today no need to argue on the importance of user training, as actors in SHS field are in full concordance. User training covers the following aspects:

- basic knowledge about how the system works,
- load management,
- maintenance,
- explicit 'do's' and 'don'ts',
- knowing when to call for advanced technical assistance.

Experience has also shown that providing a user manual is essential. Again, the manual should be well thought of, well laid out, of reasonable length, contain as little wording as possible, but rather more pictures and diagrams. It is often not necessary to produce glossy full colour manuals.

Although installers, who are usually technicians of retailers, do not have the whole day to train a single user, adequate time should be given to this. Also important here is the question of who is being trained. Purchasers of SHS are usually the heads of households, who are commonly men. But it is common for men to migrate to urban centres for employment, coming home during weekends or holidays. This leaves women being responsible for general home management, including the system. This fact therefore warrants that attempts be made to ensure that the household women take part in the user training. It is also normal for people dwelling in urban centres to purchase a system for their relatives at home. So again care should be taken to ensure that the actual users of the system, and not just the purchaser, are given the user training. Grown up children, for example those already attending high school, should not be undermined. If responsible, they can be important in supporting their parents, who are sometimes not so eager to take necessary precautions or measures. This would ensure that the system is taken care of even in the purchaser's absence.

End-user training is not always easy however, in particular where literacy levels are very low. Huacuz et al (1995) records a very interesting case to illustrate this point, where trying to simplify concepts may result in misconceptions. They report: 'For instance, the sentence 'batteries need water' is frequently associated with the statements 'plants need water', 'animals need water', 'humans need water', so that users may end up adding water to their batteries daily'. Indeed their study found that low electrolyte density was the most prevalent battery anomaly.

## 5.7 Building endogenous capacity

The discussion above emphasised on user training, and to a lesser extent other training levels, beginners, intermediate and non-technical training given to technicians, private sector, financiers, implementation teams and so on. This, as discussed, is essential and fitting.

There is however another calling. The promotion of PV in developing countries is also to be understood as an issue of technology transfer. As such, there is need to build endogenous capabilities in institutions of higher learning. Endogenous capability will be hardly built if the capacity to generate knowledge is not established in developing countries. Indeed generating knowledge is expensive, that is why much of it is generated in industrialised societies. But institutes of higher learning can take advantage of knowledge already generated oversees (a process commonly called 'leapfrogging') and perhaps generate their own through joint ventures with international institutes. There are of course constraints in this, but opportunities should be actively sought and seized.

Basic and applied research in PV is not only limited to technical aspects, but also to social and economic aspects. This fact broadens the possibilities to include PV related in research and education in universities, colleges and technical institutes[20]. Some countries including India, South Africa and Mozambique are already at various stages of this process of endogenous capacity building and strengthening centres of excellence in PV (inter alia Cuamba, 1994). It is also of great importance that research be in partnership with industry, as in the case of Mexico (see Annex A.1) and that research findings and updates are published regularly and in media easily accessible. It is amazing to know how much research is going on in institutions, which the private sector and general public have absolutely no clue about.

At a lower, and yet important level, this endogenous capacity building can be stimulated at primary and high school levels. There are ample opportunities to do this including competitions and debates on renewable energies, with prizes as incentives. Many countries also have science projects for school children, which also would be an opportunity for teachers and renewable energy associations to seize.

## 5.8 The Internet and other information networks

SHS project developers and entrepreneurs should take full advantage of the communication revolution, the Internet in particular. Many developing countries now have access to the Internet and sharing information via computers is increasingly gaining pace. A whole wealth of information is now available on SHS, PV in general, financing and projects going on around the world. Therefore, there are many opportunities for doing new things, and doing old things differently.

Furthermore, there are other information networks on renewable energy, albeit with varying efficiencies and response times, which still could be used for accessing information conveniently and quicker. Annex A.1 gives some of the numerous networks with useful resources.

[20] Renewable Energy Education and Training is one of the activities which was considered highest priority in the World Solar Summit Process. The Global Renewable Energy Education and Training programme is prepared by UNESCO.

# 6. STANDARDS AND QUALITY ASSURANCE

## 6.1 Introduction

Again in literature reporters show unanimity in the call for standards and quality assurance frameworks in terrestrial PV applications in general, and SHS in particular (e.g. Cabraal, 1996, Foley, 1995, Diniz, 1998). This is primarily intended to protect the end-user and PV industry from incompetent and sometimes unscrupulous suppliers or installers. Deliberate undersizing, poor quality components and poor installations often lead to poor or unsafe system operation and sometimes complete failure. Further lack of consistency of quality in PV products could threaten the credibility of both the industry and the technology.

Standards are, in a generic sense, documented agreements embodying technical specifications or other precise criteria to be used uniformly as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are good for their purpose.

The IEC/ISO[21] Guide 2 defines a standard as, ‘a document, established by consensus and approved by a recognised body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. An international standard is a standard adopted by an international standards organisation and made available to the public.’

The word ‘consensus’ emphasises the need for a standard to represent a common ground for all stakeholders including government, manufacturers, retailers, end-users and general interest groups. The need for international standards arises from the fact that non-harmonised standards and norms for similar technologies in different countries or regions present so-called ‘technical barriers to trade’ (ISO, 1998). In this sense, whether local or international, standards should not be meant to fight imports or to elbow out competitors, but rather to provide a basis for quality assurance procedures, and to enhance market competitiveness and export capability.

## 6.2 Applying standards

Literature often recommends that governments ‘enforce’ standards, sometimes implying with legal instruments. This is rather too stalwart, and may not be necessary. Governments and other agencies may require a supplier or retailer to comply to certain acceptable standards for procurement, instalment, etc. in its own programmes. But retailers and suppliers in general do not need to be forced to comply to standards, but may be motivated or encouraged to do so. For instance, suppliers, retailers or other interested groups may form associations, where they can discuss issues including standards and so create a self-monitoring environment without excessive government interventionism. In this scenario, the role of the government would be to support such associations and to communicate to the public information about approved products, recommended marks or seals, quality brand names and so on. In short, it is possible to stimulate voluntary adherence to standards. Another important role that governments can play is the promotion of the issuance of guarantees by suppliers or retailers on components sold. This is an important indication to the consumer, reassuring him that the product is of good repute and quality.

[21] The IEC and ISO are international standards organisations based in Geneva, Switzerland. The IEC is responsible for standards related to electrical, electronic and related technologies.

## 6.3 The present situation

Table 6.1 shows some features of components that are presently not (internationally) standardised in SHS. The main issues have to do with electrical and operational safety requirements, performance and compatibility with operational surroundings. The charge regulator presents the most complex challenges.

Table 6.1 *Features of components presently not standardised in SHS*

| Component | Some features that could be standardised |
|---|---|
| Battery | • the amount and density of the electrolyte<br>• the maximum depth of discharge<br>• the period of autonomy<br>• the battery cycle life<br>• the allowed self-discharge rate |
| Charge regulator | • warning indicators<br>• the (voltage) levels of 'load-disconnect' and 'load-reconnect'<br>• the end-of-charge and reposition voltages<br>• the switching accuracy<br>• tolerances<br>• allowed voltage drop between battery and regulator<br>• type and quality of the casing<br>• electromagnetic compatibility |
| Support structure | • material durability, particularly with respect to outdoor exposure; corrosion resistance<br>• type of material used, e.g. aluminium, stainless steel, etc.<br>• resistance against wind<br>• tilt angle to optimise energy collection |
| Lights | • ballast performance (for fluorescent lamps)<br>• electromagnetic compatibility<br>• luminous yield of lamp assembly |
| Wiring | • allowed voltage drops<br>• minimum acceptable cross-section<br>• resistance to outdoor conditions<br>• quality of cable terminals<br>• protection features of wiring harness, including fuse ratings<br>• type and quality of switches |
| Energy requirements | • system sizing |
| Installation | • ease of access to components<br>• bolts and screw sizes<br>• norms for mounting cables, module, lamps, charge regulator etc |
| Safety | • battery siting and ventilation<br>• short circuit and current surge protection<br>• lighting protection<br>• electrical and operational safety |

PV modules are the most reliable component of SHS since they are highly standardised and have internationally validated certification procedures.

For example, after four years of crystalline silicon module testing to specification CEC503/IEC 1215 at the European Commission Joint Research Centre in Italy, Bishop et al (1994) reports:

- 64% of module types, out of 74 types for which testing had been conducted, achieved qualification at the first attempt,
- 27% exhibited major defects but passed subsequent repeat tests,
- and only 9% exhibited major defects during repeated tests and failed to achieve qualification.

This example shows the high success rate of modules from different manufacturers. The 9% shows though that there are some substandard modules, which by the way are very likely to be shipped to developing countries, or are being manufactured there. Not until recently have standards for the balance of system been proposed.

## 6.4 Current actors

Several international, regional and national organisations have already developed (or are in the process of) standards for PV systems and/or components. The International Electrotechnical Commission (IEC), the American Society for Testing and Materials (ASTM), the Institute for Electrical and Electronics Engineers (IEEE), and the Underwriters Laboratory Inc. (UL) all have standards for components and/or systems. The IEC in particular has specific TC 82 series (some are still being developed) of standards, covering modules, batteries, BOS and certification procedures.

Two important recent developments in international standardisation worth mentioning here are the Global Approval Programme for Photovoltaics (PV GAP) and the Thermie B: SUP-995-96, EC-DGXVII: Universal Technical Standard for Solar Home Systems.

### 6.4.1 PV GAP

PV GAP is a global, PV industry-driven organisation that aims at promoting and maintaining a set of qualification standards and certification procedures for the performance of PV products and systems, born in 1997. PV GAP is housed under the IEC headquarters in Geneva and works in collaboration with the IEC. PV GAP has an approval system to qualify testing laboratories world-wide, both independent labs and labs in PV companies.

PV GAP has already developed a ‘PV Quality Mark’ for PV components and ‘PV Quality Seal’ for PV systems, so that manufacturers, distributors and installers which are approved under the PV GAP system can be licensed to utilise and display the Seal or Mark. In this way customers will be able to distinguish between products of known quality from those of unknown quality.

PV Gap further reports that there is a large interest in having a standard for outdoor testing of PV systems, which is deemed to be important for SHS in developing countries. An interim test method was already completed by the National Renewable Energy Laboratory (NREL).

### 6.4.2 Universal SHS Technical Standards

There is now also a proposed new standard which has been developed for small direct current SHS, with the leadership of the Instituto de EnergPa Solar, Spain, under the framework of the EC-DGXVII, 1998. The proper reference of this work is ‘Universal Technical Standard for Solar Home Systems’. In preparation of this standard, the authors examined different existent technical standards world-wide and also consulted the authors of these standards. In parallel to this, they also interviewed persons involved in PV rural electrification programmes regarding the usefulness and applicability of universal standards for SHS.

At this point, it seems prudent for countries without SHS standards at the moment, to review the suggestions in this proposed standard if and when development of a local standard is deemed necessary. The usefulness of this standard hinges on how much acceptance it will receive among actors in the PV industry, especially in developing countries. There is also a need to publicise it rather actively. Bearing in mind the advantages of universality of standards, as briefly described above, it would seem sensible to support such initiatives.

# 7. CONCLUSIONS

Five topics have been deliberated both with the views that could be found in literature and with objective arguments. The topic of finance is ranking highest at the moment. It has been repeatedly emphasised that the SHS investment costs are too high for the normal consumer, who would be able to afford a system if these costs were divided into acceptable terms. Nowadays, considerable experience has been gained in setting up and maintaining credit schemes. The leasing or utility concept is relatively new, but promises a better reach to the relatively modest and better services as well. However, low tariffs charged in many schemes at present cannot achieve full cost recovery.

Direct interventions in energy markets have also been criticised. Rather, judicious indirect subsidies through fiscal instruments, for example tax and duty waivers and policy interventions has shown to pay-off handsomely. Further, support from governments and other financiers is still required in addressing remaining barriers inhibiting market development. Import and sales duties on SHS equipment still exist in many developing countries. There is a need to lower these tariffs or eliminate them entirely, as has been done in some countries already.

Additionally, it has also been argued that the issue of financing SHS is intertwined with that of setting in place prudent and innovative institutional arrangements. Maintaining the finance delivery process requires capable institutional links. Using and strengthening existing institutions as much as is feasible has been favoured as compared to setting up new structures. It is also important to set an efficient (decentralised) maintenance scheme, with adequately trained technicians and sufficient replacement stock.

All actors in SHS are in need of some kind of information without which programmes and ventures cannot function properly. Governments and other high level decision makers require reliable and timely information to enhance their decision making process. The private sector has information needs regarding markets and products. Other institutional intermediaries like NGOs and co-operatives need to be informed in order to properly equip them to handle SHS programmes. The end-user also has also information needs, especially about attributes of different SHS products. When customers are inadequately informed their choices may not reflect their actual preferences. Training has also been favoured. Again all the actors have some training needs. Past efforts have concentrated on end-user and intermediate training (e.g. technician) needs. While this is commendable, endogenous capacity building through specialised institutions and universities is also vital to support the technology transfer process.

There is a real need for standards and technical norms. A lot has been done on this already, but harmonising these standards on an international level will benefit the PV market and possibly eliminate the need to establish dedicated national testing centres. It is not recommended to rigorously enforce standards but rather that, in projects or programmes, suppliers be required to comply to (modified) suitable standards in procurement processes. PV GAP standards and the Thermie B SUP-995-96 are examples from which project implementers can take advantage.

Finally, project developers should take advantage of all the experience on best practices that has been gained and documented to this stage. Nowadays there is no need to repeat errors of the past, there is ample opportunity to plan and implement successful SHS projects.

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# ANNEX A SOME CASES OF SHS PROJECTS

## A.1 The Mexican Government PV rural electrification project - to 1996

Table A.1 below summarises the roles and responsibilities of different actors in this programme.

Table A.1 *The roles and responsibilities of different actors in this programme*[1]

| | Planning | Project promotion | Request for funds | Project formulation | Funding | Project implementation | Quality assurance | Training | After-sales service |
|---|---|---|---|---|---|---|---|---|---|
| Levels of government | × | | | | × | | | | |
| Implementing agents | × | × | × | × | | × | | | |
| Electric utility (CFE) | × | × | | × | | | × | | |
| Research Institute (IIE) | | | | × | | | × | × | |
| PV Industry | | | | | | × | | × | × |
| Community (users) | × | × | × | × | × | × | | | |

[1]Adapted from Huacuz (1998)

Two types of PV rural electrification are in practice in Mexico: government financed and normal business, where retailers sell directly to consumers on commercial terms. The commercial activity alone has been able to sell around 20,000 SHS. Government programmes have to date electrified over 1250 rural communities by SHS and other stand-alone PV systems.

There are five main actors in the government programme, viz.:

a) *The government*
Three levels of government exist: federal, state and municipal. They are all involved in funding and overall programme funding and supervision.

b) *The utility*
The electricity utility Comisi∴n Federal de Electricida (CFE), oversees quality issues of every project. With partnership from the Electrical Research Institute of Mexico (IIE), the utility is also responsible for the development and review of technical parameters including design guidelines. For this purpose, the utility engineers were given extensive training. The IIE has developed strict technical specifications regarding quality, installation and safety of systems. Final payment to the supplier is made only when the utility has certified that installation meets these standards.

c) *Implementation agents*
Different government organisations, at federal and state levels, are involved in project planning and management. NGOs also play a role in these activities.

d) *PV industry*
PV industry supplies equipment, installs systems, and is charged with after-sales services. Hired by public bids, they are also obliged by contract to give basic operation and maintenance training to users.

e) *Communities*
The community is responsible for creating a fund raising structure for SHS maintenance and capacity expansion.

The events leading to project success are as follows. The community requests funds from government. With the help of an implementation agent, the government analyses requests, and when approved, releases funds to purchase equipment from industry. Industry installs systems and formally hands them over to communities. The systems are therefore the responsibility of the community assembly. A typical cost of an installed SHS is around US$ 12/Wp. It is estimated that an SHS will require O&M costs of the order of US$ 600 in its entire lifetime. Communities typically have community fund, which is not only dedicated to SHS, but also to other community projects like construction of schools, water schemes and so on. However, for SHS projects, a dedicated Electrification Committee oversees funds. Individual contributions to the community fund, fund management and penalties for defaulters are set by consensus of the community members.

The Mexican programme attributes its success to concerted efforts, harmonising government agencies, the PV industry, the electric utility, the research institute and traditional community structures.

## A.2 Solar Home Systems in Kiribati

Although SHS in Kiribati dates back to the late seventies, the first national involvement did not begin until 1984, when the Solar Energy Company of Kiribati (SEC) was founded. From 1986, the government had major shareholdings of the company and rest by the Bank of Kiribati. Since then, the Board of Directors is selected by the government, by virtue of majority shareholdership. The SEC had very rough experiences from this time, and faced serious problems regarding customer financing, poor quality installations, lack of trained personnel and inadequate stocks of parts (components). When the SEC faced bankruptcy in 1989, the idea of converting it into a rural electricity utility gained ground.

An initial pilot project to test this concept was funded by the Japanese development agency, JICA in 1993, and later a full scale project was supported by the EU through Lome II. In both cases the funding was necessary for the initial capitalisation.

In a nutshell the institutional arrangement is as follows:
- A household wishing to be ‘solar connected’ has to wait until at least 49 others also wish to have the service (in practice there was no waiting because of surge in demand).
- When the 50 households agree to be connected, each pays a connection fee of A$ 50 and signs a contract. Thereafter SEC technicians install the systems. Monthly fees are A$ 10 to A$ 50 depending on the size of the system.
- SEC divides its customers into rural electrification districts. Each district has 125 systems, which are maintained by one SEC technician (who most likely lives in that particular district). The technician visits each installation once a month to collect the monthly rates, to perform preventive maintenance, and to check if no unauthorised connections have been made to the system.
- The SEC owns the system, save for the wiring and appliances, including lights, which are owned by the customer. The utility authorises the addition of extra appliances.
- A senior technician from the head office visits the districts twice a year to oversee the district technician’s work. He is also on call, should the former encounter problems beyond his capability.

- Each district is advised to form a users committee, which represents the voice of the users and reports complaints and requests to the utility management. The committee also arbitrates in the case of proposed disconnections due to a customer's default on monthly payments. If the arrears are not made up by the agreed time, and the committee disallows a disconnection, an additional temporary charge is added to the district bill in order to compensate for the defaulter's amount.
- The utility management holds an annual general meeting with the district committees. Problems and complaints are thrashed out and the user fees for the following year are presented and justified.

By 1996, all 'minor' technical problems encountered in this 'experiment' had been resolved. Fee collections continued to be above 80% and virtually 100% within two months of the due date. Only 1% of users had been disconnected. However, by 1996, the project had not attained full cost recovery and SEC had to cross-subsidise it from its other activities.

## A.3 Solar Home Systems in Senegal

The GTZ supported an SHS dissemination programme in Senegal, beginning from 1987 to 1994, under its Special Energy Programme. The project was called the German Senegalese Project, Trial and Popularisation of PV Equipment. The co-ordination of the project was carried out by DAST (Direction dϑlϑguϑ aux Affaires Scientifiques et Techniques, department of Scientific and Technical Matters, Ministry of National Education).

The project achieved to disseminate more than 1,300 units by March 1994, which was more than 95% of all SHS's distributed in the country, therefore imposing its standard on the Senegalese market at that time. The project included a subsidy element.

A standard SHS was popularised, consisting of a 50Wp module, 50Ah battery, a regulator, four lamps and BOS (price: CFAF 285,000, which was about US$ 800; with a rate of 1 French Franc (FF) = CFAF 50).

A brief description of the project follows:

- Socio-economic studies were conducted on best popularisation methods, with the help of NGOs, research organisations and consultants.
- Community associations and co-operatives were selected to manage the dissemination process, with emphasis on those who already had experience with rural credit schemes. Conventions were signed defining among other things, contractual obligations and responsibilities of the parties involved. As an example, co-operatives were put in charge of the financial mechanisms, be they cash or credit, in their respective zones.
- At the beginning, these co-operatives/associations received from the Project Management, an initial stock of systems.
- For the credit system, households were divided into three socio-economic groups: farmers, with simple demand, mainly lighting; wage-earners and traders, with a more diverse demand; and associations. The downpayment, instalments and the repayment period also ascended in this order.
- The project implemented a decentralised maintenance system based on the community co-operatives, by training two or three maintenance agents per co-operative. The agents were provided with a set of tools and had access to stocks of spares which were created by the co-operatives themselves. Strict maintenance registers were kept, and regular site visits were conducted. The Project Management checked periodically on the maintenance routines of the co-operatives.

It was expected that, towards the end of the project, rural co-operatives would fund the dissemination process by themselves or else resort to rural credit banks. The project had an intensive popularisation effort and had built confidence among households and hopefully also rural credit financiers.

# ANNEX B USEFUL NETWORK INFORMATION SOURCES

*Information on SHS projects*

- CADDET Renewable Energy; Fax: +44 1235 433595
  http://www.caddet-re.org/html/techpv.htm
- Solar Electric Light Fund (SELF); Fax: +1 202 328 9512
  http://www.self.org
- Enersol Associates, Inc.; Fax: 978-251-5291
  http://www.enersol.org
- Global Environment Facility (GEF): GEF Secretariat; Fax: (202) 522 3240 or 522 3245
  http://www.gefweb.org/wprogram/
- E&CO; Fax: 973-680-8066
  http://www.energyhouse.com/eco/projects/
- Royal Dutch/Shell Group of Companies; Fax: (31) 70 3774848
  http://www.shell.com: Renewables
- UNESCO: World Solar Commission: Fax: (33-1) 45 68 58 21
  http://www.unesco.org/general/eng/programmes/science/wssp/priority.html.

*General information on PV*

- About PV suppliers, history, forecasts, training, finance, organisations: highly recommended http://www.pvpower.com/pvphome.html; e-mail: site@pvpower.com.

# ANNEX C EXAMPLE

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Benefits | 126 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 |
| Investment costs | 550 | | | | | | | | | | | | | | |
| O&M | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Battery replacement | | | | 60 | | | | 60 | | | | 60 | | | |
| Cash flow | -464 | 56 | 56 | -4 | 56 | 56 | 56 | -4 | 56 | 56 | 56 | -4 | 56 | 56 | 56 |
| NPV | -148.4 | | | | | | | | | | | | | | |

*Assumptions*
1. 50Wp SHS costing US$ 550
2. Utility scheme requires US$ 30 down payment and US$ 8 monthly fees
3. Battery replacement every four years (battery costs US$ 60)
4. Interest rate at 10%
5. System lifetime of fifteen years

*Conclusion*
The scheme is not commercially viable (Net Present Value = -148.4). However, this NPV may still be bigger than that of alternatives e.g grid, diesel.