Solar electrification of rural schools and clinics in South Africa : evaluation and recommendations

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Evaluation and Recommendations

Eindhoven University of Technology

Faculty of Technology Management

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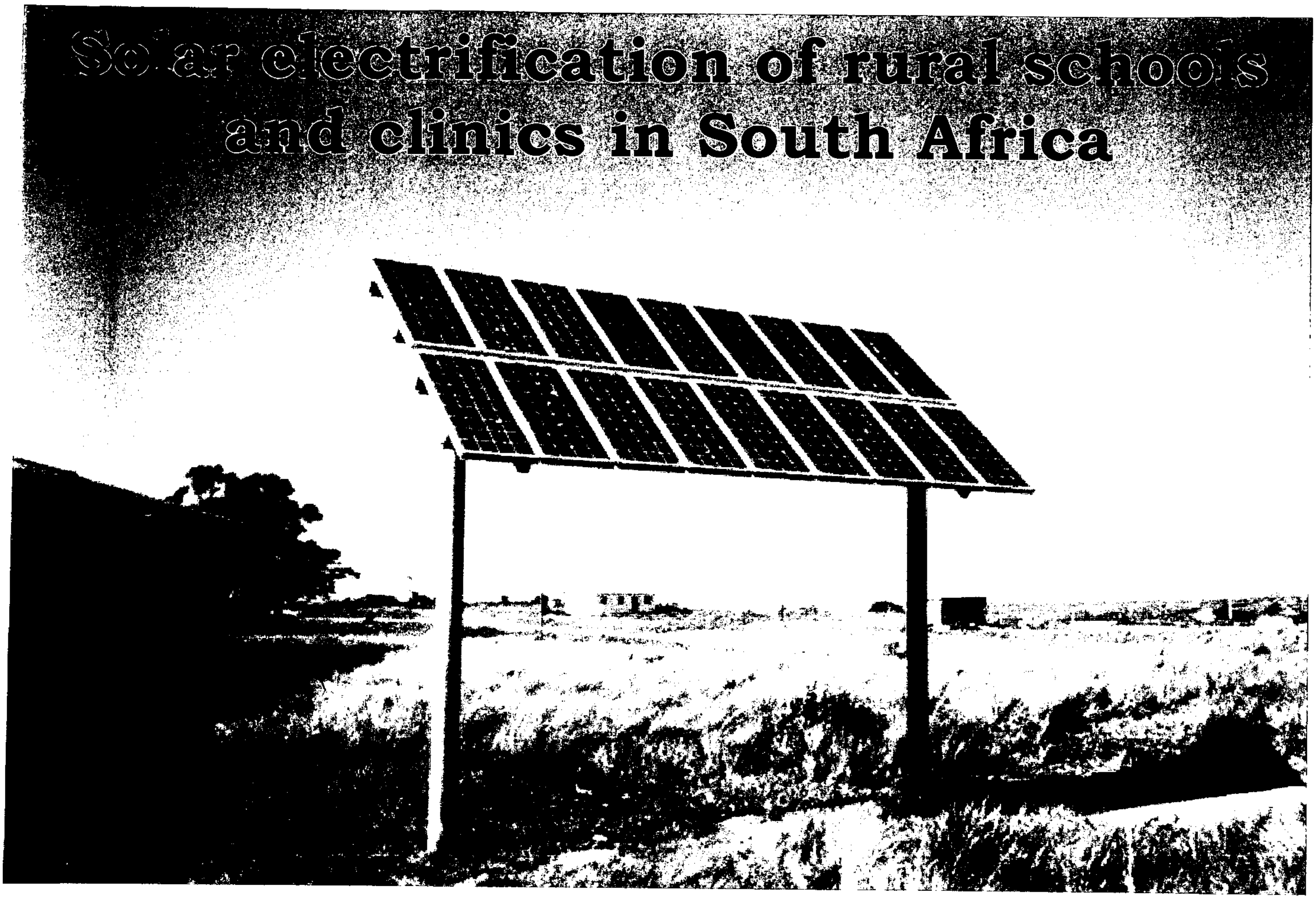

Evaluation and recommendations

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VOORWOORD:

Zuid-Afrika heeft ons beiden enorm veel geleerd. En land vol tegenstellingen, waarvan de een zegt dat het enorm goed gaat, en de ander dat alles schrikbarend achteruitgaat. Om in een dergelijke omgeving een onderzoek te doen dat juist gaat over deze tegenstellingen was een onvergetelijke ervaring.
We zouden iedereen willen bedanken die ons bij het project geholpen heeft: onze begeleiders Chris Westra en Win Klunne van ECN voor de afbakening en aanwijzingen, Tinus Pretorius die een enorme steun betekende in Pretoria, Geert Verbong en Lex Lemmens die vanuit de thuisbasis nuttige aanwijzingen gaven alsook alle mensen die we interviewden. Ook alle bekenden die ons avontuur via de mail konden volgen, en onze families die soms spannende tijden doormaakten toen we voor enkele weken in de rurale gebieden verdwenen: hartelijk dank.
Het was soms moeilijk de moed niet te verliezen bij de resultaten van het veldwerk, namelijk het enorme aantal systemen dat gestolen, vernield of kapot waren, maar toch hopen we dat ook dit rapport in de toekomst kan bijdragen tot een verbetering van de situatie.

Raf Cox
Luc Gys

Juli 2001

EXECUTIVE SUMMARY

The objective of this research is to do recommendations on the future design and implementation of solar systems on rural schools and clinics in South Africa.
After the first democratic elections in 1994, large programmes were initiated to improve the quality of live in the rural and less developed areas in South Africa. It was decided that all schools and clinics in South Africa should get electricity.
Under the Reconstruction and Development Programme, a programme to electrify 1340 schools in 1996-1997 was managed by Eskom (the national electrification provider). In 1998, an EU-funded programme to electrify another 1000 schools was initiated. The installation of these solar systems will be finished half 2001. The Independent Development Trust, an organisation that focussed on the poorest of the poor, managed the electrification of clinics, 200 clinics got solar electricity between 1996 and 2000.

No public evaluation report of these programmes was available, though a general impression existed that the projects were not without problems.
In this research, information was gathered through the study of available reports of the projects, interviews of involved experts and a field survey in which 160 schools and clinics were visited in the Northern Province and the Eastern Cape, using an extensive questionnaire.

The evaluation of the projects was structured according to the Life Cycle Theory. The systems were evaluated on their technical performance and the satisfaction of the users, together defined as success of implementation.

From the results of the field research, the following main conclusions can be drawn.

- Technical performance is not optimal mainly caused by theft of panels and batteries and technical problems.

- Theft is a major problem in the school programmes: 81% of the RDP-systems are not working because of theft and 23% of the EU-systems. In the clinics, theft is not a major problem. A clear relation was found between the fencing, night guard presence and installation of the panels on the roof and theft. Also good burglar-proof bars do prevent theft.

- No functioning support and maintenance structure is in place, causing the bad performance of 19% of the RDP-systems, 32% of the EU-systems and 45% of the clinic systems that have a technical problem.

- Schools and clinics have no budget to maintain the systems. Also the departments did not allocate budget to pay for maintenance.

- No policy for solar electrification is put place, causing a general lack of addressing responsibility and management of the projects.

The recommendations focus on a lot of different aspects, the most important are the following.

- A clear policy on all levels is needed for the rural electrification of schools and clinics, addressing responsibilities of all involved parties.
- A maintenance structure has to be designed (5 options are described in the report), and budgets allocated.
- Effective measures against theft have to be taken.
- A lot of effort is needed to involve the community, as it was indicated that community members are involved wit the criminal activities.

The following quotation by Prof. D. Holm can give a good view on the main problems in the projects that were researched.

" Energy is a cross-cutting issue, demanding vision, leadership and interdisciplinary human skills, in excess of simplistic supply side engineering that was rampant until recently. Strategies should have more of an end-user focus with the accent on energy services, and not exclusively on the supply side by one or more energy carriers. "Electricity for All" was a good slogan-but not a strategy." (Holm 2000)

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AC	Alternating current
Amph	Amperes x hours
DC	Direct current
DME	Department of Minerals and Energy
DoE	Department of Education
DoH	Department of Health
DoPW	Department of Public Works
ECN	Energy research centre of the Netherlands
EDI	Electricity Distribution Industry
EU	European Union
EU-1	Phase 1 of EU funded 1000 schools programme (500 systems)
EU-2	Phase 2 of EU funded 1000 schools programme (500 systems)
GIS	Geographic Information System
HSRC	Human Sciences Research Council
IDT	Independent Development Trust
NECC	National Electricity Co-ordinating Committee
NEP	National Electricity Plan
PV	Photo Voltaïc
R	Rand (R3,132 = 1 Hfl, 06-2001)
RDP	Reconstruction and Development Programme
TUE	Eindhoven University of Technology
UP	University of Pretoria
Wp	Watt Peak, maximum power from a solar panel

TABLE OF CONTENTS

Chapter 1:

Introduction

1.1 Introduction

In South Africa, a lot of rural areas are not grid-electrified yet. No electricity is available, people use candles and paraffin for lighting, wood, coal, gas and dung for heating and cooking. In 1994 the new government was elected after the apartheid regime. The development of these areas and improvement of the quality of life were important political issues. Good health facilities and education should be available for everyone. All schools and clinics should get electricity, for lighting, educational equipment, refrigeration of medicines and communication. For schools and clinics that were situated too far from the existing electricity grid, non-grid energy would be used. For the schools, as part of the Reconstruction and Development Plan (RDP), Eskom (the national electricity provider of South Africa) managed the electrification of 1340 schools with solar energy between 1996 and 1997. The Independent Development Trust (IDT) managed the electrification of 200 clinics with solar energy. In 1998, a project to electrify another 1000 schools with solar energy, sponsored by the European Union, was started and planned to be completed in 2001.
Information about the solar electrification of schools and clinics was limited. Neither was a report available on the performance of those solar systems. There was a general feeling that there might be a lot of problems with these projects, but what exactly was going on was not clear. ECN was interested to get a clear view on this situation, as they focus on the implementation of renewable energy and on applied research. After some discussions with involved experts in South Africa, the feeling that a lot of systems were failing was confirmed, but the reasons of failing were not clear.
The solar systems under investigation (a total of 2040 systems) were installed between 1996 and 2001, on rural schools and clinics that did not have electricity. The majority of these systems were installed in the Northern Province and the Eastern Cape, consequently this research focuses on these two provinces. Schools and clinics were treated separately in this research to identify possible differences in need, use and maintenance in both institutes.

1.2 Research Problem formulation and aim of the research

1.2.1 Research problem formulation

After the elections in 1994, a lot of rural electrification programmes were started up to improve the quality of life of rural people in South Africa. A goal was set that all the schools in South Africa had to be electrified by the year 2000.[Rensburg, 2001] Because a lot of schools are on a large distance from the existing electricity grid, criteria were put up to decide were the grid would be expanded, and were other technologies would be used, of which solar energy was the most important. This meant that around seven thousand solar systems had to be implemented in rural schools in a few years time. Because of this political instigation, decisions had to be made fast, and no real policy was available. Eskom would manage the implementation, starting in 1996-97 with a project of 1170 schools in the Eastern Cape and 170 schools in the Northern Province. After the first project, it became clear that this speed of implementation would not lead to sustainable provision of electricity. The decision was made, by DoE, DME, and Eskom to slow down the speed of implementation. In 1998 an EU funded electrification project was started, to install 1000 solar systems in rural schools, 500 in the Northern Province and 500 in the Eastern Cape.

For the clinics, IDT (Independent Development Trust) would manage the installation of solar systems on rural clinics.
At this moment, no public evaluation report is available on the success of implementation of solar systems on rural schools and clinics in South Africa. This evaluation is important to give feedback for future design and implementation of solar systems, as there is a general feeling that there are a lot of problems with the solar-systems in the field

1.2.2 Aim of the research

This research aims to define the factors that influence the success of implementation of solar systems on rural schools and clinics. Installed systems will be evaluated, the success of implementation defined, as well as the factors that influence this success. Conclusions will be drawn and recommendations for future implementation and policy on the implementation will be made, using the Life Cycle Theory as a guideline.

1.3 Research question and definition of terms

1.3.1 Research approach question

The main research question is:

What are the possible improvements on the implementation of solar systems on schools and clinics in rural areas in South Africa?

To answer this research question the following two sub questions have to be answered first:

- What is the success of implementation of solar systems that were installed on rural schools and clinics the last 5 years?

- What are the factors that influence the success of implementation of solar systems on rural schools and clinics in South Africa?

The research can be split up in two parts.
An extensive literature study was done on the electrification of schools and clinics in South Africa and the major number of involved actors were interviewed. This part of the research provided the background information needed to execute the survey.

Also as a part of the literature study the Life Cycle theory was studied. This theory was used to derive factors that influence the success of implementation and it was used to structure the recommendations.

The second part contents a field study that was executed to evaluate the solar systems in the field. For the field research, a co-operation with the EU-funded evaluation project was put up. With this co-operation the size of the sample could be enlarged for both researches.

1.3.2 Definition of terms

In this paragraph, terms used in the research questions will be defined shortly. Some of the terms will be explained more in detail in Chapter 2, giving background information.

Rural areas:
Rural areas in the scope of this research will be defined as areas where no grid-electricity is available (and will not be available in the near future). The rural areas are less developed and the density of people is low to very low. Rural areas are situated far away from cities and urban areas. These areas will also answer the more general description of rural areas, given in paragraph 2.4.

Schools and clinics in rural areas:
Schools and clinics that are situated in the rural areas where no grid electricity is available (and will not be available in the near future). More information on the schools and clinics is available in paragraph 2.5.

Solar systems:
This research focussed on photovoltaic solar systems, used to provide the school or clinic with electricity. The systems consist of a number of solar panels that charge batteries via a regulator. The batteries can supply a DC load, or via an inverter an AC load that requires 220 VAC. A more detailed description of the systems used in schools and clinics is given in paragraph 2.6.

Success of implementation of solar systems:
Whether a solar system is implemented successfully, depends on 2 aspects:
1. Is the solar system working technically, meeting the design specifications?
2. Does the solar system fulfil the needs of the user, is the user satisfied with the system?

It is clear that those two aspects can influence each other: when a system is not working, the satisfaction of the user will be very low. Therefore, it is impossible to quantify the success of implementation very detailed. In this research, the implementation will be seen as unsuccessful in any case when the system is not working at all. When the system is working completely or partly, the satisfaction of the user can influence the total success of implementation. Figure 1 visualises this reasoning.

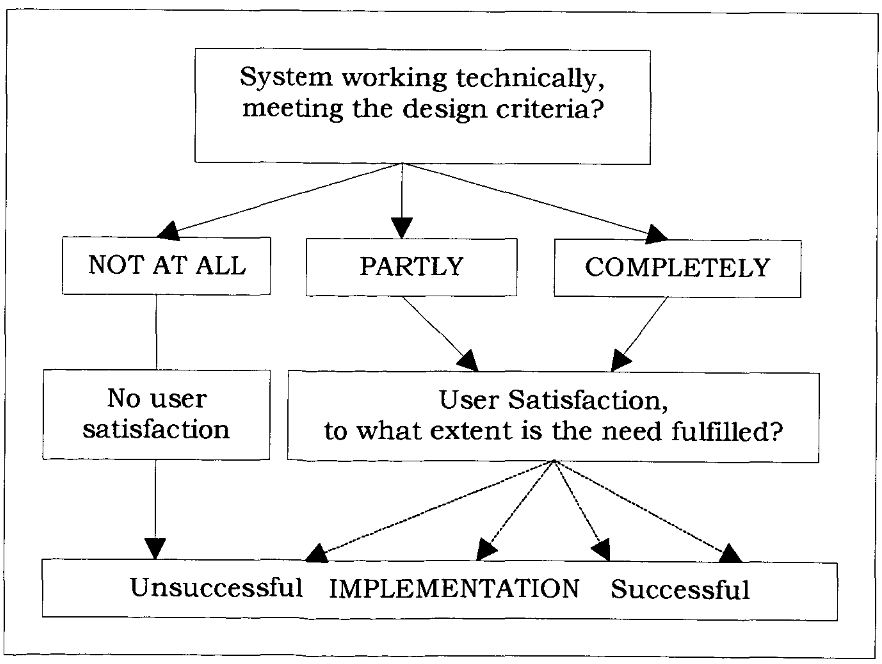


Figure 1: Success of implementation

In this research, no quantified scale of the success of implementation is designed, the extremes are unsuccessful and successful, the zone in between will be filled by analysing the remarks the users gave during the field research. For the technical evaluation, three categories are used: working completely, working partly, and not at all.
In paragraph 2.6.5, a definition of "working partly" of the solar system is given.

Factors that influence the success of implementation:
All the factors that can have an influence on the success of implementation of solar systems on schools and clinics. These factors will be derived from three sources: literature available on the solar projects under investigation, interviews of involved experts and the Life Cycle Theory.

1.4 Introduction to research methodology

To come to recommendations on the future design and implementation of solar systems on rural schools and clinics, the following methodology was used.
The research was divided in two major parts. A visualisation of the methodology is presented in Figure 2.

Part 1:
To investigate what the factors are that can influence the success of implementation, three information resources were used: First, existing policy documents and reports on the rural electrification programmes were studied. Secondly, a large number of involved experts were interviewed, using their experiences and knowledge on implementation of solar systems. After the interviews, e-mail was used to get some additional information. The results of this study can be found in Chapter 3, Policy and programmes. The third resource was the Life Cycle Theory, that is used to come to theoretical founded aspects that influence the success of implementation. The Life Cycle Theory is also used to structure the research. Chapter four describes this theory. In Chapter five, a conceptual model is presented, containing all the aspects derived from the life-cycle theory and interviews of experts, that can influence the success of implementation of solar systems in rural schools and clinics in South Africa.

Part 2:
First a draft version of the developed questionnaire was tested in the field, by visiting six schools in the Northern Province. Then the conceptual model was finalised as well as the definitive questionnaire. The field-research was a survey. A sample of 142 systems was selected. The systems were chosen in different regions in the Northern province and Eastern Cape to get rid of some specific area related items, and to have a more reliable sample. To obtain a larger sample and because of common interest a co-operation with the EU was set up. The developed questionnaire was approved by the EU. The co-operation enlarged the sample with 32 visited systems.
A detailed description of the second part of the methodology can be found in Chapter 6 Research methodology of survey.

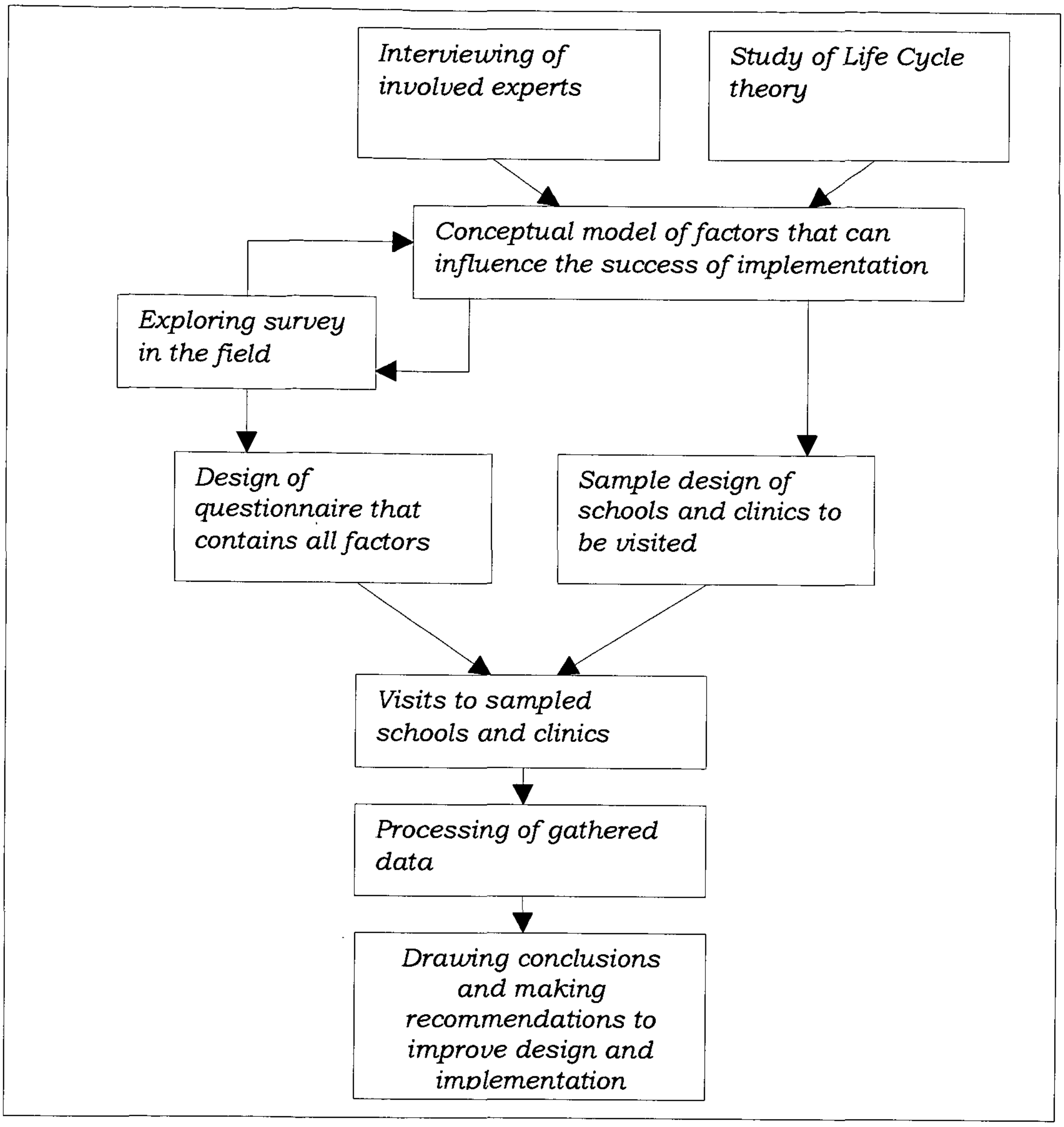


Figure 2 Methodology

An explorative research was the most suitable type of research to clear out the different factors that can have an influence on the success of implementation of solar systems. Exploring causal relations is not possible with this kind of research, so the conclusions drawn after the analyses of the data have to be considered very well. (Baarda 1998)

1.5 Outline of the report

In the second chapter, the reader can find background information on South Africa, rural areas, schools and clinics and technical information on the solar systems under investigation. Also demographic information on the Northern Province and the Eastern Cape, the two provinces where the field research was executed is enclosed, as well as information on the energy resources and consumption in South Africa to place solar energy use in a broader picture.

The third chapter contains the policy/programmes on rural electrification of schools and clinics in South Africa, under which the 2040 solar systems under investigation were installed.

In chapter four, the Life Cycle Theory is presented and used to define more factors that can have an influence on the success of implementation.

In the fifth chapter, a conceptual model is presented, with the factors derived from the life cycle theory, interviews of experts and the exploring survey in the field that can have an influence on the success of implementation of solar systems on rural schools and clinics.

Chapter six contains the research methodology that was used for the field research, focussing on the design of the sample of visited schools and clinics and the used questionnaire.

In chapter seven, the results of the field research are presented.

Chapter eight contains a detailed analyses of the results.

In chapter nine, the conclusions from the analyses are presented, and recommendations for future design and implementations made, also recommendations for future research are included.

Chapter 2:

Background information

2.1 Demographic information on South Africa

General

South Africa is the most southern country of the African continent, occupying 1219090 km^2, containing 40.58 million habitants. (Encarta 2000) South Africa is called the rainbow country because of the difference in habitants. In literature, 4 ethnic groups are distinguished: black 75.2%, white 13.6%, coloured 8.6% and Indian 2.6%. (CIA 2000). The South African currency is the Rand. The value of the Rand was 3,31 R = 1Hfl on 18-06-2001.

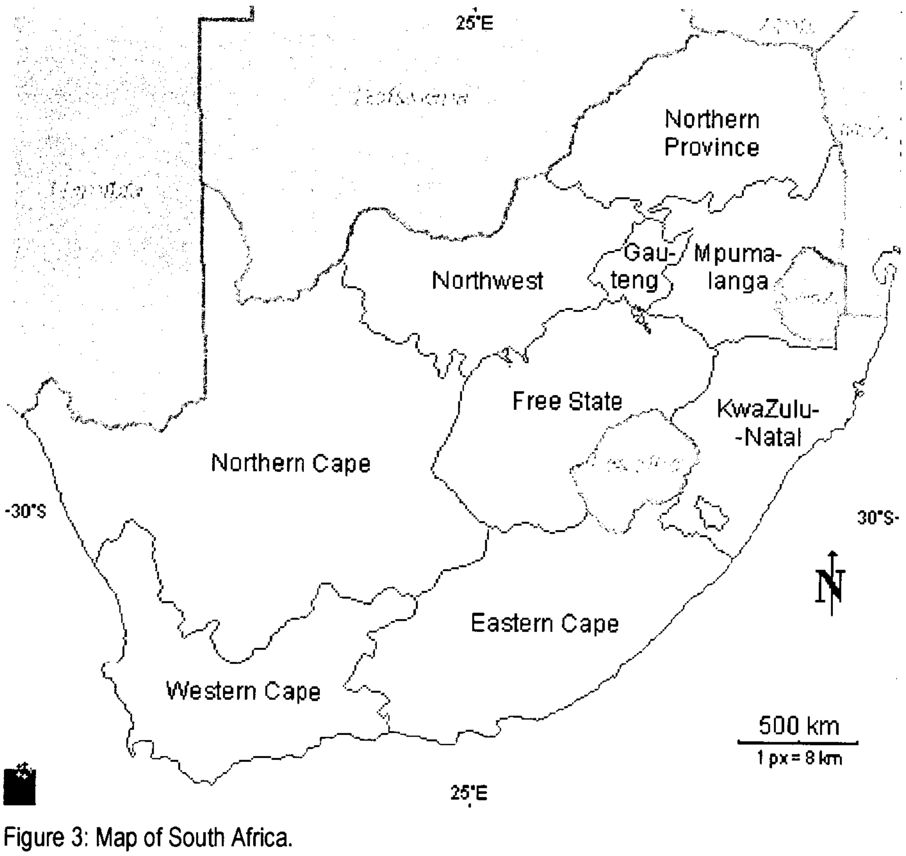


Figure 3: Map of South Africa.

(Source: http://www.sas.upenn.edu/african_studies/cia_maps/south_africa_19883.gif)

Education

In 1996, 4 million people in South Africa older than 20 years never received education, 3.5 million people received some primary education and 1.57 million completed their primary school. More than 7.13 million people have had some secondary education, and just 3.5 million people have acquired senior certificates. Close to 1.3 million have acquired higher education. (Burger 1999) Figure 4 gives a visualisation of this data.

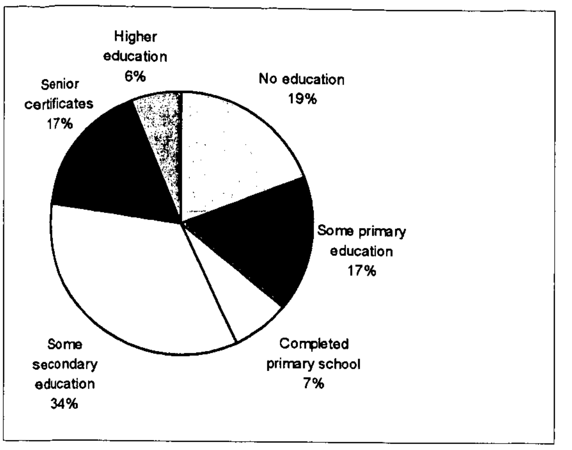


Figure 4: Education level in South Africa

(Source: Burger 1999)

The condition of the schools in the poorer provinces is very bad. What the Northern Province concerns, 33% of the schools were in poor condition in 1998. 24 per cent of the schools in South Africa had no water within walking distance. In Eastern Cape, Kwazulu Natal and Northern Province, there are extremely high classroom shortages. In 1998 there were 11,921,948 pupils in South African Public schools (grade 1-12) and approximately 360,725 educators. This means a ratio of 1: 33 on average, but since the ratio in urban areas is lower, one can imagine that the situation in rural and deep rural areas is much worse. In most rural schools, no budget is available for infrastructure (maintenance on the buildings, educational equipment etc.). There are programmes set up to improve the quality of education on South Africa.

Economy

The South African economical situation is, like other developing countries, highly susceptible to trends in the economies of its major trading partners. South Africa was protected from he worst part of the Asia crises, because of a stable macroeconomic environment. The manufacturing industry though recorded in 1998 a decline of 1.5 per cent from the levels in 1997.

In 1999, the unemployment rate was estimated on 30%. Because this is a national average, one can imagine that in certain areas (townships, rural areas) this number will be much higher. The majority of the unemployed people are black men and woman under the age of 35 years, new job-creating plans are set up. Tourism might play a major role in the future economy of South Africa, when the reputation of the country can be improved.

Small business in South Africa absorb almost half the people formally employed in the private sector and contribute about 37 per cent of the countries GDP. There are an estimated 3 million micro enterprises in the country. To improve the climate for the micro enterprises, a lot of programmes are set up, with financial support etc. Electricity in rural areas is an essential need for an entrepreneur. The availability of electricity can lead to the development of new economic activities in a region, reducing the unemployment and poverty.

Health

The Government has committed itself to providing basic health care as a fundamental right. The fundament of the national health care plan includes free health services at public primary health-care facilities such as clinics and community health care centres.

40 per cent of the South African population lives in poverty, and 75 per cent of that population lives in rural areas where they are deprived of access to health services. To provide health care to those people, a policy based on the concept of the district health system is set up. The objective is to unify the fragmented health services at all levels into a comprehensive and integrated health service. In 1998 there were 1791 medical interns, 29,369 medical practitioners and 174,754 nurses.

To provide the medical service till 1998 474 new clinics had been built and 212 upgraded. There are also 350,000 traditional healers in South Africa providing their services to between 60 and 80 per cent of their communities.

Transport

South Africa has 534,131 km of highways, of which 63,027 km (including 2,032 km of expressways) are paved (12%), and 471,104 km unpaved (88%) (1998 estimate) Cape Town, Durban, East London, Mosselbaai, Port Elizabeth, Richards Bay and Saldanha are South Africa's ports and harbours. (CIA 2000). Public transport is not very good in South Africa. Most people travel by taxi-buses.

Weather

The South African climate is very similar to that of Australia and to a lesser degree the United States. It enjoys a generally warm, temperate climate. Most of the country experiences light rainfall and long hours of sunshine.

Rainfall is typically unpredictable. Prolonged droughts often end with severe floods. Only 31 percent of the country, including the Eastern Low Veld and the Drakensberg, has an annual rainfall of more than 600 mm; 48 percent receives from 200 mm to 600 mm, including much of the High Veld, where rainfall diminishes rapidly from east to west; 21 percent, in the west, is arid, with less than 200 mm. Rain falls primarily in summer between October and April. In the drier regions of the plateaus the amount of rainfall and the beginning of the rainy season varies greatly from year to year. The extreme south west has a Mediterranean climate with westerly winds from the Atlantic bringing winter rainfall mostly between June and September.

There is a striking difference between temperatures on the east and west coasts. The east coast is influenced by the warm Agulhas Current and the west coast by the cold Benguela Current. This results in a temperature difference of 6 Celsius in the mean annual temperatures of Durban on the east coast and Port Nolloth on the west coast, which are at similar latitudes. Average temperature ranges in January are 21° to 27° C in Durban, 14° to 26° C in Johannesburg, and 16° to 26° C in Cape Town. In July the temperature ranges are 11° to 22° C in Durban, 4° to 17° C in Johannesburg, and 7° to 17° C in Cape Town. (Encarta 2000)

Electrification

In the period 1994 to 1999, close to 2.8 million new households have been electrified since 1994, bringing the household electrification level to approximately 68%, up from about 36% in 1994. The net effect, however, was that the urban areas are electrified to levels as high as 80-90%, while the impoverished rural areas are still at the 48% level. (NECC 2000) This current status of electrification in South Africa is given in Table 1.

	No. of houses electrified	No. of houses not electrified	% electrified	% not electrified
RURAL	1 793 193	2 080 795	46.3	53.7
URBAN	4 585 185	1 167 343	79.7	20.3
Total	6 378 378	3 248 138	66.3	33.7

Table 1: Status of electrification in South Africa

(Source: [NECC, 2000])

2.2 Northern Province and Eastern Cape

In this paragraph, more detailed on those two provinces is presented to give the reader background information on the areas where the field research is done. The reason for the choice of these two provinces is twofold: Most of the solar systems are installed in the Northern Province and the Eastern Cape, and practical restrictions in time and budget for the fieldwork .

2.2.1 The Northern Province

General

The capital of the Northern Province is Pietersburg. The principal languages are Sepedi , Xitsonga and Tshivenda. The surface is 123,910 km^2, and there live 4,929 million people (48/km^2, in the Netherlands 452/km^2).

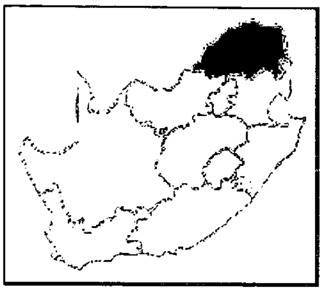


Figure 5: Northern Province
(Source: http://www.tourism.org.za/sa/provinces/flashprovincesinfo.html)

Economics

Agriculture is a large employer in the Northern Province. Especially in the rural areas this is the main source of income. The Northern Province is rich in minerals including copper, asbestos, coal, iron, platinum chrome, diamonds and phosphates.
The province is a typical developing area, exporting primary goods and importing manufactured goods and services. 41 per cent of the economic active inhabitants were unemployed in 1998. The Government was the largest employer, contributing 25 per cent of the economic output.

Weather

The average temperature in Pietersburg in January is 22.6°C and 12.2°C in July and the average hours of sunshine are 253 in January and 279 in July.

2.2.2 The Eastern Cape

General

The capital of the Eastern Cape is Bisho. A large area of what is now called Eastern Cape were former homelands (Transkei and Ciskei). The Eastern Cape has 6,303 million habitants, where most of the people live in the rural areas. The surface is 169,580 km^2 (37 inhabitants/km^2, in the Netherlands 452/km^2), with lots of rolling hills, valleys and rivers. The main languages are IsiXhosa, Afrikaans and English. 20.9 per cent of the population above 20 year has received no education, while 4.7 per cent of the population has completed a higher level of education.

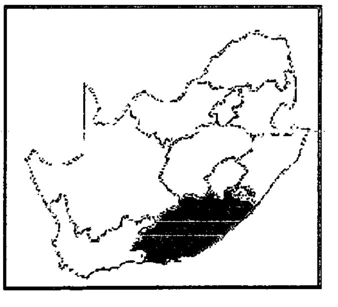


Figure 6: Eastern Cape
(Source: http://www.tourism.org.za/sa/provinces/ flashprovincesinfo.html)

Economics

The main income of the Eastern Cape is agriculture and fishing. There are no mineral recourses. The main crops are pine-apples, chicory, coffee, cattle maize and sorghum. The fishing industry generates about R200 million a year. The economies in the cities Port Elisabeth and East London are mainly based on manufacturing.

Weather

The average temperature in Bisho in January is 22.1°C and 13.8°C in July and the average hours of sunshine are 214 in January and 289 in July.

2.3 Energy resources and consumption in South Africa

In this paragraph, an overview of the energy use and consumption in South Africa is presented, to place the solar electricity in a broader picture.

2.3.1 Resources:

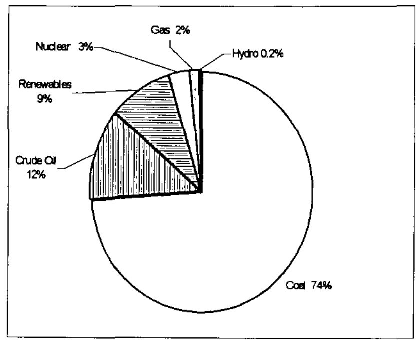


Figure 7: Energy resources South Africa 1997
(Source http://www.gov.za/yearbook/mining.htm)

Coal

Coal is the primary fuel produced and consumed in South Africa. South Africa is the third leading coal exporter in the world, and coal is South Africa's second largest foreign exchange earner after gold. South Africa's coal reserves are mainly bituminous, with relatively high ash content (about 45%) and low sulfer content (about 1%). Three fields (Waterberg, Witbank and Highfield) hold 70% of total recoverable reserves. Estimated South African coal production was 246.8 million short tons (mmst). Several South African companies are planning mine expansions or new mine developments to help boost production. (EIA 2000) Although South Africa is also one of the largest coal exporters, the estimated resource depletion rate at 1997 production levels is still well below 1% of the proven resource per annum. (Kotzé 1997)

Synthetic fuels

South Africa has a highly developed synthetic fuels industry, which takes advantage of the country's abundant coal resources and offshore natural gas and condensate production in Mossel Bay. The two major players are Sasol (coal-to-oil/chemicals) and Mossgas (natural gas-to-petroleum products). Sasol has the capacity to produce 150,000 barrels per day, and Mossgas 45,000 barrels per day.

Oil and natural gas

With the exception of offshore gas reserves in Mossel Bay, South Africa has been slow to develop its reserves of conventional oil and natural gas. The country imports crude oil primarily from the Middle East, with Iran as its chief supplier.

Uranium

South Africa's uranium resources exceed 500,000 tons. In 1999 the country produced 981 tons of uranium, or about 3 percent of world production in 1999. (Institute 2000) All uranium in South Africa is produced as a by-product from mining-operations.

Renewable

The most widely used renewable energy source in South Africa is fuelwood, which meets the daily energy needs of more than one-third of the country's population. Fuelwood can only be seen as a renewable energy source if the use of the fuelwood is compensated by the growth of new trees. Due to increased fuelwood consumption by a growing population, the growth of new trees is exceeded by the consumption of wood, causing deforestation and all the problems that come with it. This has prompted interest in other renewable energy sources, particularly solar, which could play an important role in supplying power to isolated rural areas not currently connected to the electric power grid.
Southern Africa is exceptionally well endowed with solar energy. On the most recent world map of total insolation, it contains the largest single area in the highest category, above 6.5 kilowatt hour per square metre per day. (Scheffler) These figures are proof that the availability factor in Africa is high and hence solar PV and solar

thermal projects present a great potential for energy provision. (Gope 1997) There are also some pilot-projects done on the use of wind-energy, and a lot of small-scale windmills for water-pumping (278,000 units(EC 2000)) and electricity generators are in use. Large scale use of solar and wind energy is at this moment not economically feasible because of the very low electricity prices Eskom offers. This because of the enormous quantities of cheap coal that are available. Also the methods for design and implementation of PV-systems require a different kind of technologic and economic assessment by market players such as the manufacturing and construction industries, insurance companies, finance houses etc. compared to conventional energy production technologies. (Gope 1997) In 1999, the total installed PV capacity was estimated at 7.5 MWp: telecommunications 2.6 MWp; domestic lightening and recreation 1.8MWp; schools and clinics 1.5MWp and water-pumping 0.7 MWp. [Burger, 1999 #28] With the current emphasis on the expansion of the telephone services in the rural areas and the rapid growth in the cellular telephone industry, this figure stands to grow significantly over the short to medium term. (Kotzé 1997)

2.3.2 Consumption:

Eskom, one of the largest electricity providers in the world, generates nearly all (98%) of South Africa's electricity. Generating capacity (36,500MW), which is primarily coal-fired, also includes one nuclear power station at Koeberg (1,930MW), two gas turbine facilities and two conventional hydroelectric plants. Also two hydro-electric pumped-storage systems are used for peak-shaving.
In the period 1994 to 1999 close on 2.8 million households were connected to the national grid, increasing the electrification level from about 36% in 1994 to about 68% at the end of 1999. South Africa has the second lowest electricity price (12.29 c/kWh [1998 Rand Value, normal consumer price] in the world because of the immense reserves of easy accessible coal. (Kotze 2001)

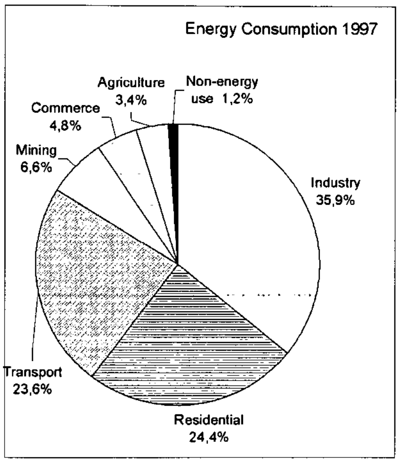


Figure 8: Chart energy use RSA
(Source: Energy , 2000#29)

In 1998, 76% of total energy consumption in South Africa was from coal consumption. Estimated consumption of coal in South Africa was 177.1 mmst in 1998.
The majority of domestic consumption is steam coal used to produce electricity. Other major steam coal consuming sectors include: gold mining, the cement industry, and the brick and tile industry.

Energy consumed by households represents some 22 per cent of the country's net use. Most household energy is obtained from fuelwood (65 per cent of net energy), primarily in rural areas. (Burger 1999)

Energy consumption in rural areas
The main consumption of energy in the rural and deep rural areas at the moment is wood and kerosene or gas to cook on, paraffin, candles and electricity (if available) for lightening and wood, gasoline and petrol for heating. Some equipment like a refrigerator, radio, TV, computer, overhead-projectors, require electricity. Car batteries and dry batteries are used in areas without an electricity-grid. (Davis 1998) The rural areas have a limited service of providing some of the fuels, and because of the low density of the people and the limited funds available for electricity, it is not feasible to provide all of the population in the rural areas with grid electricity. In

these areas, alternative energy sources as wind and solar power might be a feasible and sustainable option.

2.4 Rural areas

In rural areas, the density of people is very low. The majority of people in the rural areas rely on subsistence farming, each family will produce enough food for the family members, but (almost) no financial resources are available by trading the goods. This limited purchasing power causes that availability of goods is also limited. The main source of income is harvest of crops and cattle. Another source of income is people (mostly low educated) working in the urban industries (like mining), returning home to support their families every few months. The availability of work in the rural areas is very limited. Because of the very low density of people in rural areas the construction of an electricity grid connecting every house, water grid, roads and other services is very expensive. Besides these economical reasons, also political reasons caused the underdevelopment of certain areas.
As public transport is very bad in south Africa taxi-busses are the most important way of transport for the majority of people

Before 1994, under the Apartheid regime, the black people were forced to live in certain areas, the so-called homelands. These homelands were declared independent states, by the South African government to which each African was assigned according the record of origin. From 1976 to 1981, four of these homelands were created, denationalising nine million South Africans. (StanfordEducation) The people were only allowed to leave the homeland with a special permission, for example to work in the mines. Because no big profitable economic system was present, these homelands were poor and little infrastructure was available.

The first post apartheid Government set up a RDP (Reconstruction and Development Plan) in 1994. One of the main priorities of that plan was the provision of basic social infrastructure in areas that have been historically neglected by the state, and stimulate economical growth. To establish this economical growth, services as availability of water, electricity, health and education should be improved and giant building-programs were initiated. It was under the Reconstruction and Development Programme that the first non-grid electrification projects on schools and clinics were started.

Because field work had to be done in rural areas, a perception of these areas is necessary to understand the differences with a research in a developed environment. A lot of people warned the researchers that the rural areas could be dangerous for white people to travel, especially at night. This feeling is present, because of the history of these areas (homelands). As a result, very few white people travel in the rural areas, though most people are aware of the beauty of the nature. The chance of getting lost is present, as there are no road signs, the maps are not up-to-date, it is a mountainous area etc. A lot of local people don't speak English, which can cause problems in critical situations. In some areas, cell phones are not working, limiting the possibilities to communicate.
The roads are in a very bad condition, varying from potholes in tarred roads, to dirt roads that are completely washed away, and collapsed bridges, so rivers have to be crossed. Due to the limited budget that was available for the research, the field research had to be done with an old vehicle without four wheel drive. Regarding the raining season, this could cause problems, especially in the Eastern Cape.
The absence of hotels and camping spots also caused that a good planning had to be made to spend the night in a safe area. This caused some long travelling distance in some cases.

2.5 Rural schools and clinics

Some 25900 rural schools and a number of rural clinics were identified for electrification in 1995. Of these, 16,400 rural schools and 2000 clinics were identified for non-grid electrification. In 1995, Eskom estimated that approximately 75% (15.178) of schools and 47% (2950) of clinics in South Africa would still be unelectrified by the end of 1999. (Bedford 1996)

2.5.1 Rural schools

Information on schools is very limited in South Africa. Until 1996, no accurate national database was available on the number, location and individual situation of the schools in South Africa. In 1996 the 'School register of needs survey' was done by the Department of Education to make a start with the monitoring of the situation. Some interesting findings were published in the report at survey, which are summarised below.

Almost a quarter (21.85%) of the schools in South Africa are located in the Eastern Cape Province. The Eastern Cape Province, together with the Northern Province and Kwazulu-Natal had more than half (56.6%) the schools as well as more than half the pupils in the country. The school buildings were in 17% (i.e. 4,407 schools) in poor or very poor condition. In the Northern Province, the average learner-classroom ratio was 48.6:1, and in the Eastern Cape 54.6:1. 45% of the learners (i.e. 5.4 million) in South Africa received education in schools that did not have electricity at the time of the survey, in the Eastern Cape Province more than 80% of the schools did not have electricity. See Table 2 for detailed information on electrification of schools.

PROVINCE	Number of schools	Number of schools with grid electricity *	Number of schools without grid electricity**	Percentage in province without grid electricity	Number of schools with solar system***
Eastern Cape	5,916	1,082	4,799	**81.6 %**	1,170
Northern Province	4,174	873	3,270	**78.9 %**	170
Kwazulu-Natal	5,234	1,944	3,267	**62.7 %**	***
Gauteng	2,229	1,929	286	12.9 %	***
Free State	2,898	1,200	1,663	58.1 %	***
Mpumalanga	1,900	957	931	49.3 %	***
North West	2,413	1,004	1,382	57.9 %	***
Northern Cape	530	412	111	21.2 %	***
Western Cape	1,772	1,553	202	11.5 %	***
TOTAL	27,066	10,954	15,911	59.2 %	***

Table 2: Situation of schools electrification (Information as on February 16th 1998)

(Source: Department of Education, 1999)

*Includes only schools that are wired and supplied with grid electricity.
**Includes schools that are wired but not supplied with grid electricity, that are not wired and/or have no electricity, that have generators and a category called 'other energy supply", including solar energy.
*** Only for EC and NP numbers were available but in the other provinces, no or very few systems are installed

Most schools that did not have electricity in 1998 were situated in the Eastern Cape, Kwazulu-Natal and Northern Province. This was the reason why the rural electrification (non-grid) of schools started in these 3 provinces (together with political reasons). Also this research focussed on the Eastern Cape and the Northern Province, because of the practical boundaries of doing the field research and the occurrence of most PV-systems on schools and clinics in these provinces. The budgets for non-personnel costs for schools (educational equipment, etc.) have always been very limited. Expenditure on personnel consumed 87.2% of the provincial education budget in 1995/96. The projected expenditure for 1999/2000 was expected to be 90.7%. (Visser 1998) These numbers show the very difficult situation to allocate budgets for maintenance of schools (and PV-systems).

2.5.2 Rural clinics

IDT has estimated in 1995 that there were about 900 unelectrified major clinics in South Africa and 161 visiting points, while about 250 new rural clinics will require electrification. (Thom 1995). See Table 3 for more detailed information on electrification of clinics.

PROVINCE	Total number of clinics (electrified and unelectrified)*			Number of major clinics unelectrified	Number of visiting points unelectrified
	Total	Urban	Rural		
Eastern Cape	450	249	201	**317**	**40**
Northern Province	400	48	352	**282**	**10**
Kwazulu-Natal	348	271	77	**77**	**31**
Gauteng	430	428	2	0	0
Free State	240	177	63	5	7
Eastern Transvaal	220	95	125	100	7
North West	290	127	163	125	8
Northern Cape	120	94	26	5	20
Western Cape	450	428	22	0	25
TOTAL	2,948	1917	1031	901	161

Table 3: Situation of clinics electrification in1995

(Source: IDT, 1995c)

* Residential clinics, day clinics and health centres, only opened weekdays, 8h/day

Until 1995, no solar systems were installed on clinics yet, apart from some pilot projects which were called 'not successful' in some discussions with experts.

2.6 Technical information on solar systems

In this paragraph, the solar systems that were investigated will be described technically by programme (RDP-schools, EU-schools and IDT clinics). First the general working of a solar system will be explained, then each type of system used in the programmes is described in detail.
Details on the number of installed systems can be found in paragraph 6.2.1.

2.6.1 Working of a solar system

The main parts in a solar system are the following:
1. solar panel(s)
2. charge controller (or regulator)
3. batteries
4. DC load panel
5. inverter (optional)
6. AC load panel (optional)

In Appendix 1, a basic design procedure for solar systems is presented. (Siemens 1998)

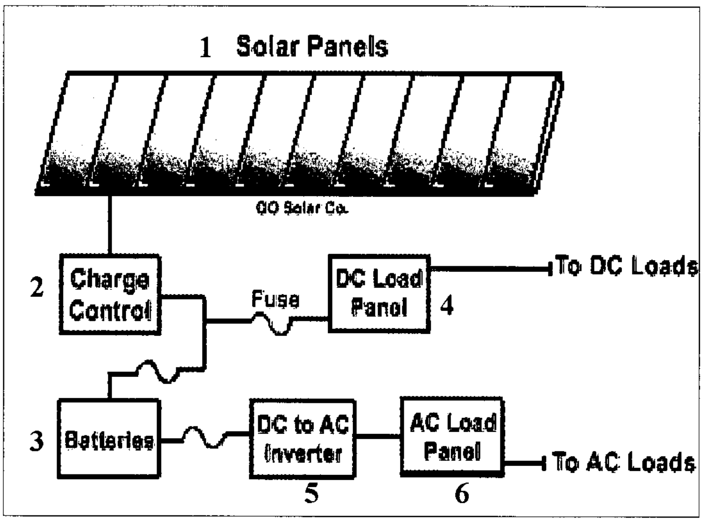


Figure 9: Working of a solar system (Source: http://acre.murdoch.edu.au/html)

1. The solar panels that are used the most at this moment are mono or polycrystalline cells or amorphous cells. Each cell will produce electricity when it is exposed to light. The total power of the solar panel depends on the number off cells that are connected in 1 module (serie - parallel) . Most solar panels produce a rated voltage of 14-17Vdc. (Siemens 1998)

2. The charge controller in a solar system will primarily serve to protect the battery against both deep discharging and overcharging. Basically, there are two kinds of charge regulators; the main difference lies in the position of the switching device. The "Series" type interrupts the connection between the solar generator and the batteries, while the "Shunt" type short-circuits the solar generator. In addition there are two main types of control strategies. In a "Two-step" control arrangement, the charging current is completely interrupted when the end-of charge voltage is reached. With a "Pulse-Width Modulation" control, on the other hand, the charging current is gradually reduced to the end-of-charge voltage level, thus keeping the voltage constant. There is no real disadvantage associated with either type of regulator or control strategy in terms of improvements to battery lifetime. (Zusammenarbeit 2000)

3. The storage batteries are still the weakest, most vulnerable components in a photovoltaïc power supply system. This might also be the reason why different types of batteries, ranging from automotive starter batteries and so-called "solar batteries", all the way to high-quality industrial tubular plate (POZS) batteries, and also sealed maintenance-free batteries are used in PV systems. Automotive starter batteries are usually the cheapest batteries when compared in terms of nominal capacity, they are often locally produced and are widely available. Their main disadvantage is the relative short lifetime (2-3 years). Modified automotive batteries or solar batteries (thicker electrolyte plates and a larger quantity of acid solution in the space above the plates) should be preferred to starter batteries, because of their longer lifetime. "Low maintenance" batteries (employing grids containing calcium alloys) use less water and are particularly vulnerable to damage from deep discharge. "No-maintenance" batteries (using a semi-solid electrolyte, gel or malting) are more often resistant to deep discharges, but they are usually very expensive, and require specific recycling facilities. [Zusammenarbeit), 2000 #41]

4. To the DC load panel, all the DC loads (for example lights, refrigerator, radio etc.) will be connected. It is important to install suitable fuses between all loads and the batteries.

5. An inverter has to be installed when 220V AC is required, transforming the 12 or 24 Volts DC of the batteries in 220 Volts AC. Also when the possibility of connecting the installation to the electricity-grid in the future exists, it is advisable to use 220V AC.

2.6.2 Solar system used in RDP-programme (schools)

Background information on this programme can be found in paragraph 3.3.
The solar system used has 12-18 solar panels, placed on a frame next to the building. The installed lights are working on 24VDC, an inverter(24VDC-220VAC) is installed for the plugs. Lights were installed in 3+1 classrooms (three classrooms and optional the headmasters room or another classroom). The battery box is installed in the back of 1 classroom, a tube is installed to remove the battery gasses.

In Table 4 the technical configuration of the visited systems is shown.

Part of the solar system	**Number**	**Brand**	**Power**	**Expected Lifetime**
Solar panels	12-18	Siemens, Solarex, Kyocera LA 361K51S, Helios, BP Solar, Total, FranklinH800, Suncorp SC50AL, Photowatt PWX500 and ASE SC50A	50-51Wp	20 years
Batteries	16	Raylite, Willard	96Amph	3 years
Regulator	1	Photo Voltage Regulator	-	-
Inverter	1	MLT Drives, Franklin	+/- 1KW	10-15 years
Fuses		Merlin German	Main fuse:50A Lights: 1*32A, 3*10A Plugs: 3A	-
Lights	12-16	Philips	24VDC	-

Table 4: Technical configuration RDP-systems

2.6.3 Solar system used in EU-programme (schools)

Background information on this programme can be found in paragraph 3.4.
In this programme, 1 standard system was designed and used. 8 solar panels are installed on a galvanised steel frame, next to the school building. The galvanised steel battery box is placed under the solar panels, a box containing the regulator and inverter is attached to the frame.
12 batteries are installed, and 3 or 4 classrooms are provided with lights, and a plug (220VAC). Also a TV and satellite dish will be delivered to the schools.

Part of the solar system	**Number**	**Brand**	**Power**	**Expected Lifetime**
Solar panels	8	Isofoton	110W	20 years
Batteries	12	First National Batteries, Solar batteries	510 Amph	7-8years
Regulator	1	Steca	-	10 years
Inverter	1	Steca, Solarix Sinuswechselrichter*	800W	10 years
Plugs	3-4		220V	-
Lights	12-16		15W, 220V	-

Table 5: Technical configuration of EU-systems

* (Steca)

2.6.4 Solar system used in IDT programme (clinics)

Background information on this programme can be found in paragraph 3.5.
A dual PV system was installed in the clinics, joined by a common bus, so that the critical loads could be supplied by a high-reliability generously sized system and the remaining lightening and nurses' accommodation loads could be met by a more economically sized unit. The common bus was designed to allow surplus energy from either unit to be utilised by the other. The configuration normally installed in a large clinic (with nurse home) is: 16 solar modules(50Wp), 2-4 battery banks (300Amph, 6*2.2V), 1 regulation unit, 1 inverter, 1 vaccine refrigerator, 1 street light, 10 external lights with motion detector, +/- 30 indoor lights and 20 plugs. (IDT 1999) The solar panels are installed on the roof of the clinic, or on a frame next to the clinic.

Part of the solar system	Number	Brand	Power	Expected Lifetime
Solar panels	8-16	Kyocera, Siemens	51W, 75W	20 years
Batteries	12-18-24	Willard M-11 Solar, First National Batteries		7-8years
Regulator	1	PDI prioritised, boost-float regulation, 3 priority load-shedding	30 Amp., 12 VDC	10 years
Inverter	1	ASP TC 04/12 Frontius Steca	400W, sin-wave, 80-90% efficient, fully protected 800W	10 years
Refrigerator	1	Minus 40, 90 litre, model B90-10-12V	12VDC, 45Amp, 700Wh per 24hrs at 43°C ambient temperature	15-20 years*
Examination light	1		220V	-
2-way radio	1	Moterolla GM 950		-
Lights		Osram Dulux (compact fluorescent	15W, 220V	-

Table 6: Technical configuration of IDT-systems

*(Minus-40 2001)

The estimated cost for a solar energy system range between R 100,000 for a small and R 140,000 for a large clinic (including a nurse home). (IDT 1999)

2.6.5 Technical performance of a solar system

A solar system is completely working if the amount (Ah) and quality (stable 24VDC, 220VAC) of electricity available meets the design criteria. A lot of technical problems can occur, influencing the performance. Some problems are listed below:

1. Fuse-problem: if one of the fuses in the circuit is faulty, the system will work partly or not at all, depending on the location of the fuse in the circuit.
2. Battery-problem: a lot of factors can influence the battery-performance (age, temperature, charge-cycle, maintenance etc.) When the battery performance drops, the storage capacity will go down, influencing the working of the whole solar system. In this research, when the battery performance is bad but the battery is still working, the system will be defined as "partly working".
3. Inverter-problem: when the inverter is faulty, none of the AC loads in the system is working. If only AC loads are connected, the system will be defined "not working at all" if the inverter is faulty. When also DC loads are connected (lights, refrigerator), the system will be defined partly working if the inverter is faulty.
4. Regulator problem: if there is a problem with the regulator, the batteries will not charge efficiently, causing a complete breakdown of the system, or influencing the battery-performance.
5. If a switch, light, television, radio, examination light or refrigerator is not working, the system will be defined as "partly working".
6. When other problems occur (disconnected panels, faulty wiring etc) the influence on working of the solar system can vary from working completely (for example one panel disconnected in a over-designed system) to not working at all (for example wiring from solar panels cut).

2.7 Cost comparison between solar system and grid connection

2.7.1. Introduction:

In this paragraph, the costs of a solar installation will be compared with the cost of grid extension. Only direct maintenance costs are included, so a central database, costs of keeping stock, costs for communication etc. are not included, a detailed research should define these costs.
It is very difficult to compare the costs of grid extension with the installation of solar systems, because there are a lot of factors that can influence the costs substantially. In this paragraph, a general overview of the costs are depicted, for a detailed cost analyses, taking into account all factors that can influence the costs, further research is necessary.

Only the costs for the maintenance of the solar systems on schools are discussed, because no prices were available for the clinic systems. One can expect that there will not be a big difference, as the systems are quite comparable.

The costs of the installation will be pointed out over a period of 20 years. This period is chosen because the minimum required expected lifetime of a solar panel had to be 20 years (Eskom 1999). Theft is not included in this cost calculation, after the field experiences this is a courageous assumption, but the policy of Eskom and the European Union is to add anti-burglar bars as a protection measure to reduce the vandalism.

2.7.2. Cost of Solar Electrification

The purchase and installation cost of a solar system, as installed in the field in the European Union Project, is approximately R60,000. (Louineau 2000) This includes a 1-year service contact (two visits on site, replacement of broken parts).

Cost calculation: expected lifetime 20 years

The detailed maintenance budget is presented in Appendix 4. A short explanation of the cost will be presented in the next paragraph. It is important to realise that not all costs are included: overhead costs of the maintenance, monitoring and evaluation are not mentioned (labour, computers, infrastructure etc.).

The maintenance plan includes two visits a year per site, and in the 20 years, one replacement of the inverter and the regulator are calculated. Also the costs of four replacements of the batteries is calculated. In this calculation, the prices of a RDP system are taken. There will be a difference between the maintenance costs of an EU-system and a RDP. The inverter and the regulator have similar life expectations. The batteries of the RDP systems have an expected lifetime of 3-5 years. This means for a lifetime of 20 years the have to be changed at least 4 times. The expected lifetime of the batteries installed during the EU project is 7-8 years (Louineau 2000) what means that in the calculation the batteries have to be replaced at least twice times in 20 years. The required lifetime of an inverter and regulator is 10 years. This means that one replacement has to be counted for assurance the lifetime of the system to be 20 years.

The yearly cost of maintenance in that case is approximately R5328 per system (Appendix 4)

The cost of the system over 20 years is:

Purchase and installation:	R60,000
Maintenance per year:	R5,328
Maintenance over 20 years:	R106,544

The total cost over a lifetime of 20 years are R166,544.

The inflation is left out of this calculation, as it is expected that the budgets to maintain the systems will also rise. If the whole maintenance budget for the 20 years would be put on an account in the first year, interest would compensate the inflation.

> CONCLUSION: The purchase of the system (R 60,000) is only 36 % of the lifecycle cost.

2.7.3. Cost of grid extension:

Eskom's rural tariff for conventional rural grid extension (11 or 22 kilovolts lines) costs were R28,000 per kilometre in 1992. This included transformer costs.(EDRC 1992)
In 2001 these costs are R54,500 per kilometre. The costs for maintenance (normally very low) are paid by Eskom, costs of electricity use (price for schools and clinics) are R0.42 per kWh. (Eskom 2001)
With an average use of 560 kWh/year (all lights on for 25h per week), the costs of electricity are than R 235 per year, or R 4,700 over 20 years.

The extension of the electricity line is the main costs.
Regarding the total costs of a solar system, R 166,544, the break-even point for solar electricity is 3.05 km (R 166,544/54,500R/km), when a lifetime of 20 years is expected for the solar system, and no maintenance costs for the grid line.
This means a distance of 3 km will be economical feasible to provide with grid-electricity.

> CONCLUSION: Break-even point grid-solar electrification is more than 3 km.

A remark that has to be made in this regard is that in quite a number of situations, grid extension is not a practical feasible option. Solar systems are installed in areas closer than 3 km from the grid because the electricity is needed on short term and Eskom is not able to expand the grid during the next 5 years in the whole country, because of limitations in material, finances and human recourses.
Another remark is that the electricity line will probably not be used exclusively by the school/clinic, also a number of other electricity consumers will be connected, reducing the investment cost per connection. When enough households near the school or clinic decide to purchase a connection the distance where grid electrification is feasible will increase. This means the distance can be much longer if a lot of people/businesses/schools/clinics etc. can be connected.

Chapter 3:

Policy and programmes

3.1 Introduction:

In this chapter, an overview of the non-grid electrification programmes for schools and clinics is given, focussing on the past 5 years. Because little literature was available, a lot of information was gathered by interviewing involved experts. From all the interviews and study of the available reports, a number of factors is derived that can influence the success of implementation of the projects under investigation. From the interviews, a general impression was acquired how the projects were managed, what problems could be occurring in the field etc. In Chapter 4, the Life Cycle Theory will be studied, to look at possible reasons if problems occur in the field from a theoretical point of view. This theory will also be used to structure the recommendations that will be made in chapter 8.
In paragraph 3.2, general remarks are made on the information gathering process. Paragraph 3.3 discusses the Schools non-grid electrification programme, managed by Eskom, also called RDP-schools programme in this report. Paragraph 3.4 describes the EU-funded 1000 schools programme. Paragraph 3.5 deals with the Clinics non-grid electrification programme, managed by the Independent Development Trust. In Paragraph 3.6, a chronological overview of the implemented projects is given. Paragraph 3.7 gives conclusions on which factors can influence the success of implementations.

3.2 General remarks about the Interviews and Policy research.

This paragraph gives a broader picture of the information gathering process. After a month of interviewing and reading it was clear that a lot was written down, but real "hand on policy " was never developed, evaluation reports were scarce, and if produced not easy available.

South Africa is, especially compared to Belgium and The Netherlands, a very large country. This means that responsibilities are delegated to lower authorities. This gave the difficulty that very little information was present at the central departments, and no national overview of all projects was available at all. Electrification and maintenance of schools and clinics involves the Department of Minerals and Energy, Department of Education, Department of Health and the Department of Public Works.

All departments have their specific organisational structure and their specific responsibilities. It was difficult to get the correct information, as it sometimes was fragmented over the different departments and the different levels of the department. This had as consequence that some questions remained unanswered after several interviews, because they were directed to the wrong parties, or were answered differently. The different answers (on the same questions) made it sometimes hard to judge the value of an answer.

Also to collect and derive correct information from earlier published reports was very difficult. Different reports gave different numbers, and pointed out a different perspective. This gave a broader picture of the situation, but was also very confusing at some moments.
Also ideas to improve the situations were written down from past experiences, but communication between different involved parties was not always found optimal, and most recommendations made in the past are not used at all in the following projects.

The next paragraphs give a summary of the findings of the existing policy.

3.3 RDP schools non-grid electrification programme

The programme as defined in 1995
During 1994 the Non-grid Electrification (NGE) unit in Eskom's Technology Group launched a schools electrification programme which would utilise off-grid technologies (Eskom 1995). The government project was initiated under the Reconstruction and Development Programme (RDP), and financed by the South African government and foreign funds. The objective was to electrify 1,170 schools by March 1996. A clear governmental policy was not available, as stated in (Bedford 1997): "What is clear is that Eskom is operating in a policy vacuum-whether this is policy from the Department of Energy or the Department of Education". The project description as given below, is a resume from interviews and project reports that were available.

Need identification and characteristics of end users
Areas where grid-electricity would be installed in the next 5 years were excluded for non-grid electrification. In the schools, chosen in liaison with the government departments, that were farther then 3 km from the electricity grid, lights would be installed in 3 classrooms and 1 extra room. This would be the same for all the schools, independent from the type of school (age of students, number of students and number of classrooms), no individual need assessment would be executed. A television would be provided to all schools by the Department of Education. As there was a lot of political pressure to electrify large numbers of schools in a very short period, no detailed need research was executed.

Technical design
Provision was made for lightening in three classrooms, the staff room and the principal's office, as well as one or two power outlets for a television, video, overhead projector etc. The average cost per installation, excluding electrical equipment was estimated as between R40,000 and R50,000. (Rensburg 2000) A technical description of the installed systems is given in paragraph 2.6.2.

Informing the community
Consultation with the communities where the facilities would be located, would start once the funding had been secured. (Rensburg 2000) In this community meeting, the reason for the electrification with solar energy would be explained, the system that would be installed and application forms were left.

Maintenance
The provincial Departments of Education was expected to provide for maintenance costs in their annual budgets and would be responsible for the maintenance of the off-grid systems.

Training of the user
After installation, the installer would explain the working of the system and the maintenance requirements ' to some people that were available '.

3.4 EU-funded 1000 schools programme

This programme was started in 1998. The European Union would fund the electrification of 1000 government built schools in South Africa with solar energy, 500 schools in the Northern Province, and 500 schools in the Eastern Cape. A single size system was chosen for this project. The design of the system was done by Eskom, also the implementation was managed by Eskom. The installation of the systems is planned to be ended half 2001. The system design was based on the assumption that the need for and use of electricity would increase, but no need analysis was executed.

Tendering

The tendering, started in the beginning of 1999 was divided into two parts:

- an international tender for the supply and delivery of PV modules, batteries, regulator, inverter and control gear for the 1000 systems.
- a local South African tender for the delivery to site and installation of the above-mentioned equipment, and the supply, delivery and installation of the battery enclosure, distribution board, array structure, and auxiliary equipment.

Installation and equipment

Eight solar panels of 110Wp are installed on a structure next to the building. The battery enclosure, containing 12 batteries (501Amph), is placed under the array structure. Lights and 2 plugs are installed in 4 classrooms, a steel box for a television is installed, a TV , VCR and satellite dish will be provided. All electrical loads work on 220VAC. More technical information can be found in Paragraph 2.6.3.

Maintenance

There is an installer guarantee for 1 year after installation. A visit after 6 months and 1 year was planned. After the first year, the Department of Education becomes responsible for the maintenance.

3.5 Clinics non-grid electrification programme

IDT (Independent Development Trust) was established in 1992 with funds from the South African Government to assist welfare and development amongst the poorest communities in the country. Under the IDT Health and Rural Development portfolio, one of the key aims has been to upgrade facilities for rural healthcare.

The goals

The IDT (Independent Development Trust) is involved in rural clinic electrification in a number of ways, including the following:

- the funding of the 'uneconomic portion' of the extension of the electrical network by utilities to rural settlements where there are clinics.
- the funding of the upgrading of the wiring and the electrical installation at clinics which are to be grid-connected.
- the funding of the extension of the network to existing non-electrified hospitals in the Eastern Cape Province.
- the funding of the upgrading of the electrical installation of selected rural hospitals
- the funding of the implementation of the electrification of off-grid clinics.
- the provision of a full electrical supply for off-grid clinics, including the power supply, wiring, lightening and some equipment, as well as the electrical system for nurses' quarters associated with off-grid clinics.
- the funding of a proportion of the maintenance costs of off-grid clinics during their design life.

The electrification procedure

Depending on the location of a clinic in relation to the electricity network, it is either provided with grid electricity (< 3km from the grid), a combination of a generator-plus-battery system and liquid petroleum gas (LPG) vaccine refrigeration (between 3 and 10km from the grid), or full PV electrification (>10km from the grid). Some clinics also got a small wind generator in combination with the solar system. The design of the clinic system is based on general clinic system performance requirements as well as a demand assessment by a visit to each site.

The general approach taken to off-grid implementation has been to undertake a pilot project in a chosen area of the country, and thereafter to commence in all regions simultaneously.

Once the clinics which will be electrified using off-grid technology have been identified in an area, a needs assessment survey is undertaken which involves a visit to each site. This also allows the location of the clinic to be determined accurately. This programme has been undertaken on an individual clinic base. Each clinic is visited and a needs assessment done before commencing.

Installation and equipment

Three types of solar systems were designed (small-medium-large), depending on the energy needs of the clinic. Lights inside and outside the clinic and in the nurses house, a communication radio, a fridge and a medical light were provided (large systems). More technical information can be found in Paragraph 2.6.4.

Maintenance of the systems

The IDT programme makes extensive provision for the maintenance of off-grid systems, as this is recognised as essential to ensure long-term sustainability. As a part of the contractor's obligations the entire PV system is guaranteed for 12 months, while the contract also requires that PV panels be guaranteed for ten years. A full set of spares is also stored at the provincial department of Health offices as a part of the installation contract. The IDT also planned to establish a Joint Maintenance Fund in which money would be deposited for continued maintenance of installed clinic PV systems for the next ten years. This would amount to approximately R15 000 per clinic. This Fund has never fully taken form.

Funding of the programme

IDT gets its funds from the South African Government. No foreign funds were used in the rural electrification of clinics.

3.6 Projects chronological:

In Figure 10, the projects that are studied in this report, and the important programmes are placed in chronological order. This is a general overview, that is not pretending to enumerate every PV-project on schools and clinics in South Africa of the past years.

1991-94 Pilot projects on PV-system use set up by the Technology Department of Eskom, section Energy Technologies.

1992 Independent **D**evelopment **T**rust was established, to focus on the poorest of the poor.

1994 Elections and start of ***R**econstruction and **D**evelopment **P**rogramme.*

Eskom started to electrify rural areas to meet the RDP-goals. The Non-grid Electrification (NGE) unit in Eskom's Technology Group launched a *schools-electrification-programme* which would utilise off-grid technologies
There was no governmental policy on rural electrification yet, and Eskom used own budget to finance the rural electrification projects. A very ambitious gaol was set to electrify 1000 schools per year (grid and non-grid).
1340 schools got a solar system under this programme

The IDT started to electrify rural clinics, in co-operation with the Department of Health. No governmental policy on rural electrification of clinics was available.

1994 Eskom opened non-grid electrification offices in Pietersburg, Kimberley, Kwazulu-Natal and in the Eastern Cape.

1995 Comprehensive survey of all clinics in Eastern Cape undertaken as a joint project between IDT and Provincial DoH.
Joint decision taken between IDT and DoH that Region E will be the pilot area for the clinics electrification programme in the Eastern Cape.(Bedford 1997)

1996 The Department of Education carried out the 'School register of needs survey'.

1996 IDT provided 50 clinics with PV in Region E in the Eastern Cape, then another 50 clinics in Region D in the Eastern Cape (Phase 1 IDT). (Percell 2000)

1998 Start of the EU-1000 schools programme. The actual installation started in 1999, and is planned to be finished in June 2001.

1998 Eskom electrified 90 schools with PV-systems, grant from Dutch government

The *White Paper on the Energy Policy* was published.
In this paper is defined that annual connection targets, and related subsidies, will be allocated for off-grid electrification in accordance with the national electrification strategy.

1999 The second phase of the IDT clinic electrification is started (Eastern Cape).

2000 The **N**ational **E**lectrification **Co**-ordinating **C**ommittee (NECC)designed a policy document on the electrification of South Africa.
Grid and non-grid electrification goals are set, as well as a clear distribution of responsibilities and involved parties. Also the financing of the rural electrification is described.

Figure 10: Non-grid electrification projects chronological

3.7 Conclusions of literature study and interviews with experts:

From interviews and discussing the policy, the aspects that can influence the success of implementation are derived. These aspects will be used to base the conceptual model on in Chapter 5, on which the questionnaire that will be used in the field research is based. The success of implementation is defined in 1.3.2 as the technical performance of the solar system (compared to the design criteria) and the satisfaction of the user. These aspects are derived from all interviews and reports that were studied, so not all references are inserted.

Need

The need for a product or a service is essential to make implementation a success. Especially products and services that are supplied for free (top down), a proper need assessment needs to be done. In a market economy, products have to fulfil a need otherwise no customers will purchase those products or services (bottom up) (Westra 2001). This means that a need analyse is an important factor that influences the success of implementation.

The need for electrification of schools and clinics was driven by the government, stated in the Reconstruction and Development Plan. No detailed need analyses of the schools was done, which can be a reason for the high level of non-functioning in the schools programme. (Percell 2000) The decision was made to install lights in three or four classrooms and provide a TV with a VCR. For the EU-funded programme, the same as for the RDP schools need was assumed. The Independent Development Trust (IDT), that managed the electrification of the clinics, had done a need study (EDG 1993).

A conclusion of an evaluation of a Solar Home System Project in the Freestate also mentioned: "Greater participation by workers in determining the need for solar electricity, as an alternative to grid electricity and in the process of supply, installation, operation and maintenance would ensure better utilisation and reliability." (Hochmuth 1998)

Hypothesis

- **An increased need for applications that require electricity will on average lead to an increase in success of implementation.**

Involvement of the user & Knowledge of the user

If the headmaster and teachers are not interested in the system and don't feel involved, this can have a big influence on the working of the system. (Mackay 2000) Technology use and maintenance requires knowledge and involvement. This involvement, in most cases, comes from the advantages the user has or can have. The more knowledge a user has of the implemented technology, the better he will be able to adopt his behaviour to use the technology. (Slaughter 1992)

The knowledge and involvement is important according to Eskom and the EU as they employed fieldworkers to inform teachers and try to involve the local communities. (Louineau 2000) User training was an item in all projects.

Hypothesis

- **An increased involvement of the end user of the solar system will on average lead to an increase of the success of implementation of solar systems.**
- **Increase of knowledge of the end user of the solar-system will on average lead to an increase of the success of implementation of solar systems.**

Environmental Characteristics

Environmental characteristics could, similar to characteristics of the user (Need, Involvement and Knowledge), have an impact on the performance of the system and satisfaction of the user. The availability of communication to report problems with the system, and the condition of the road are examples of environmental aspects that can influence the performance of the system. (Mafu 2000)

In the selection criteria of the schools, the item "condition of the school" is mentioned as being important for the success of implementation. Non-permanent structures are not selected in the programme. Also the possible alternatives (grid extension) are indirectly mentioned in the selection criteria, as the selected school or clinic may not be in the grid extension plan of the next 5 years of Eskom. (EU school project selection criteria, and IDT selection criteria). Especially in areas with very bad roads, mountainous areas, areas without fixed telephone lines or GSM cover and areas with a lot of crime, these environmental circumstances have to be considered.

Hypothesis:

- **Typical environmental characteristics of the rural areas in South Africa will influence the success of implementation.**

Technical design

The technical design has a major influence on the performance of the system. A system with maintenance free batteries, that have a longer lifetime and require no maintenance but are more expensive, can perform totally different from a system with short lifetime batteries (Adams 2001). To do a research on the technical performance, it is essential to compare the technical specifications with the performance in the field. The technical specifications of the different systems can be found in chapters 2.6.2 to 2.6.5.

The quality control of all parts of the solar system, the installation and the maintenance can play an important role in the success of a project. (Louineau 2000)

Hypothesis:

- **The technical design of the solar system influences the success of implementation.**

Ownership of the system/responsibility/financial aspects

The owner of a product or service is normally the person or the company that pays for it. In the case of supplying the solar systems to schools and clinics in rural areas, where the system is supplied for free to the user, ownership is not always that clear. Also the allocation of different responsibilities to all involved parties are not always clear. In the policy, ownership and the different responsibilities (the installation, funding of the systems, maintenance of the system, funding of the maintenance, informing the users etc.) are defined generally. No strong commitments are made. In interviews ((Rensburg 2000), (Bezuidenhout 2000),(Adams 2001), (Percell 2000)) it was pointed out that the allocation of responsibilities was not clear in the past, what caused a lot of problems. Because the systems are provided to the schools and clinics for free, some users don't feel responsible for it, and do not report when there is a problem. (Otto 2000)

Hypothesis:

- **Clear allocation of the responsibilities to involved parties enhances the success of implementation.**

Security

Security of the system is a specific item that influences the performance of the solar systems. In the standard design of a solar system, theft prevention is not a design criteria, although it can be important, especially because the schools and clinics are completely desolated several weeks during the year. Security did not appear in any policy or theory, but was found out throughout the experience of experts. Theft was assumed to be an important cause of non functioning of the solar systems. (Mackay 2000) In the EU-programme, all solar systems will get anti-burglar bars around the panels, because of experienced problems with theft. In an audit of energy usage in Kwazulu-Natal (Green 1998), security of the technology associated with harnessing solar power is a problem in the area, with theft of the solar panels from public places not an uncommon occurrence.

Hypothesis

- **The security of the solar systems (protection against theft and vandalism) will influence success of implementation of solar systems.**

User training and informing the community

As stated in Knowledge and involvement of the user, it is important to have knowledge on how to use and maintain the system, and report problems. Training is an important variable to improve knowledge on the system. The informing of the community can improve the involvement of the community to protect and maintain the system. (Rensburg 2000) If the community sees the benefits of the solar systems for the children, patients and themselves, they will be motivated to do some effort to keep the system working.

Responsibility for the training is stated in the policy of the different projects. The installers have first responsibility to train the staff (RDP, EU). For the IDT project, the responsible part for the training was IDT (the training was done by a consultant). For the EU-funded programme, fieldworkers were employed, who work under supervision of Eskom, to improve the informing of the community.

Hypothesis

- **More/better training of the end users will in general lead to an increase of the success of implementation of solar systems.**
- **More involvement of the end users and the community members will in general lead to an increase of the success of implementation.**

Financial aspects:

Of all the responsibilities, the financial aspects are taken apart. In South Africa, the involved parties have their own responsibilities and limited budgets. This makes it very important that financial issues are directed and executed strictly. In the areas and schools/clinics were the systems are installed, almost no budget is available for the maintenance of the solar systems.

Directing different financial aspect to different parties might have an influence on the success of the implementation.

Hypothesis

- **Clear allocation of finance and differentiation of financial responsibilities enhances the success of implementation of solar systems.**

Chapter 4:

Life Cycle Theory

4.1 Introduction

The implementation of technology in a certain environment requires knowledge both on the technology itself and the society it will be used in. Society in this context must be seen as the people as well as the environmental aspects. The sociological aspects will influence and determine certain technological performance aspects. Especially in the case of transferring a high tech product like a solar system in a country with third world characteristics, the non-technical aspects can be very important to reach a successful implementation. Where a solar system has proven to work perfectly in a first world environment, totally different implementation problems can occur in a less developed society. One can not ignore the skills and cognition of the users, available infrastructure, financial situation, user environment etc. To solve the occurring problems, the whole lifecycle of the product from need analyses of the user to disposal of the product must be reviewed.
This is why the Life Cycle Theory is used to derive factors that can influence the success of implementation.

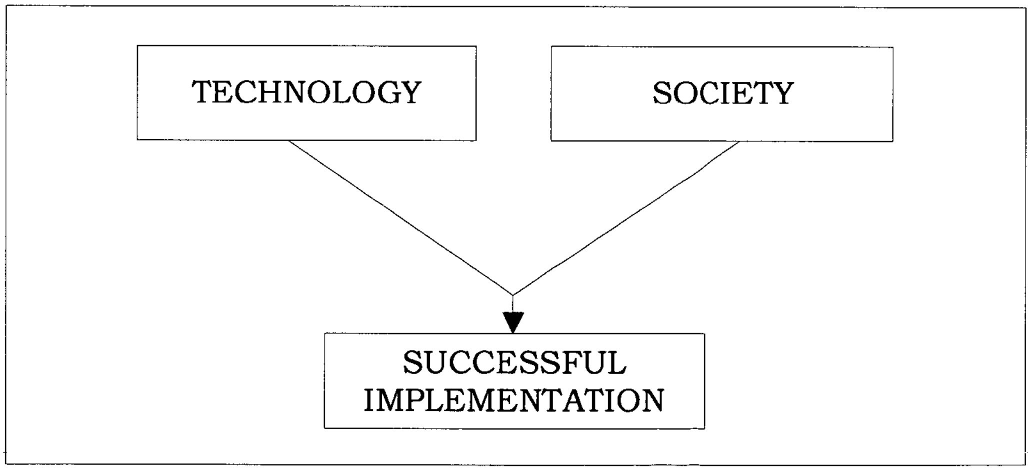


Figure 11:Technology and society

The aim of this research is to come to recommendations for the design and implementation of solar systems in the future. The life cycle theory describes the different stages of a product from need identification before design, manufacturing use till disposal.

The Life Cycle Theory is chosen to derive factors that can influence the success of implementation in the different design stages. This theory is also chosen as a framework to structure the recommendations on future design and implementation of solar systems.

Paragraph 4.2 describes all the phases of the Life Cycle of a product. In Paragraph 4.3, the Support and Service Lifecycle is described, emphasising the importance of taking into account all aspects beside the technical product itself. In Paragraph 4.4, it is stressed that it is important to visualise the whole lifecycle cost, not only the cost of purchasing the product. In Paragraph 4.5, conclusions are made on the factors that can influence the success of implementation, derived from the theory.

4.2 Product Life Cycle

If a complicated system as a solar system will be used for the electrification of rural schools and clinics, it is important to consider the overall system of which the solar system will be a part. From the early stage of the design of the system, the whole lifecycle must be kept in mind during the engineering. Fundamental is an understanding of the life-cycle process, illustrated in Figure 12.

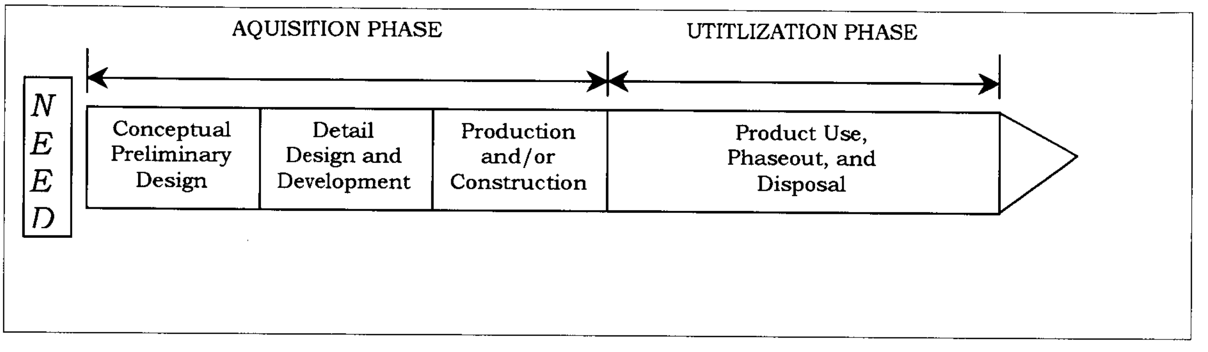


Figure12: Product Life Cycle (Source[Blanchard, 1997 #34])

From the field data, most information on the utilisation phase is gathered, although from the interviews of key persons and literature study, also some information on the acquisition phase of the solar systems is used in the report. From a technology-management point of view, the acquisition phase is technically-dominated, whereas in the utilisation phase more social factors will have an important influence on the performance of the solar system.

4.2.1 Acquisition phase:

1. Need identification:

The lifecycle begins with the identification of the need of the user. Defining the exact problem is the most difficult part. However, a design project is often initiated as a result of a personal interest or a political whim, without first having adequately defined the requirement. (Blanchard 1997)
It is essential that the result of the description of the current deficiency and need truly reflect a requirement. This objective can be met best by involving the user in the process from the beginning.
For schools and clinics, a proper need-analyses needs to be done, to find out what the needs for electricity are. It might appear that the need for electricity has not a as high priority for the end user as expected, or that other needs have a much higher priority. It is also important to realise that need for electricity and its applications will change over time, as people get used to availability of electricity.

2. Conceptual design phase:
After the definition of the need, it is then necessary to (1) identify possible system-level design approaches that can be pursued to meet the need, (2) evaluate the most likely approaches in terms of performance, effectiveness, maintenance and logistic support, and economic criteria; and (3) recommend a preferred course of action.
It is at this early stage in the life cycle that major decisions are made relative to adapting a specific design-approach, and that the results of such decisions can have a great impact on the ultimate characteristics and life-cycle cost of a system. Not only the capital costs of the different options are compared, but more important the life-cycle cost of the complete system.

In this research, the design decisions for the used solar systems in schools and clinics were made in the past, consequently only an evaluation of these decisions is possible in this research.
For rural schools and clinics, three system-level design options were possible:

1. The electrification of the school/clinic by expansion of the electricity-grid.
2. The use of non-grid electricity: fuel powered generators, windmills, a solar system or a combination of these.
3. For the clinics refrigerators, also gas was an option.

The decision was made that schools that were located further then 3km from the existing grid, would get a solar system. (Rensburg 2000) Clinics that were between 3 and 10km from the existing grid would get a generator, clinics further than 10km from the grid would get a solar system. (Percell 2000)

After the need analysis is combined with the selection of feasible technical approach, one is ready to project the relevant information to derive anticipated operation requirements, including the following considerations: (Blanchard 1997)

1. *Operational distribution or deployment*:-the number of customers sites where the system will be used, the geographical distribution and deployment schedule, and the type and number of system components at each location. The number of system that has to be implemented can have a major influence on the quality and success of the programme. Under the RDP programme, 1340 solar systems were installed, while the IDT installed 100 systems in the same period of time. (Percell 2000)

2. *Mission profile or scenario*-what is the system to accomplish and what functions must be performed in responding to the need?

3. *Performance and related parameters*-definition of the basic operating characteristics or functions of the system. What are the critical parameters needed to accomplish the mission at the various sites?

4. *Utilisation requirements*-anticipated usage of the system in accomplishing its mission. This refers to hours of use per day, maximum load that can be connected etc.

5. *Effectiveness requirements*-system requirements to include cost/system effectiveness (for example: automotive batteries-maintenance free batteries), operational availability, dependability (for example: refrigeration for clinics), reliability mean time between failure (quality of components), failure rate (life time of lights installed), maintenance downtime, user skill levels etc.

6. *Operational life cycle (horizon)* -the anticipated time duration that the system will be operational. Is the solar system is seen as a temporary solution for electrification (5-10 years), or as a long term solution?

7. *Environment*-definition of the environment in which the system is expected to operate in an effective manner. This is a very important aspect when first world technology will be used in a third world environment. The temperature, dust, rain, accessibility, natural environment, etc. must be taken into account, as it can influence the success drastically (for example the lifetime of batteries will decrease when exposed to big temperature changes [Zusammenarbeit), 2000 41]).

<u>3. Detail Design and Development:</u>
In this phase a detailed design of the chosen system will be put up. The different parts will be defined, decisions about developing new parts or buying parts have to be made. Also a detailed system maintenance-plan and logistic support requirements need to be developed.
In the case of a solar system, the system design will be put up from the need identification of the schools and clinics. In the Figure 13, a flow chart of this design is given.

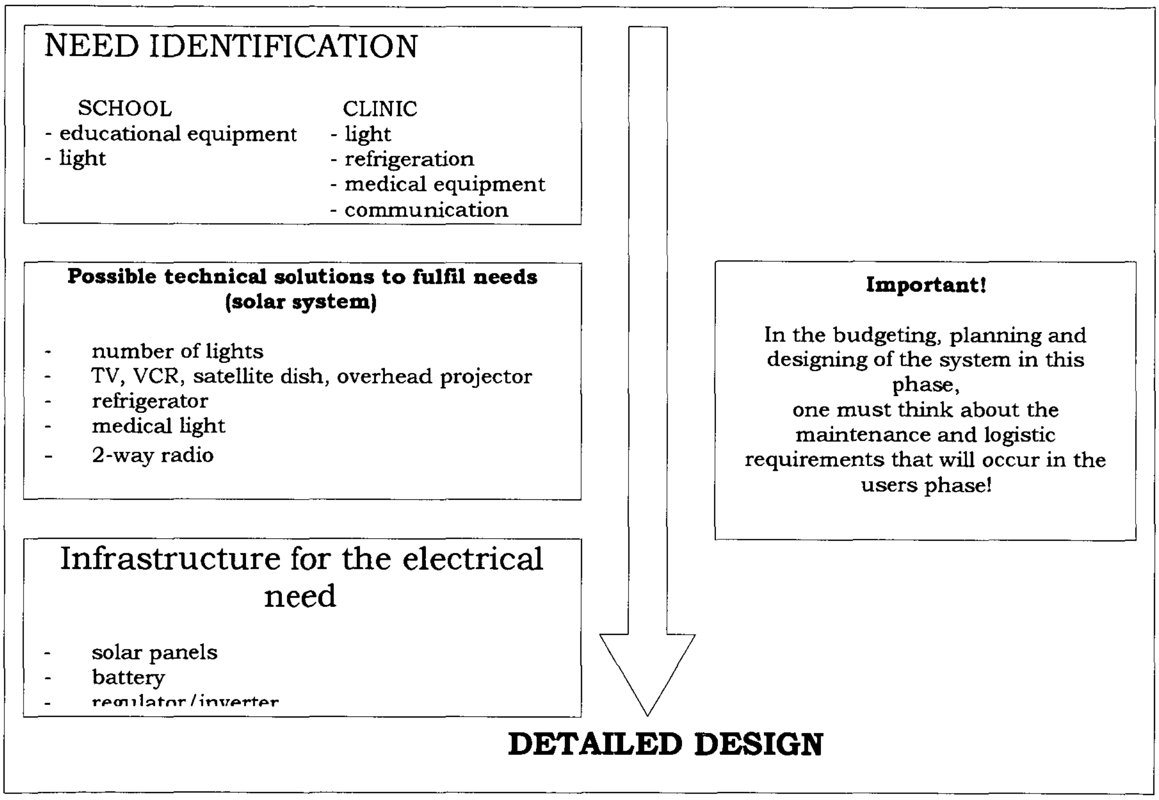


Figure 13: Detailed design: flow chart

<u>4. Production and/or construction.</u>
During this phase, no big changes to the system-design can be done anymore.
In the case of solar systems, the production of the different parts will be done in specialised production plants (solar panels, batteries, inverter, regulator, lights, etc.). The frame for the solar panels will be installed at the place of use, as well as the wiring of the building and the installation of the solar system parts. The environmental conditions in rural areas (condition of roads, weather, distances,etc.) can influence the installation of the system significantly.

4.2.2 Utilisation phase:

In the case of a solar system in a developing rural area, it is important to realise that the utilisation phase can only start after a proper training of the users, as no basic knowledge on solar electricity will be present by the user. The use of the system and the maintenance procedures will have to be explained very clearly. One must also realise that the user of the system can/will change over time due to rotation of the staff, so a continuos training system will have to be available.

In the utilisation phase, also the parallel lifecycle, or Support and Service, will be extremely important to keep the solar system working. This lifecycle is described in the next paragraph.

4.3 Support and Service Lifecycle

There is also the lifecycle of the product support and service capability, which runs parallel to the product lifecycle. Logistic and maintenance requirements planning should begin during product conceptual design in a co-ordinated manner, but is often neglected. The performance of the system can be influenced when no reliable support and service planning is designed.

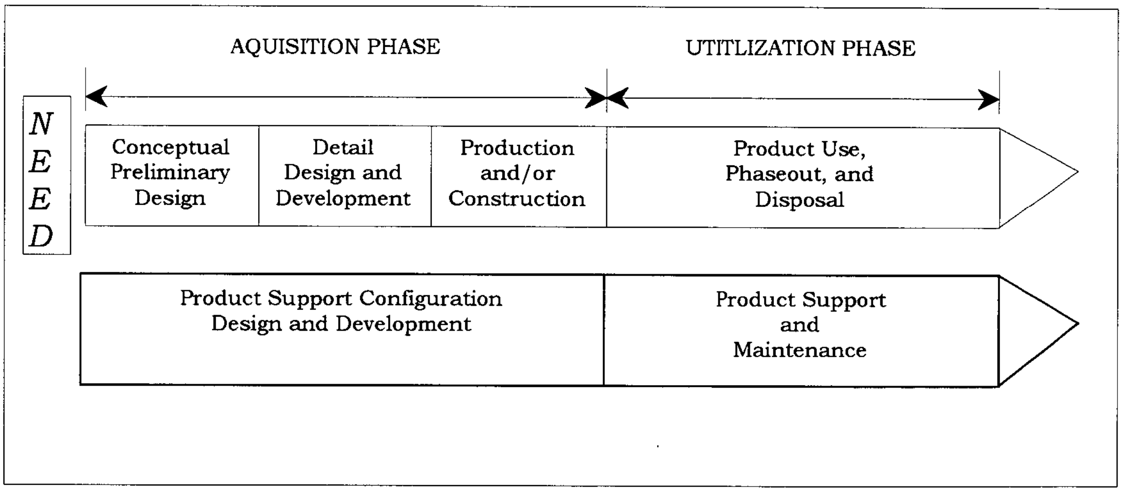


Figure 14: Support and service lifecycle (Source: Blanchard 1999)

It is essential that all aspects of the systems be considered on an integrated basis from the beginning. This includes not only the prime-mission oriented elements of the system but the support capability as well. So one should also address the characteristics of design as they pertain to the supply support network (i.e. spares, repair parts, and operating inventories), test and support equipment, personnel and training, facilities and technical data.

The maintenance concept generally includes the following information:

Maintenance Concept Information:
▪ Levels of maintenance ▪ Repair policies ▪ Organisational Responsibilities ▪ Logistic Support Elements ▪ Effectiveness Requirements ▪ Environment

Figure15: Maintenance concept information (Source: Blanchard 1997)

Levels of maintenance: Corrective and preventive maintenance on the system itself may be accomplished on three sites: (1) the site where the system is being used, for the solar systems at the school or clinic, (2) in an intermediate shop near the user site, at district or provincial workshop or local contractor for the solar systems, (3) at a depot or manufacturer plant facility. Anticipated frequency of maintenance, task complexity, personnel skill-level requirements, special facility needs, and so on, dictate to a great extent the specific maintenance functions to be accomplished at each level.

Repair policies: There may be several possibilities specifying the extent to which repair of a system or system component will be accomplished. For the solar systems, the choice which parts will be repairable have to be made, before a maintenance plan can be designed.

Organisational responsibilities: The accomplishment of maintenance may be the responsibility of the customer, the producer or supplier, a third party (contractor) or a combination thereof. The responsibilities may vary, not only with different components of the system but as one progresses in time through the operational use and system support phase.

Logistic support elements: These elements include supply support (spare and repair parts, associated inventories, provisioning data), test and support equipment, personnel and training, transportation and handling equipment, facilities, data and computer resources.

Effectiveness requirements: This constitutes the effectiveness factors associated with the support capability. In the supply support area, this may include a spare part demand rate, the probability of spare parts being available when required etc. In transportation, transport rates, transportation times, the reliability of transportation and transportation costs are of significance. For personnel and training, one should be interested in personnel numbers and skill levels, training rates, training times, and training equipment available. The effectiveness requirements applicable to the support capability must complement the requirements for the overall system.

Environment: Definition of the environment can be very important for the maintenance and support. For the solar systems, the distance to the tarred road and the condition of the dirt roads, the distance to the nearest part supply depot, the stability in the environment, etc. have to be taken into account for maintenance activities and related transportation, handling and storage functions.
In the case of solar systems that will be used in underdeveloped rural areas, these this environment information can be extremely important for both acquisition and user phase of the lifecycle. The construction of a solar system in a difficult inaccessible area will influence the design criteria and the planning. In the user phase, the design of user-manuals and training will have to be suited to the end-user, the maintenance plan and linked logistics will have to look at all the environmental aspects.

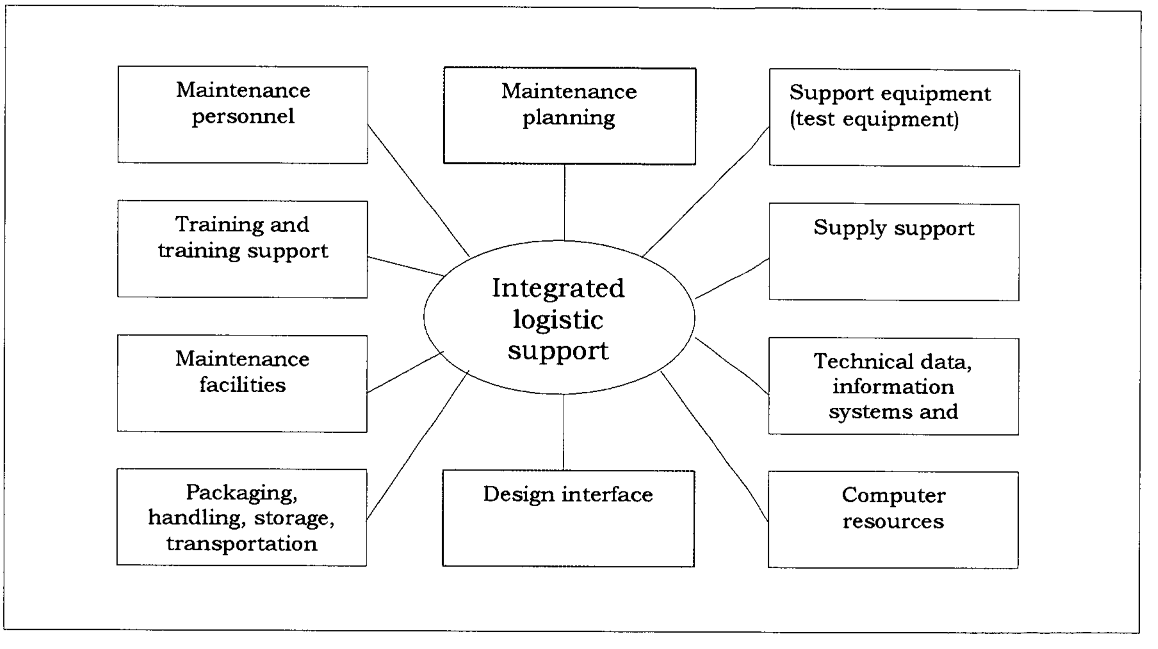


Figure 16: The elements of support (Source: Blanchard 1997)

In Figure 16 the elements of support are shown. These elements have to be integrated to support the infrastructure to maintain the system.
To look at the logistic part of the maintenance is very important, especially when the systems are implemented in rural areas, where education and infrastructure of road and telecommunication are less developed.

4.4 Life Cycle Cost visibility problem: 'The Iceberg Effect'

Total system cost is often not visible, particularly those costs associated with system operation and support. The cost visibility problem can be related to the 'Iceberg Effect', illustrated in the Figure 17. (Blanchard 1997) One must not only address system acquisition cost, but other costs as well. Doing quality control on the installation, putting up a service an maintenance infrastructure, training of installers, users and maintenance personnel, future maintenance and replacement costs etc. have to be considered at the start of the project. The "invisible costs" must be visualised clearly, otherwise a sustainable implementation is impossible.

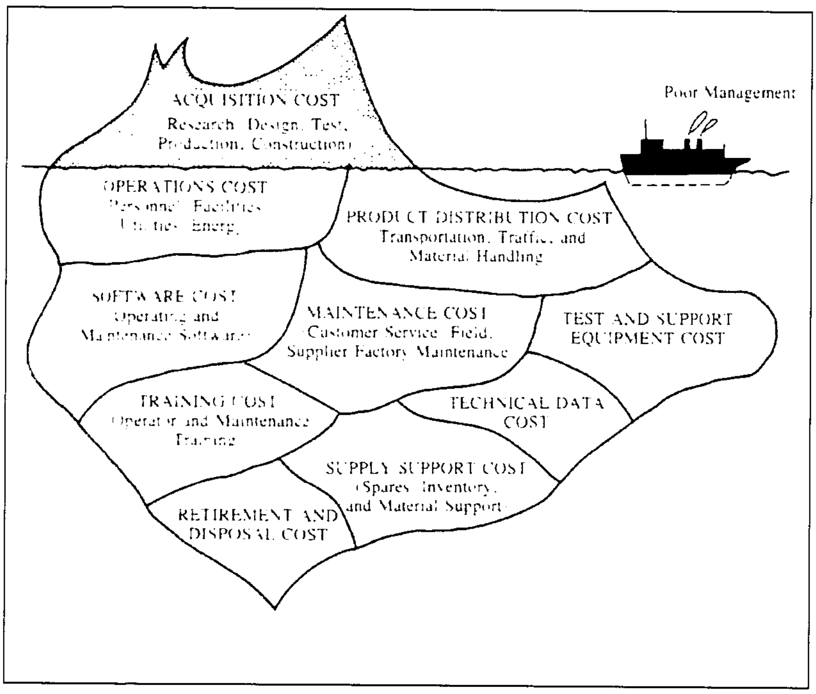


Figure 17: Total cost visibility (Source: Blanchard 1997)

An example in this regard, is a Solar Home Systems project in Indonesia, where there is no cost-effective way to properly service the solar systems, because populations are so dispersed. (Philips 2000) If in a project like that only the purchase cost of the solar systems are reckoned, sustainable implementation is impossible.

In Paragraph 2.7 and Appendix 4, a calculation of the life-cycle cost of a solar system is done, taking into account the purchase and the maintenance costs. No costs for training and overhead costs for the maintenance are included, therefor further research is necessary. It is important at the start of a project, to consider all the costs and allocate budget for it, and not the "top of the iceberg" alone, being the purchase of the solar system.

4.5 Conclusions of the Life Cycle Theory:

Together with the factors that were derived from the policy and discussions with experts in Chapter 3, also from the theoretical point of view, some factors that can influence the success of implementation of the solar systems are added to the conceptual model. In Chapter 5, all the factors will be placed in a conceptual model, which is the base for the design of the questionnaire. With the results of the field research, conclusions about the success of implementation can be drawn, and recommendations made for future projects.

Need
In the lifecycle theory, the need is stated as an important variable for the success of implementation, as the whole design must be based on the needs of the user. It will be tested in the field if this need is fulfilled with the implementation of the solar system. Practical this means that the user has applications that require electricity, and have a need for the applications. The following hypotheses was also derived in Chapter 3.

Hypotheses

- **An increased need for applications that require electricity, will on average lead to an increase in success of implementation.**

Technical design
The product is designed to fulfil the need that was analysed in the first phase of the life cycle. This technical design will obviously have an influence on the success of implementation.

Hypotheses

- **The technical design of the solar system influences the success of implementation.**

Characteristics of the environment
In the conceptual design phase, the characteristics of the environment are stressed, because in the case of the solar systems, the technology will be used in an environment with special, demanding characteristics. Environmental aspects also influence the support and maintenance structure. This aspect also followed in Chapter 3 from interviews of experts, who experienced the difficulties in the field.

Hypotheses

- **Typical environmental aspects of rural areas in South Africa will influence the success of implementation.**

Maintenance
In the maintenance and service lifecycle paragraph is discussed that the maintenance and support structure is important for the sustainability of the systems, what means that a maintenance structure is essential for the success of implementation on the long term.

Hypotheses:

- **The availability of a maintenance and support structure on average improves the success of implementation of solar systems on longer term.**

Chapter 5:

Conceptual model

5.1 Introduction

In this chapter, a conceptual model is presented that contains all the factors that can influence the success of implementation of the solar systems in rural schools and clinics. The conceptual model is designed to do a field research in the rural areas, to see what problems occur, what the causes of the problems are, and make recommendations for future solar projects. As it is a practical research, focussing on the specific situation of solar systems in rural areas in South Africa, the aim is not to develop a complete theoretical model, but to design a tool to structure the map of the field situation.
The factors that are supposed to have a possible influence on the success of implementation are derived in Chapter 3 from the policy reports and discussions with experts, and in Chapter 4 from the Life Cycle Theory.
On each factor, a number of questions will be put in the questionnaire.
The data from the field research will be analysed to discover possible relations between all the factors and the success of implementation. This information will be used as feedback for future projects, this is further explained in Paragraph 5.3. The Life Cycle Theory will be used to structure these recommendations.

5.2 Conceptual model

The conceptual model will be used to investigate the relation between the different factors and the success of implementation of solar systems. This can only be done by evaluating the current situation in the field, as the previous phases of the life cycle theory (pre-design activities, design, production, installation) are executed in the past. The aim is to relate possible occurring problems in the field to one or more factors, so that recommendations can be made.

Dependent variable:
In the model the dependent variable is success of implementation. As explained in paragraph 1.4.2 and shown in figure 2 the success of implementation depends on 2 variables:

1. Is the solar system working technically, meeting the design specifications?
2. Does the solar system fulfil the needs of the user, is the user satisfied with the system?

The success of implementation will be determined in two stages: first the technical performance of the system will be looked at: three categories are used (working completely, working partly and not working at all). This is explained in detail in paragraph 2.6.5. If the system is not working at all, there is no success of implementation at all. Secondly, when the system is working partly or completely, the user satisfaction can influence the general success. Figure 18 visualises this reasoning. As satisfaction is very difficult to measure in a short interview (especially when the research is executed by two white researchers in the rural areas in South Africa), also side remarks and the impressions of the interviewers will be used. Also external factors can influence the satisfaction dramatically: When grid electricity was promised to the people in an area, it is possible that they will complain about the limitations of solar energy, no matter what the performance of the system is.

It is clear that it is very difficult to create a quantified scale of success of implementation for the solar systems. All the more because no clear mission profile was defined in the solar projects (where should the system be used for, how many hours per week, what is the ultimate goal?), where the field situations could be compared with.

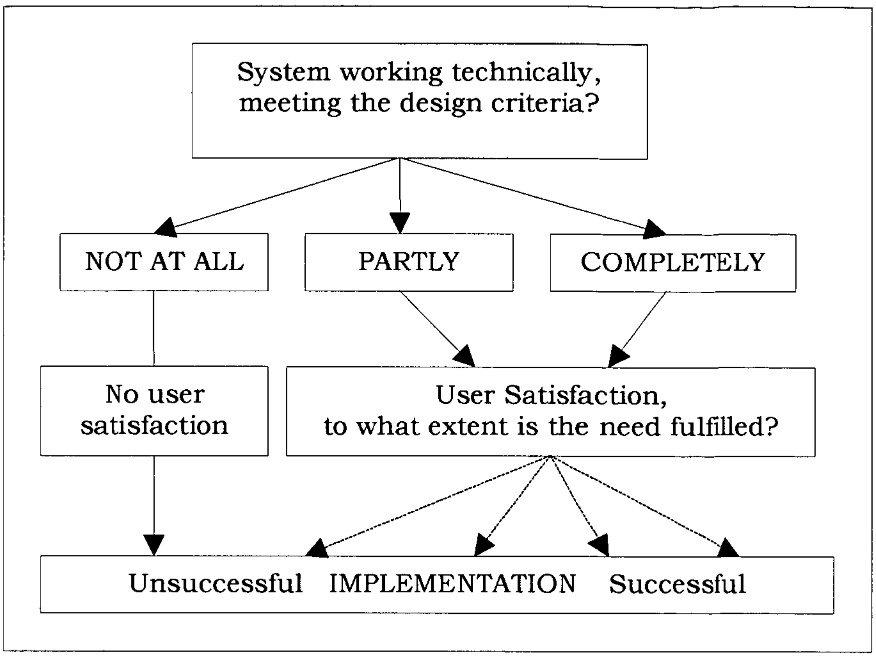


Figure 18: Success of implementation

In this research, no quantitative scale of the success of implementation is designed, the extremes are unsuccessful and successful. The zone in between will be filled by analysing the remarks the users gave during the field research.

Independent variables:
The independent variables are the factors (as presented in the conclusions of Chapter 3 and 4) that can influence the dependent variable, the success of implementation. The mutual relations between the different independent variables are taken into account, but are not tested in this research.

In Chapter 3 and 4 the following hypotheses were set up:

- An increased need for applications that require electricity, will on average lead to an increase in success of implementation of solar systems.
- An increased involvement of the end user of the solar system will, on average, lead to an increase of the success of implementation of solar systems.
- Increase of knowledge of the end user of the solar system will, on average, lead to an increase of the success of implementation of solar systems.
- Typical environmental characteristics of rural areas in South Africa will influence the success of implementation.
- The technical design of the solar system influences the success of implementation.
- Clear allocation of responsibilities to involved parties enhances the success of implementation.
- The security of the solar systems (protection against theft) will influence success of implementation of solar systems.
- More/better training of the end users will in general lead to an increase of the success of implementation of solar systems.

- More involvement of the end users and the community members will in general lead to an increase of the success of implementation.
- Clear allocation of finance and differentiation of financial responsibilities enhance the success of implementation of solar systems.
- The availability of a maintenance and support structure on average improves the success of implementation of solar systems on longer term.

The hypotheses represent the factors that appear in the conceptual model. In Figure 19, the conceptual model is visualised. On these hypotheses, the questionnaire will be based to verify if these relations occur in reality.

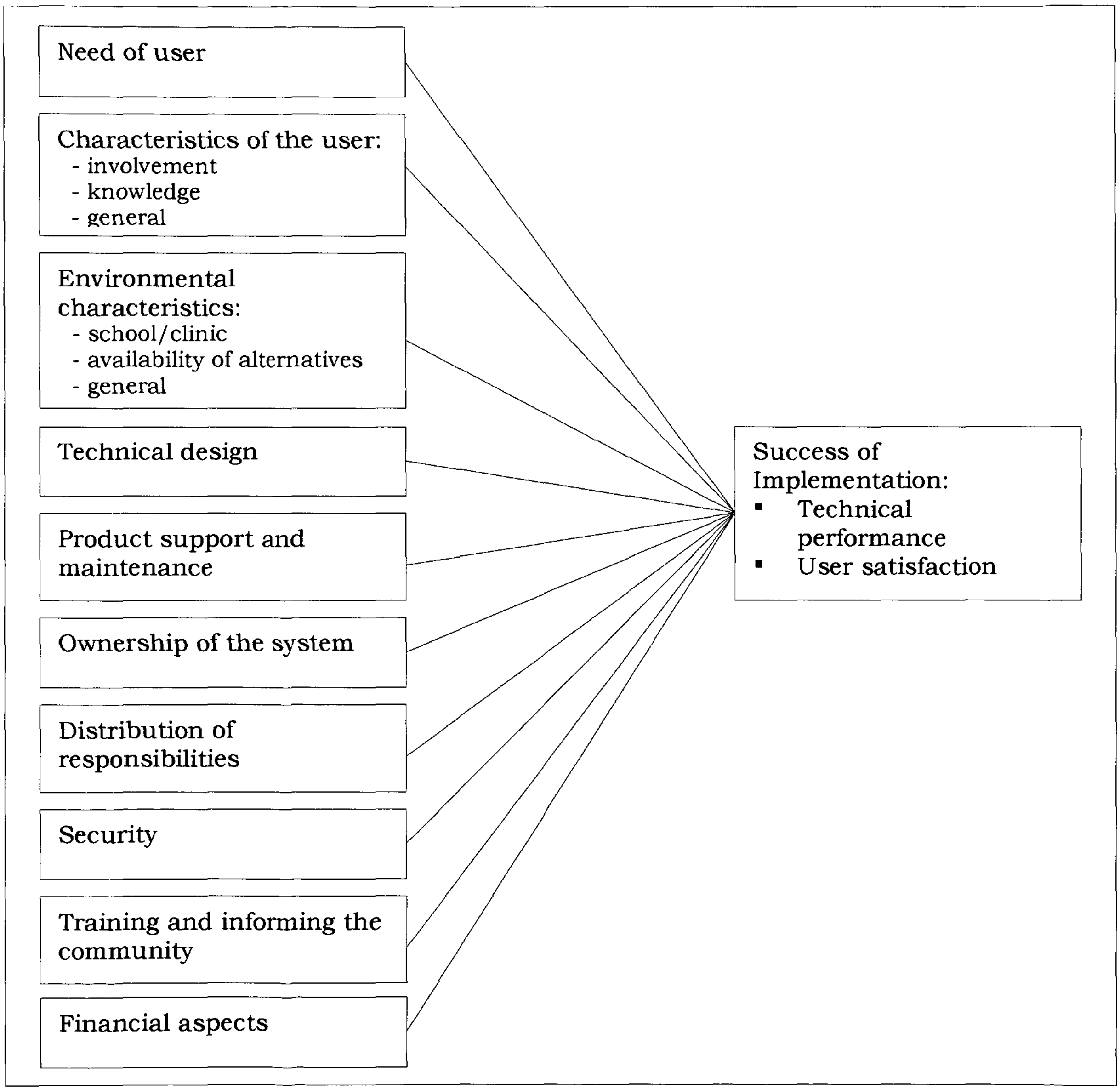


Figure 19: Conceptual model

5.3 Feedback

The information that will be gathered in the field research on each factor will be analysed and used as feedback for future projects.

In the acquisition phase, all the external factors that can influence the system in the user phase, have to be taken into account. In the ideal situation, the user need is completely fulfilled by a completely working system, based on a design that has taken into account all the external factors that can influence the use and service and support of the system.
In a practical situation however, the design will never be perfect. This is why good feedback loops have to be implemented, to evaluate the success of implementation and use this information to make changes in the design. In this evaluation process, all the factors that can influence the success of implementation have to be investigated. Information on these external factors will then be used to change the design of the system.

The feedback of the evaluation of the different factors to the previous stages in the lifecycle is shown in Figure 20.

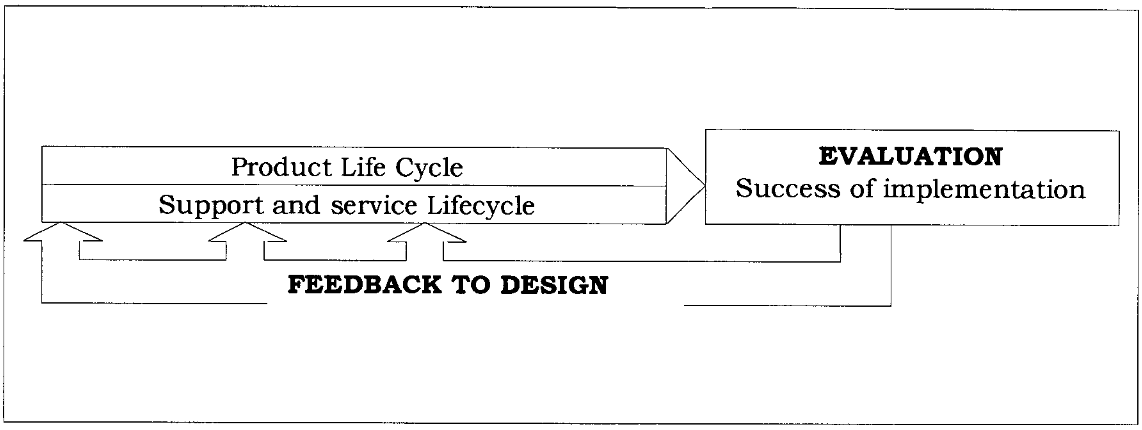


Figure 20: Feedback of evaluation to design

Chapter 6:

Research methodology of survey

6.1 Introduction

This chapter describes the methodology used to test the conceptual model presented in chapter five. The methodology to come to this conceptual model was described earlier in Paragraph 1.4.
For the testing of the conceptual model, a survey was used, and data collected in the field. In the survey, a sample of 142 schools and clinics that were equipped with a solar system was visited. During the visits, a detailed questionnaire was used to interview users of the solar system and also data was gathered by observation. A survey is the most suitable way to gain a lot information about the condition of the solar systems, the users and the environment.

Paragraph 6.2 describes the design of the questionnaire that was used during the visits, the complete questionnaire can be found in Appendix 2. In Paragraph 6.3 the sample design is described in detail.

6.2 Questionnaire design

To be able to do a good evaluation of the installed systems, it is important to set up a questionnaire in which the dependable variable can be linked to the independent variables. See Appendix 2 for the questionnaire.
The questionnaire used in this research focussed on the factors that can influence the success of implementation of solar systems. These factors, derived from Life Cycle Theory, interviews of experts and an exploring survey in the field, were used to design the conceptual model presented in chapter five. Al these parameters can have an impact on the usability, performance, lifetime, and sustainability of the system and so on the success of implementation. After the analysis of the gathered data, the influence of the different parameters on the success of implementation will be determined. Some factors will influence each other, but these mutual relations will not be focussed on in this research.

The design of the final questionnaire was done in a few steps. The first step was the study of some examples that were used in other research reports. By interviews of, people of the central government, people of Eskom and IDT that worked on policy aspects and gave direction on the implementation of solar energy, local and provincial government and fieldworkers who had a more practical view, the information was gained.
The second step was the design of a draft questionnaire. The consistency and ease of use of this questionnaire was validated in field visits to a sample of 6 schools in the Northern Province. Also a community meeting was attended. Then these practical experiences were processed, and the questionnaire was sent to experts in the rural energy business to utilise their comments.
An exploring survey in the field was executed for two major reasons. First, to enable the researchers to improve their understanding and feeling of the field situation as well as to facilitate planning for the fieldwork. A clear idea of the condition of the roads, the distances to rural schools and clinics and the way interviewees react on the visits was acquired. The second reason was that the questionnaire that was designed had to be tested, to check the quality and way of interpretation of the questions. Also some factors that can influence the success of implementation were added. Some questions were added in the scope of the co-operation with the evaluation of the EU-project.

6.3 Sample design

To come to reliable conclusions about the PV-systems on schools and clinics, a careful sampling-methodology is indispensable.

6.3.1 Population

By far the most solar systems installed on schools and clinics in South Africa are installed in the Northern Province and the Eastern Cape. For practical reasons concerning the field-research, only PV-systems in those two provinces will be in the sample-population of implemented solar systems on schools and clinics. The total number of systems in the population under investigation is 2040, 1670 in the Eastern Cape and 370 in the Northern Province.

The population of schools and clinics can be divided in different sub-populations.

- RDP-schools (Northern Province and Eastern Cape).
- EU-funded solar systems (Northern Province and Eastern Cape)
- Clinics that received a solar system under the IDT programme

RDP-schools: These are schools that received a solar system under the Reconstruction and Development Programme (1996-1999). This are 1170 systems in the Eastern Cape. In the Northern Province 170 of these systems are installed.

The EU-funded programme was set up in 1998 to electrify 1000 schools, 500 in the Northern Province and 500 in the Eastern Cape. This programme will be finished mid 2001. Of these 1000 schools in the Northern Province, 200 systems were handed over to the Department of Education (November 2000), the other 300 systems will be handed over in the beginning of 2001. For the Eastern Cape, the numbers of EU-funded solar systems handed over (November 2000) are 300, the other 200 will be handed over in the beginning 2001. In this research, only the handed over systems are integrated in the population, because at the time of the field-research, the solar panels and batteries were not yet installed on the systems of Phase2.

The Independent Development Trust provided 200 clinics with a PV system in the Eastern Cape. The systems are installed between 1996 and 2000.

6.3.2 Sample

During the design of the sample, a lot of aspects had to be taken into account. Because there were a some practical constraints (time, money and accessibility of the systems) to do the field research, a sample size was designed on a practical base, without losing the needed accuracy of the results out of sight . Advice of experts was used to come to final numbers of systems that would be visited.

In the planning of the research, 2 months were available to do field visits. After different conversations with experts and evaluation of the budget available, the conclusion was that about 3 systems could be visited per day. There were 40 days of fieldwork available, so 120 systems were planned to be visited by the researchers.

During the research, there was a joint venture between this research and the EU-programme. The EU programme was stopped in November 2000 to do an evaluation of the project, because of some unexpected problems. After some discussions, a co-operation was set up. Some specific questions were added to the questionnaire, designed by the researchers, so that this questionnaire could be used for the internal evaluation of the EU-project executed by IT-power. So this was an opportunity to enlarge the sample and to increase the reliability of this research.

The information of 22 EU-schools that would be visited by field workers of the EU programme, could be added by the sample.
So in total, the sample consisted of 142 solar systems.

Because for the evaluation of the EU programme, a sample of 15% was required, 30 EU-schools had to be visited in the Northern Province, and 45 in the Eastern Cape. This gave us the possibility to visit 142-(30+45)= 67 other solar systems (RDP schools and clinics).
A choice was made to visit 10% of the clinics, giving a sample of 20 clinics.
Of the RDP-schools in the Northern Province, also 10% would be in the sample (17 schools). This leads to a sample of 30 RDP schools that could be visited in the Eastern Cape (2,6 % of the population). The sample of 47 RDP schools could be justified as from discussions with experts appeared that a lot of those systems were not working anymore, and that the same problems caused this failure. Also at Eskom, the RDP schools electrification programme was seen as a complete failure.

In Table 7, a visualisation of the sampling for the schools and clinics is given, Figure 21 shows the sampling per province.

Programme	**Province**	**Time of installation**	**Numbers Installed**	**Sample**	**% visited of installed systems**
RDP Schools	Northern Province	1996-1998	170	17	10
RDP Schools	Eastern Cape	1996-1998	1170	30	2.6
EU Schools	Northern Province	1998-2000	200	30	15
EU Schools	Eastern Cape	1998-2000	300	45	15
IDT Clinics	Eastern Cape	1997-2000	200	20	10
TOTAL			**2040**	**142**	**7.0**

Table 7: Sample of solar systems

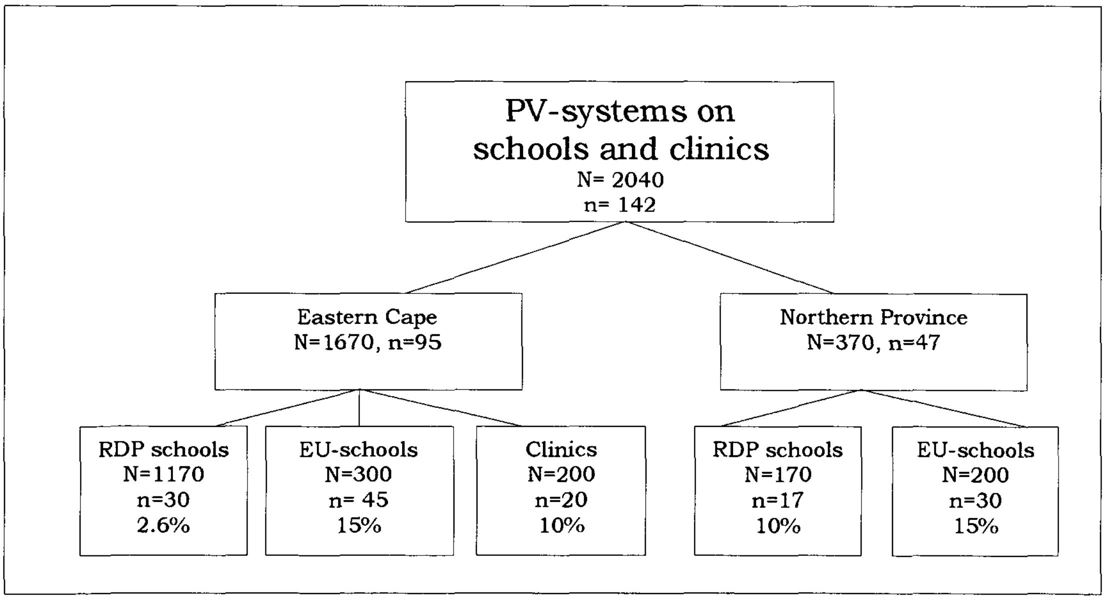


Figure 21: Sampling per province

Because of the enormous area where the schools and clinics with a solar system are installed, a limitation of the area where the field visits would be done had to be made. This due to practical limitations (accessibility, travel distances). A sample of districts were the systems are installed was taken.
In the Northern Province, solar systems on schools are installed in the following districts: Mokerong, Giyani, Mutale, Thohoyandou, Nebo, Bochum, Seshego, Tshitale, Vuwami, Dzanani, Praktiseer and Mankweng.
The Nebo district, Mutale, Tshitale, Vuwami and Dzanani were chosen.
In the Eastern Cape, solar systems are installed in the following districts: Bizana, Flagstaff, Lusikisiki, Matatiele, Mt. Ayliff, Mt. Fletcher, Mt. Frere, Tabankulu, Elliotdale/Mqanduli, Engcobe, Nqamakwe, Willovale, Centane, Tsomo, Cala/Lady Frere, Cofimvaba, Ezibeleni, Qumbu, Tsolo, Umzinkulu and Port St. Johns.
Centane, Lusikisiki, Port St. Johns, Elliotdale and Willovale in the old Transkei), Mt. Ayliff and Mt. Fletcher were chosen. See Figure 22 for the visited areas.

Figure 22: Visited areas Eastern Cape

All the schools and clinics in the sample were indicated on detailed maps (1:250.000). The co-ordinates off all schools and clinics, registered with GPS technology, are available in a database of Human Science Research Council (HSRC). This database was used to draw all the schools and clinics in the sample on the detailed topographic maps.

Because of the absence of co-ordinates of some schools and clinics, it was impossible to track those schools on a map. That made it difficult to derive a map with the schools and clinics indicated. Also the database that was available at HSRC did not always match with the information as it was supplied by the lists of the Department of Health. This made some additional work necessary before the maps were ready for the fieldwork.
Especially the condition of the roads and the safety situation in the rural areas during night time made good road maps essential. Also the fact that this was the first research of this kind that was executed in this environment made a good and decent preparation necessary. There was little experience available about what to expect in the field.

Chapter 7:

Results

In this chapter, the results of the field research are presented.
In the first paragraph, general results for all programmes are shown. In Paragraph 7.2, the specific results for the RDP programme are presented. Paragraph 7.3 contains the results for the EU-programme, and paragraph 7.4 the results for the IDT-programme (clinics). In Paragraph 7.5, some interesting remarks that users gave during the visit are recorded.

7.1 General results: all programmes (RDP, EU, IDT)

The results of 149 field visits will be used.

Visited Sample	Northern Province	Eastern Cape	Total
RDP schools	20	28	48
EU1 schools	33	46	79
IDT clinics	0	22	22
Total	53	96	**149**

Interviewed persons:

SCHOOLS	**Frequency**	**Percent**
Headmaster	76	60
Teacher(s)	41	40
Total	127	100
CLINICS		
Head nurse	8	40
Nurse	12	60
Total	20	100

No answer in 2 cases.

Number of students/patients per month in visited schools/clinics.

	Mean number of students per school/patients per month
RDP	399
EU	334
ITD	1123

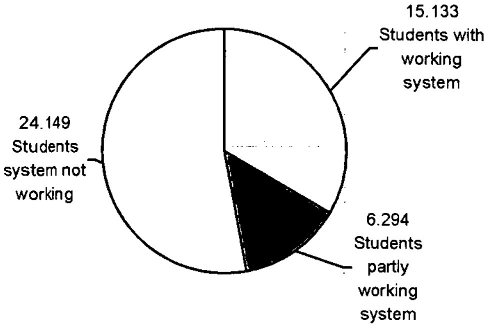
The numbers of pupils in a school varies from 50 to 900.
The most schools were in the pupil-range from 200-500.

Number of students/patients per month benefiting from the solar system.

	Completely working system [students/patients per month]	Partly working system [students/patients per month]	Not working at all [students/patients per month]
RDP	0	1120	14876*
EU	15133	5174	4411**
ITD	10457*	12759	0

*Of 8 non working RDP systems the number of pupils was not indicated (on average this is an extra 3192 pupils).
** Of 5 not working EU systems the number of pupils was not indicated (on average this is an extra 1670 pupils).
*** of 1 working IDT system the number of patients per month was not indicated (in average this is an extra 1123 patients).

In the schools, 15.133 (33%) students benefit from a completely working system, 6.294 (14%) students from a partly working system, and 24.149 (53%) students have a school with a not working system from the visited sample of schools.



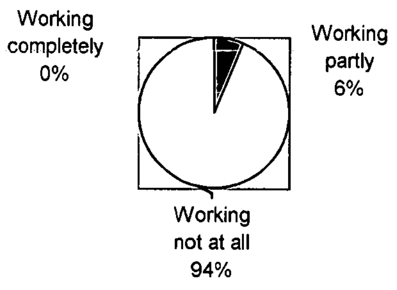
7.1.1 Technical performance of the solar systems

Performance per programme:

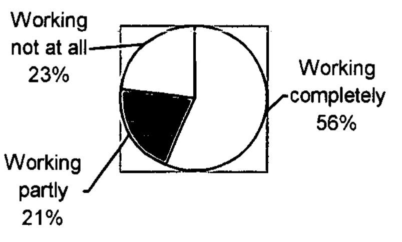
Northern Province and Eastern Cape

	Working Completely	Partly Working	Working not at all	Totals
RPD	0 (0%)	3 (6%)	45 (94%)	48
EU1	44 (57%)	16 (21%)	19 (22%)	79
IDT	12 (55%)	10 (45%)	0 (0%)	22
Totals	56	29	64	149

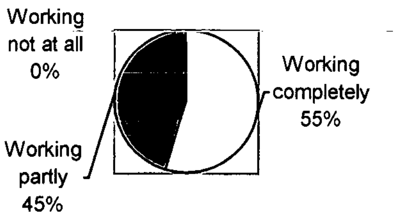
Performance RDP-systems



Performance EU-systems



Performance IDT-systems



The results show that 0% of the visited systems installed during the RDProgramme work completely, 6% is working partly (broken inverter) and 94% is working not at all.

Of the systems visited of the EU programme is 57% completely working. 21% partly and 22% is not working at all.

None of the visited system installed during the IDT programme are not working at all. 45% are partly working, mainly because of old batteries problems, and 55% is working completely. The technical problems will be discussed later per programme.

Performance per province:

Northern Province

NORTHERN PROVINCE	Working completely	Partly Working	Working not at all	Totals
RPD	0 (0%)	1 (5%)	19 (95%)	20
EU1	20 (61%)	8 (24%)	5 (15%)	33
Totals	20	9	24	53

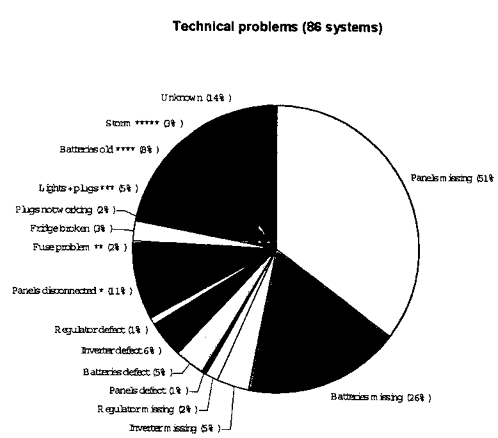
Eastern Cape

EASTERN CAPE	Working completely	Partly Working	Working not at all	Totals
RPD	0 (0%)	2 (7%)	26 (93%)	28
EU1	24 (53%)	8 (17%)	14 (30%)	46
IDT	12 (55%)	10 (45%)	0 (0%)	22
Totals	36	20	40	96

The results of the RDP and the EU programmes are not significant different in the two different provinces. 0% of the RDP systems is working completely in both provinces, 5% is partly working in the Northern Province. In the Eastern Cape is this 7%.
The EU systems give within margins a similar picture in both provinces. 61% is working completely in the Northern Province, in the Eastern Cape is this 53%. 24% is partly working in the Northern Province, and in the Eastern Cape this is 17%, and 15% is not working at all in Northern Province, where for the Eastern Cape this is 30%.
The figures show the same trend for both provinces, the differences are too small to make significant conclusions on environmental aspects. This confirms the impressions of the researchers in the field.

Technical problems:

Problem	Frequency	Percent
Panels missing	45	51
Batteries missing	23	26
Inverter missing	4	5
Regulator missing	2	2
Panels defect	1	1
Batteries defect	4	5
Inverter defect	5	6
Regulator defect	1	1
Panels disconnected *	10	11
Fuse problem **	2	2
Fridge broken	3	3
Plugs not working	2	2
Lights +plugs ***	4	5
Batteries old ****	7	8
Storm *****	3	3
Unknown	12	14



* In some schools, the panels were disconnected by the users because of fear that they would be stolen otherwise.

** In 1 case, the automatic fuses were all out (unclear reason, was fixed during visit), in another case the fuse was not making contact (fixed during visit).

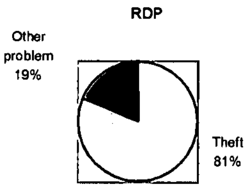
*** The plugs only work when the lights are burning, problem seen with EU-systems.

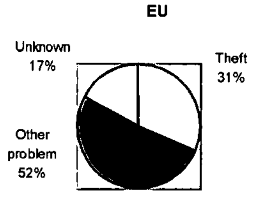
**** When the lights go out when the sun is not shining, the problem is defined as a battery problem. This problem occurred mostly in the clinics, where the lights in the nurse home go out.

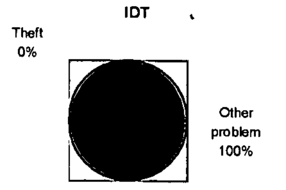
***** In 1 case (clinic), the array structure was bent due to storm, and wires were not fixed. (problem was
fixed during the visit). In the 2 other cases, batteries were not loading, but the reason was unclear.

Reasons for not working completely:

	Theft	Other problem	Unknown
RDP	39 (81%)	9 (19%)	0
EU	11 (31%)	18 (51%)	6(18%)
IDT	0	10 (100%)	0







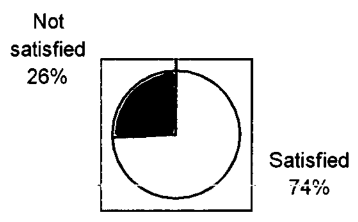
If there was theft of the panels or batteries, this is seen as the major problem of not working (even if there are other technical problems). It is possible (especially for RDP systems) that the systems broke down, and later panels or batteries were stolen.

Conclusions technical performance:

- Theft is a big cause of bad technical performance, in the EU and IDT programme, other technical problems mainly cause the bad performance.
- The performance of the RDP systems is very bad (only 6% still working).
- The performance of the EU-systems is better.
- The performance of the IDT systems is better, no systems are completely broken down, only technical problems cause bad performance.

7.1.2 User satisfaction:

Are you/were you satisfied with the solar electricity?



	Frequency	Percent
Yes	97	74
No	34	26
Total	131	100

No answer in 18 cases (system not working for a very long time).

Would you recommend a solar system like this to another school/clinic?

	Yes	No
RDP-schools	49%	51%
EU-schools	91%	9%
IDT-clinics	85%	15%

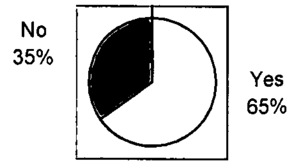
No answer in 18 cases (system not working for very long time).

The users in the RDP-schools are rather sceptic towards solar energy.
Most users of the EU-programme are positive. Also in the IDT programme, most users are positive, but because some systems start failing due to battery problems, some users would recommend grid electricity instead of a solar system.

Does the system meet your expectations in terms of what was set would be provided?

	Frequency	Percent
Yes	76	65
No	41	35
Total	117	100

No answer in 32 cases.
Different programmes (Yes: RDP 40%, EU 74%, IDT 78%).



It is clear that the users of the RDP-systems expected more from the system (working for a long time and television).

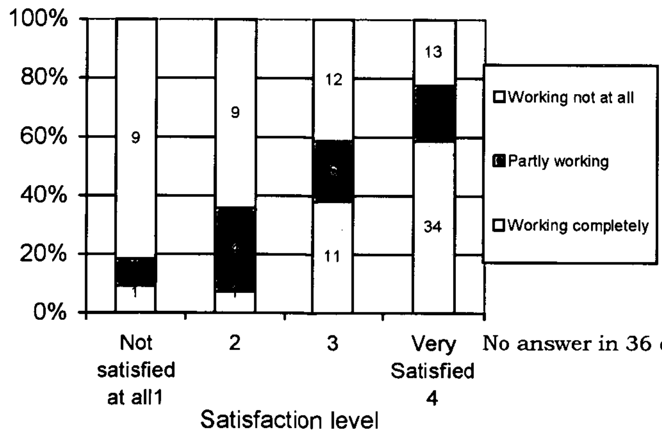
General level of satisfaction.

This level was calculated:
Would you recommend a system like this to another school/clinic?
+Does the system meet your expectations?
+ Are you satisfied with the solar electricity?

= General satisfaction level.

(If 1 of these variables was not indicated, the level was not calculated.)
No answer in 36 cases.

Satisfaction level if system working-partly-not at all.



No answer in 36 cases.

It is clear that the satisfaction of the users depends on the working of the system.

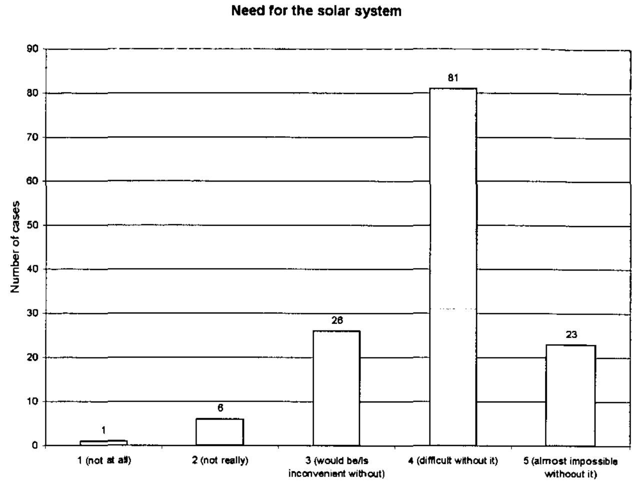
<u>Conclusions on user satisfaction:</u>

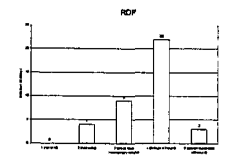
- Most users are/were satisfied to very satisfied with the solar system.
- The researchers have the impression that the answers were also biased because the users thought that their answers can influence their future situation. (So even some users with a not working system say that they are satisfied).
- The satisfaction is clearly influenced by the performance of the system.

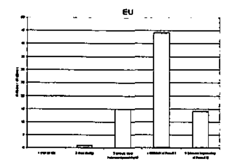
7.1.3 *Influencing factors*

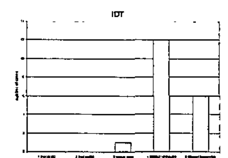
Need of the user

How badly do you need the solar system?



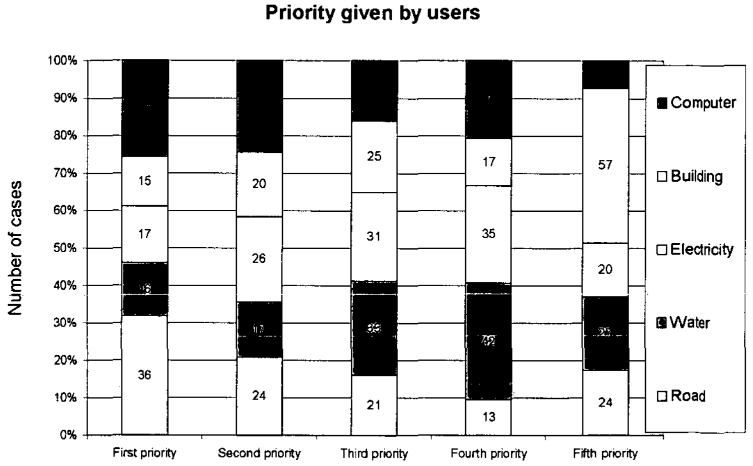






There is no big difference between the different programmes, the users in the clinics all tend to need the system very much.

What do you need the most for the school/clinic (give a priority)?

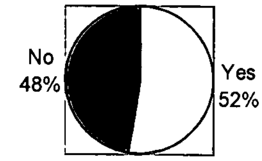


There is no clear priority given by the respondents. Transport is a very important for rural people, so the roads are an important issue. A computer is seen as an important connection with the "modern world", so very wanted, although only 30% of the respondents said they know, or someone in the school knows how to work with a computer. Electricity got a lower priority, the general answer was "we already have it", when the solar system is working.

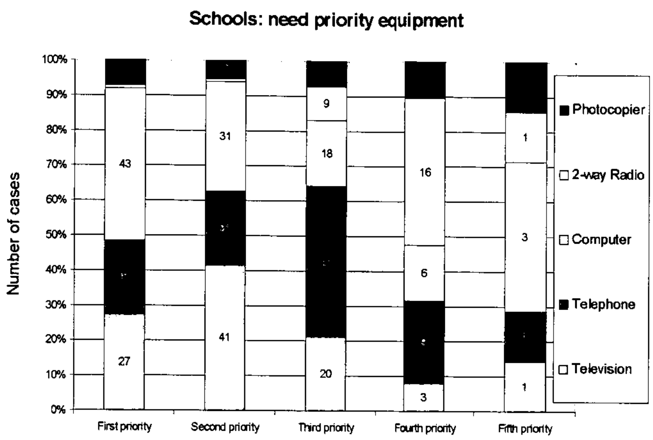
Did you really want the system in the beginning?

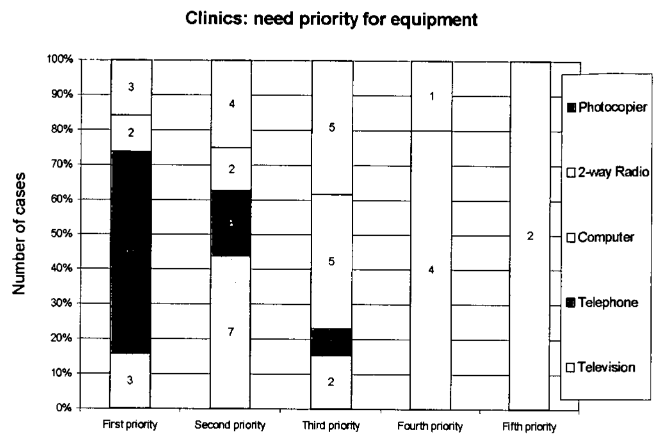
	Frequency	Percent
Yes	63	53
No	57	47
Total	120	100

No answer in 29 cases. No also means it was installed without informing the users first.



Need for electrical equipment





In the schools, a computer, television and telephone are given the highest priorities. Some remarks have to be made: most schools were already promised a television, and a lot of users counted on getting them anyway in the future, so they gave a lower priority to television. The researchers had the feeling the users expected to get a computer in the past of they gave it a higher priority.
In the clinics, telephone has clearly the highest priority, together with a television, to be used for the patients to give health information, and in the evenings in the nurses home.

Actual use of the solar systems, number of hours that the lights are burning per week.

The actual use of the system can be a good indication of the existing need for light, when no additional equipment is present on schools and clinics (except some radio's that were used and the charging of cell phones).

Programme	Mean of hours	Maximum value of hours
RDP	15	60
EU	25	91
ITD	58	180

No difference was made between working and not working systems. For not working systems, the number of hours when the system was in use was counted. At schools the maximum use of lights was 91 hours a week, in clinics 180. This is an indication of the need of electricity what makes it a design criteria for the system.
In a lot of schools, the number given is in the exam period, when students come to study in the evenings. During the year, a lot of school systems are only used when it is cloudy or cold. It is remarkable that respondents answered "We use the lights to heat the classroom", as the fluorescent lights give a very low radiation.

Conclusions on need of the user:

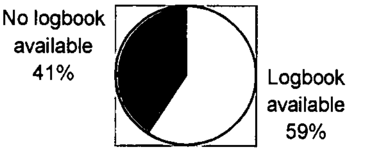
- Most users say they need electricity a lot, but no clear priority for electricity was found. "We need everything on the list" was the general answer.
- Half of the users said the system was installed without them really asking for it.
- A lot of respondents said they were still waiting for the television, now only the lights were used (and in some cases the plugs to charge cell phones).
- For electrical equipment, the schools give priority to computer, television and telephone, the clinics to telephone and television.

Characteristics of the user:

Involvement of the user:

Availability of logbook of solar system:
Here is presupposed that a logbook and user manual was provided with all the solar systems, and the availability can be a measure for the involvement.

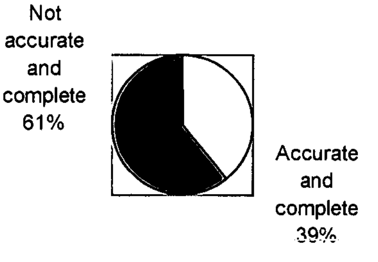
	Frequency	Percent
Logbook available	75	59
No logbook available	52	41
Total	127	100



In 22 cases, no answer was given, didn't know.
Users of systems that were not working for a long time said they had the logbook until the system broke down.

Accuracy and completeness of logbook:

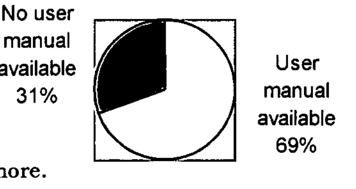
	Frequency	Percent
Accurate and complete	42	39
Not accurate and complete	65	61
Total	107	100



In 42 cases, no answer was given, didn't know or no logbook available.

Availability of user manual:

	Frequency	Percent
User manual available	86	69
No user manual available	38	31
Total	124	100

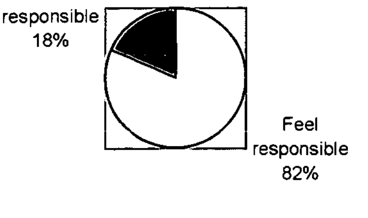


In 25 cases, no answer was given, didn't know.
Most user manuals are not available with systems that are not working anymore.

Do you feel responsible for the solar system?

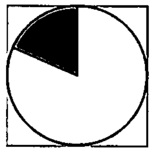
	Frequency	Percent
Yes	106	81
No	24	19
Total	130	100

No answer in 19 cases. People that feel not responsible, said the government, Eskom or the department should be responsible.



Is the problem with the solar system reported (systems with problem)?

	Frequency	Percent
Problem reported	66	82
Problem not reported	15	18
Total	81	100



In 68 cases, there was no answer .

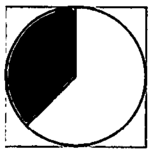
Conclusions on the user involvement:

- Most users say they feel responsible for the solar system to look after it.
- A lot of users lost the logbook and user manual and stopped completing the logbook after the system broke down.
- Most users report the brake down of the system (but the problems are not solved).

Knowledge of the user

Do you know what happens if you do not use distilled water for the batteries?

	Frequency	Percent
Yes	77	62
No	47	38
Total	124	100



No answer in 25 cases. No big differences between the different programmes. (Yes: RDP 63%, EU 61%, IDT 52%).

Do you know where to get more distilled water for the batteries?

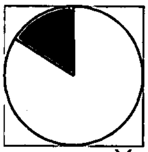
	Yes	No
RDP	24 (74%)	8 (26%)
EU*	43 (58%)	31 (42%)
ITD	6 (30%)	14 (70%)

No answer in 22 cases.

The supply of distilled water in the IDT programme in most cases is done by the hospital to which the clinic is linked, and is supplied in 30 litre drums. The RDP and the EU systems were supplied with a 10-litre drum of distilled water. No additional water was ever supplied according to the users.

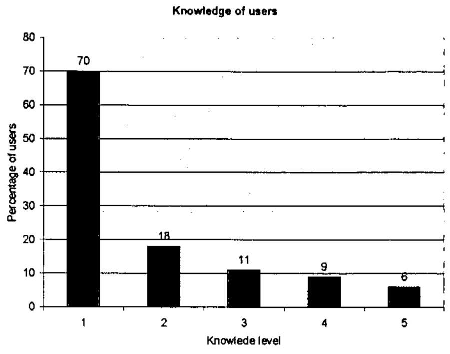
Did you ever get a training to use and maintain the system?

	Frequency	Percent
Yes	109	84
No	21	16
Total	130	100



No answer in 18 cases.

Can you explain shortly how the system works?

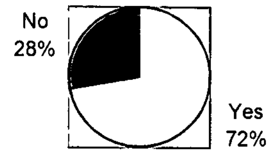


Users were asked to explain how the system works (sun into solar cells, electricity to batteries, electricity used in school or clinic).
1= very little knowledge
5=very good knowledge
No answer in 34 cases (system down for a long time).

Do you know what to do when there is a problem with the solar system?

	Frequency	Percent
Yes	93	72
No	36	28
Total	129	100

No answer in 20 cases. This was almost the same for the 3 programmes (Yes: RDP 69%, EU 70%, IDT 86%).



Do you know whether the system has a warranty period?

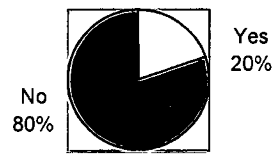
	Yes	No
RDP	8 (25%)	24 (75%)
EU*	19 (25%)	56 (75%)
ITD	0 (0%)	10 (100%)

Frequency missing: 32

The warranty period of one year that is included in the RDP and the EU programme is in only 25% known by the respondents. It is not clear it was never told to the respondent, or the respondent could not recall the information.

Do you know how to claim against the warranty?

	Frequency	Percent
Yes	22	20
No	90	80
Total	112	100

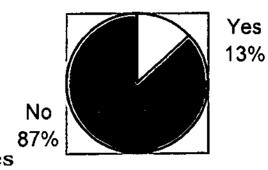


No answer in 36 cases (system not working for very long time, someone else will know).

Can you cook water on with the solar system?
This question tests the knowledge of the people, as it was told not to use kettles in all training sessions. (so Yes is a wrong answer).

	Frequency	Percent
Yes	16	13
No	106	87
Total	122	100

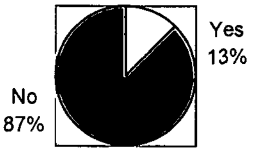
No answer in 27 cases (mostly the system was not working at all for a long time yet) There is no significant difference between the programmes (Yes: RDP 14%, EU15%, IDT 6%).



Did anyone tell you that the batteries/inverter/regulator had to be replaced sometimes?

	Frequency	Percent
Yes	16	13
No	112	87
Total	128	100

No answer in 21 cases (system not working for very long time).



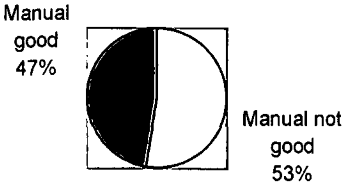
No big differences between different programmes.
(Yes: RDP 9%, EU 16%, IDT 5%)

The lifetime of the batteries is almost never known by the respondents. This can give problems if the responsibility for the payment of the maintenance and replacements of the batteries is not clearly directed. If the school or clinic itself is not responsible for the replacements, this is not necessarily a problem. If the school or clinic itself is responsible, the knowledge should be available. The respondents with a EU-system are better informed than those of the RDP and the clinic programme.

Is the manual good?

	Frequency	Percent
Yes	46	47
No	51	53
Total	97	100

In 51 cases, no answer. 'No' here means also that the interviewed never used the manual.



Conclusions on knowledge of the users:

- Most users got a training how to use and maintain the solar system.
- Most users do not know how the systems works, what the lifetime is or the purchase costs are.
- Half of the users say the manual is not good, or never used it.
- Most users do not know there is a guarantee on the systems for the first year.

Characteristics of the users

How long are you related to this school/clinic yet?

	0-3 year	4-10 years	Longer than 10
RDP	9 (20%)	14 (31%)	22 (48%)
EU*	2 (3%)	30 (43%)	38 (54%)
ITD	9 (47%)	8 (42%)	2 (11%)

No answer in 24 cases.

The time the staff is related to the clinic are relative shorter than the time teachers relate to the school. A change of staff is also an indication about the loss of knowledge about the solar system, as trained staff is often replaced by new untrained staff.

Staff rotation: staff change in last 2 years.

	No staff changed	Some staff changed	A lot of staff changed	Almost all staff changed
RDP	19 (54%)	14 (40%)	2 (6%)	0 (0%)
EU*	43 (58%)	25 (34%)	5 (7%)	1 (1%)
ITD	5 (25%)	11 (55%)	4 (20%)	0 (0%)

No answer in 20 cases.

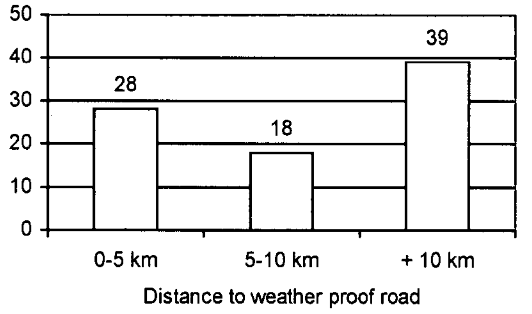
More than 50% of all schools had no staff changes during the last two years. In the clinics there was more rotation of the staff. The figures show a similar pattern as the time the staff was related to the school/clinic. Although the change of staff is not very large it can be important to provide training for new staff.

Conclusions on characteristics of users:

- At almost all schools and clinics there was someone who ever got a training, but staff rotation can be a problem, a training possibility should be available for new staff.

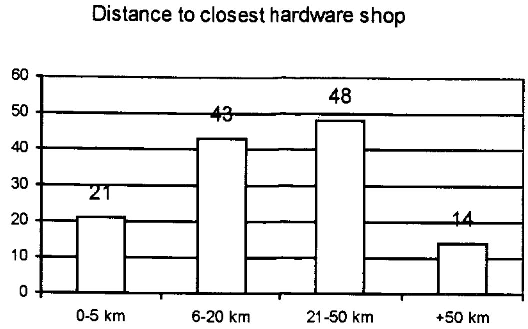
Environmental characteristics

What is the distance to the closest weather proof road?



This question was very difficult to answer by the respondents. It depends on the type of car, and feelings the users have. Mostly they say it is more than 10km, or less than 5 km. The researchers have the impression that about 30% of the sites is inaccessible during rain, with possible problems to go from the road to the building in almost all cases, because of the lack or bad condition of the driveway.
Experts mentioned that most sites are accessible with a 4WD, some sites are completely inaccessible during rain (mostly in mountainous areas).

What is the distance to the closest hardware shop (selling light bulbs, fuses, etc.)?



No answer in 26 cases.

Most respondents mentioned that it would be possible to get parts (asking someone to bring it, or go to the shop themselves), if a budget was available.

Condition of the building.

The condition of the building was given a rate from 1 (very bad) to 5 (very good).

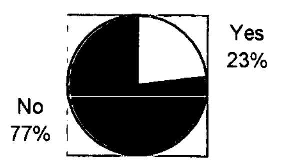
	Mean rate of condition
RDP	2,97
EU	3,59
ITD	3,82

Clinics are general in a better condition than schools. The selection criteria to install a solar system of RDP schools did not exclude "non permanent structures" to be electrified, what explains the difference between RDP schools and EU schools. Non permanent structures are excluded from electrification because the wiring can't be fixed to the structure.

Availability of alternatives: Do you have other ways of lightening the school/clinic?

	Frequency	Percent
Yes	34	27
No	92	73
Total	125	100

No answer in 24 cases. Most clinics also have candles or lamps for emergencies, schools almost never have alternatives.



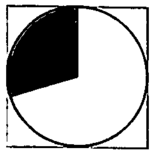
Conclusions on environmental characteristics:

- A lot of schools are not accessible by car during rain periods. This can considerably influence installation and maintenance programmes.
- Most schools and clinics are far away from the closest hardware shop, but users indicated this is not a problem when budget for spares would be available.
- The school buildings are in a worse condition than the clinics, with a lot of broken windows, bad doors, cracks in the walls etc.
- In most clinics, candles or lights are available for emergencies, schools do not have alternatives.

Technical design

Does/did the system give enough electricity?

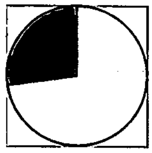
	Frequency	Percent
Yes	92	70
No	39	30
Total	131	100



No answer in 17 cases. Some users in schools would prefer all classrooms to be electrified, users in clinics complained that the lights in the nurses home were going out.

Do you think the system was good designed for your need?

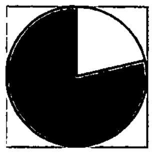
	Frequency	Percent
Yes	91	73
No	34	27
Total	125	100



No answer in 24 cases.
Different programmes (Yes: RDP 59%, EU 81%, IDT 67%).

Did the system have breakdowns previously (theft included)?

	Frequency	Percent
Yes	27	21
No	100	79
Total	127	100



No answer in 22 cases, theft was also seen as a problem.

Conclusions technical design:

- A third of the users say the system is too weak (compared to grid), they would like to use the lights more, use heaters etc.
- Most users say it is good designed, but it should be working completely (if not so).
- Most systems did not have breakdowns (before theft, final breakdown or working as it is now).

Product support and maintenance

How long did it take to repair the system?

	Frequency
1 week	3
3 weeks	1
4 weeks	2
8 weeks	1
13 weeks	1
Total	8

In only 8 cases the system was ever repaired. (after installation)

Who does/would do repairs on the system?

	Frequency
Eskom	14
Dep. of Health	0
Dep. of Education	1
Installer	6
Dep. of Public Works	0
Total	21

Also repairs during installation or in the first year are counted.(for example after theft or vandalism during the installation period). It is not always clear to the users who did the installation (Eskom or a contractor).

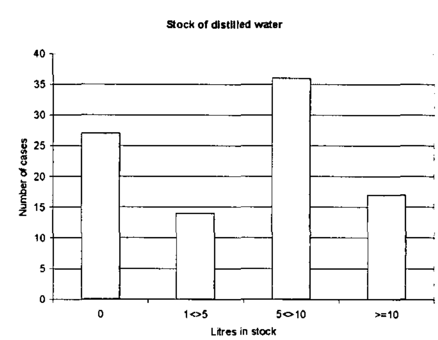
What is the water level in the batteries?

	Performance	95-100%	70-90%	Some <70%	All <70%	Some overfilled	All overfilled	Total
EU	Completely working	18	4	7		4	4	37
	Partly working	8	2	2		1	3	16
	Not at all	2		2	2		5	11
	Total	28	6	11	2	5	12	64
IDT	Completely working	7	1	1	2			11
	Partly working	4	2	3	1			10
	Total	11	3	4	3			21

For the EU-programme, the batteries of 34 (28+6) systems (44%) are correctly maintained. In 14 (11+2) cases (22%), there is a lack of maintenance.
For the IDT programme, the batteries of 14 (11+3) systems (67%) are correctly maintained. In 7 (4+3) cases, (33%) there is a lack of maintenance.
There is no clear relation between the condition of the batteries and the performance of the system.

How many litres of distilled water are there still in stock?

Litres	Frequency	Percent
0	27	29
1	4	4
2	4	4
3	3	3
4	3	3
5	25	27
6	7	7
7	2	2
9	2	2
10	12	13
15	2	2
20	2	2
25	1	1
Total	94	100



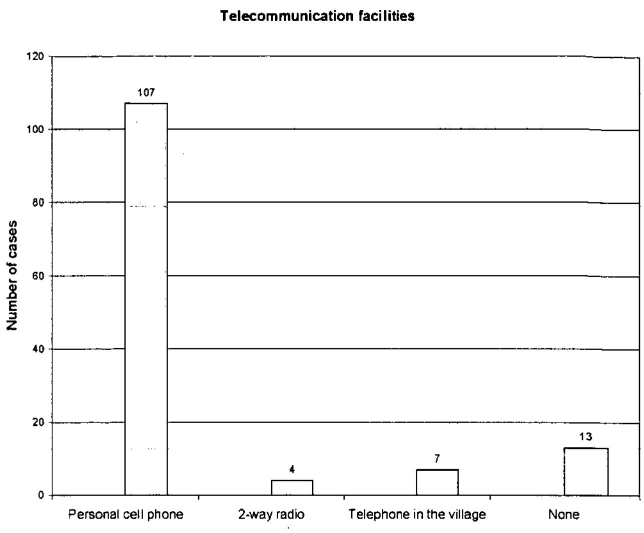
No answer in 69 cases (where the system was not working).

How many spares light bulbs do you have in stock?

	0	**1**	**2**	**3**	**4**	**8**	**Total**
RDP	68%	7%	25%				100%
EU	30%	9%	61%				100%
IDT	53%			23%	18%	6%	100%

No answer in 49 cases.

What kind of telecommunication facilities do you have?



82 % of all users have a personal cell phone. 10% have no communication facilities.
No answer in 18 cases.

Number of times someone came to check the system.

	0 times	1-2 times	More	Mean of visit
RDP	18 (50%)	8 (23%)	10 (27%)	1,67
EU	21 (28%)	27 (36%)	26 (36%)	2,459
IDT	11 (79%)	2 (15%)	1 (8%)	0,857

No answer in 23 cases.

Visit indicates the number of times a representative of Eskom, IDT, the commissioning officer or the contractor visited the school or clinic after installation (according to the user). The clinics are visited the least of the three programmes.. The RDP schools are visited less than the EU schools. Indicated at the other figures is the number of visits the Eskom extension worker paid on each visited site according to the user. The values for the EU indicate that Eskom visited the RDP schools not significant more than the EU schools. It was not always clear to the respondents who visited the school or clinic.

Conclusions on support and maintenance:

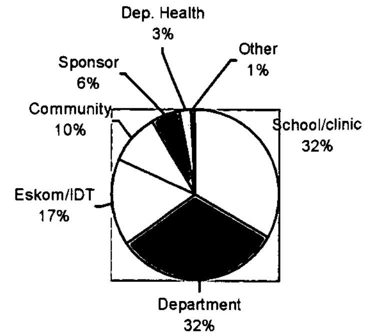
- In only 8 cases, repairs were done on the system, 37 systems are not working because of a technical problem.
- No maintenance structure is in place at all in the RDP and IDT programme, the EU-systems will be visited twice in the first year, after that no clear structure is in place yet. After installation, 50% of RDP, 28% of EU and 79% if IDT systems was never visited again according to the users.
- In the EU programme, 22% of the users are not maintaining the batteries properly; in the IDT programme 33%.
- 29% of the users do not have distilled water in stock.
- 82% of all users have a personal cell phone, this can be used in the design of a maintenance and failure-report system.

Ownership of the system

Who is the owner of the system?

	Frequency	Percent
School/clinic	42	32
Department	40	32
Eskom/IDT	21	17
Community	12	10
Sponsor	1	1
Other	1	1
Total	117	100

No answer in 32 cases.



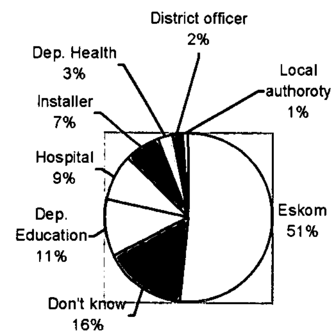
Conclusions on the ownership of the system:

- There is no clear perception among the users on who the actual owner of the system is.

Distribution of responsibilities

Who would/did you call when there is a problem?

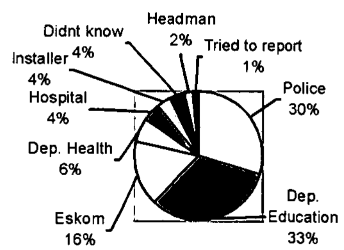
	Frequency	Percent
Eskom	52	51
Dep. of Health	3	3
Dep. of Education	11	11
District officer	2	2
Dep. of Works	0	0
Installer	7	7
Hospital	9	9
Local authority	1	1
Don't know	16	16



No answer in 50 cases. This includes the 36 cases where they did not know what to do when there is a problem, and cases where the answer was that probably someone else would know. In some cases, people contacted or would contact more institutes.

To who did you report the problem with the solar system?

REPORTED TO...	Frequency	Percent
Police	26	40
Eskom	14	22
Hospital	4	6
Dep. of Education	28	43
Dep. of Health	5	8
Installer	3	5
Headman	2	3
Tried to report	1	2
Didn't know who	3	5
Total	65	N/a



In some cases, the problem as reported to more institutes.
The departments are on district or provincial level.

Conclusions on distribution of responsibilities:

- It is not clear to the users who has to be contacted when there is a problem with the system.
- There is no central point where the users reported the problem of the system for the 2 school programmes.

Security

Do you have a night guard?

	RDP	EU	IDT
Yes	27%	60%	91%
No	73%	40%	9%
Total	100%	100%	100%

No answer in 16 cases. (system not working for a long time)

It is clear that most RDP schools had no night guard, and almost all clinics have a night guard. In the EU-programme, schools are stimulated by the Eskom field workers to employ a night guard. In some cases, the solar panels or batteries were stolen when the night guard was not on duty.
The night guard is in some cases paid by charging of cell phones of community members, or showing movies.

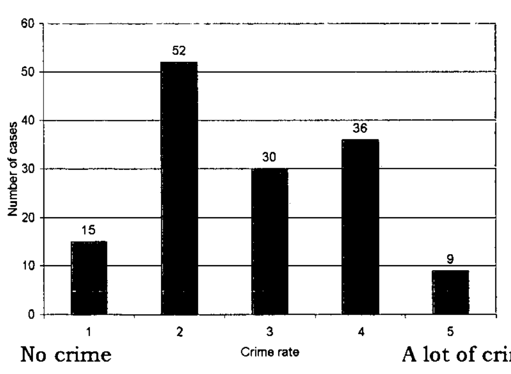
Who pays his salary?

	Frequency	Percent
Community	54	70
Dep. of Health	16	21
Dep. of Education	1	1
Other	6	8
Total	77	100

No answer in 86 cases (74 sites said to have a night guard).

In some cases, the community stopped paying the night guard after the system broke down, after which the panels or batteries were stolen.

Is there a lot of crime in the area?



Most users considered the area rather crime-free, except for the theft and vandalism to schools and the solar systems.

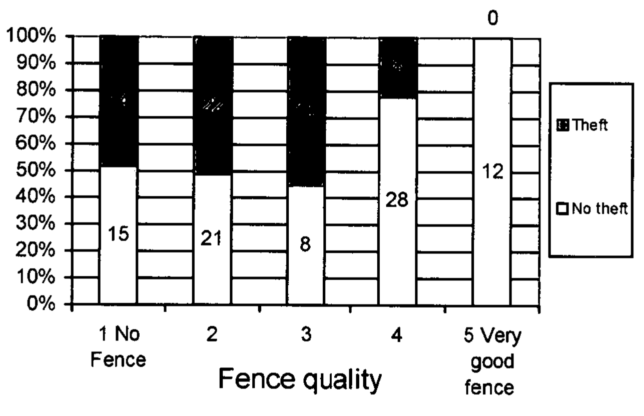
Quality of fence around the school/clinic.

A rate was given by observation, from 1 (no fence) to 5 (very good fence).

	Mean of fence rating
RDP	2,17
EU	2,72
IDT	3,94

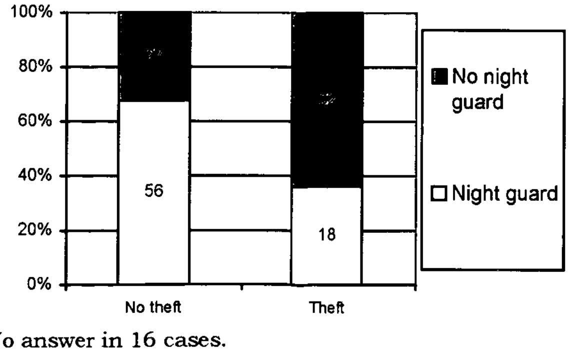
The fencing of clinics is better than the fencing around schools. This is necessary because at clinics nurses stay during the night. Good security is essential to assure the safety of the nurses.
At schools fencing is often provided by local fundraising programmes or extracted from the limited school budgets. The EU programme spends a lot of effort in informing and involving communities to protect the solar system. This explains the difference in quality of fence between RDP schools and EU schools.

Effect of fence quality on theft



No answer in 11 cases.
It is clear that only a very good fence has an influence on the theft. It must be said that most clinics had a fence 4 or 5 (barbed wire, more than 2 m high, gate with lock), but most clinics also have a night guard and the panels are installed on the roof, so that can influence the relation.

Effect of night guard on theft



No answer in 16 cases.
It is clear that a night guard has an influence on the theft, but it must be remarked that most clinics have both a night guard and a very good fence.

Other security measurements.

	Light on at night	Burglar proof bars on solar panels
RDP	6	3
EU*	13	9
ITD	8	1

* a combination of lights and burglar proof bars and a dog were both answered once.
** in all the other cases (107), no additional security measurements were taken.

The clinics have an outside light to prevent crime and vandalism. At 19 schools the users leave the lights on at night to prevent crime. The installed burglar proof bars were locally manufactured and installed mostly by people from the community. This made the bars not always strong enough to prevent the panels from being stolen, or vandalised.

Conclusions on security:

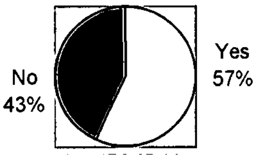
- 27% of RDP-schools, 60% of EU-schools and 91% of clinics have a night guard, mostly paid by the community (schools) or the DoH (clinics).
- The fencing of clinics is much better than of the schools.
- The combination occurring on most clinics of a night guard, a good fence and the installation of the solar panels on the roof, has clearly an influence, since theft is not a problem in the clinic programme (except for 1 panel being stolen).
- In the case of good installed burglar proof bars on the solar panels, no theft was observed. It is the feeling of the researchers that this can be a very important factor.

Training and informing the community

Did someone ever ask you if you wanted a solar system?

	Frequency	Percent
Yes	66	57
No	50	43
Total	116	100

No answer in 33 cases, mostly these systems were not working and people did not remember if someone ever asked them.



Who asked you if you wanted a solar system?

	Frequency	Percent
Eskom ext. worker	42	60
Dep. of Health	0	0
Dep. of Education	13	19
District officer	5	8
Installer	3	4
Dep. of Public Works	1	1
Don't know	5	7
Other	1	1
Total	70	100

No answer in 79 cases. In some cases, it was asked by more than 1 institute.

Who gave the training?

	Someone of Eskom	Installer	IDT
RDP	16 (52%)	15 (48%)	0
EU*	43 (66%)	24 (44%)	0
IDT	1 (6%)	3 (19%)	12 (75%)

Some users didn't know who gave the training.

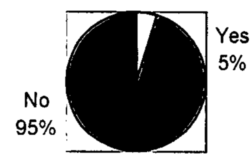
Conclusions on user training and informing the community:

- 43% of the respondents say no one ever asked them if they wanted the system, "they just came and installed it" was a general answer. In some cases, the headmaster was informed, but he did not inform the rest of the staff.
- The feeling of the researchers is that very few community members know that a school has solar panels, and almost no knowledge on the working is present.

Financial aspects

Are you saving for the replacement of the batteries/inverter/regulator?

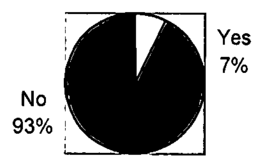
	Frequency	Percent
Yes	6	5
No	119	95
Total	125	100



No answer in 23 cases (system not working for very long time).

Are you saving for other repairs on the system?

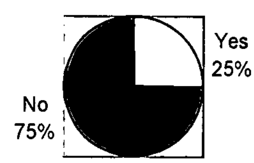
	Frequency	Percent
Yes	9	7
No	117	93
Total	126	100



No answer in 22 cases (system not working for very long time).

Would you be able to gain funds to buy a PC?

	Frequency	Percent
Yes	35	25
No	103	75
Total	138	100



No answer in 35 cases (system not working for very long time).

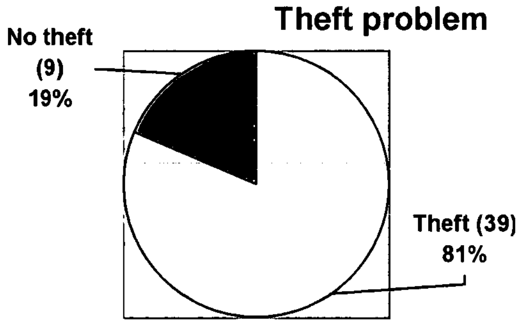
Conclusions on the financial aspects:

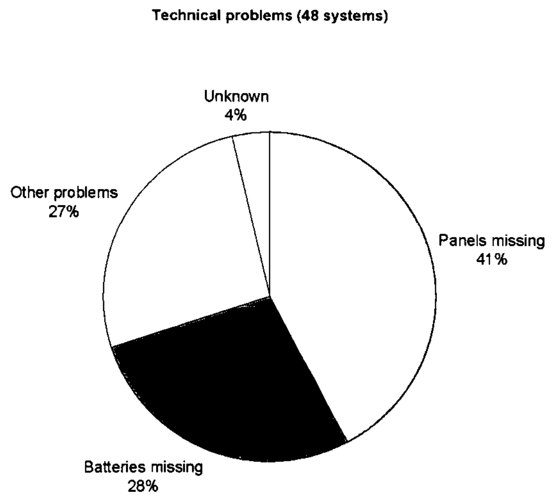
- The budgets of the schools are very limited (around 5.000 to 15.000 Rand a year), clinics have no own budget (linked to a hospital).
- Almost no schools or clinics are saving to maintain the solar system.
- 25% of the respondents say "maybe" to be able to gain funds to buy a computer, but in most cases they had no indication of the price of a computer.

7.2 RDP-systems (schools)

Vandalism and theft problem:

In 38 cases (81%), the theft of parts of the system (mostly panels and batteries) was the main reason for the failure of the system, in 9 cases (19%), other technical problems were causing the (partly) failure of the system.





Technical problems RDP-systems:

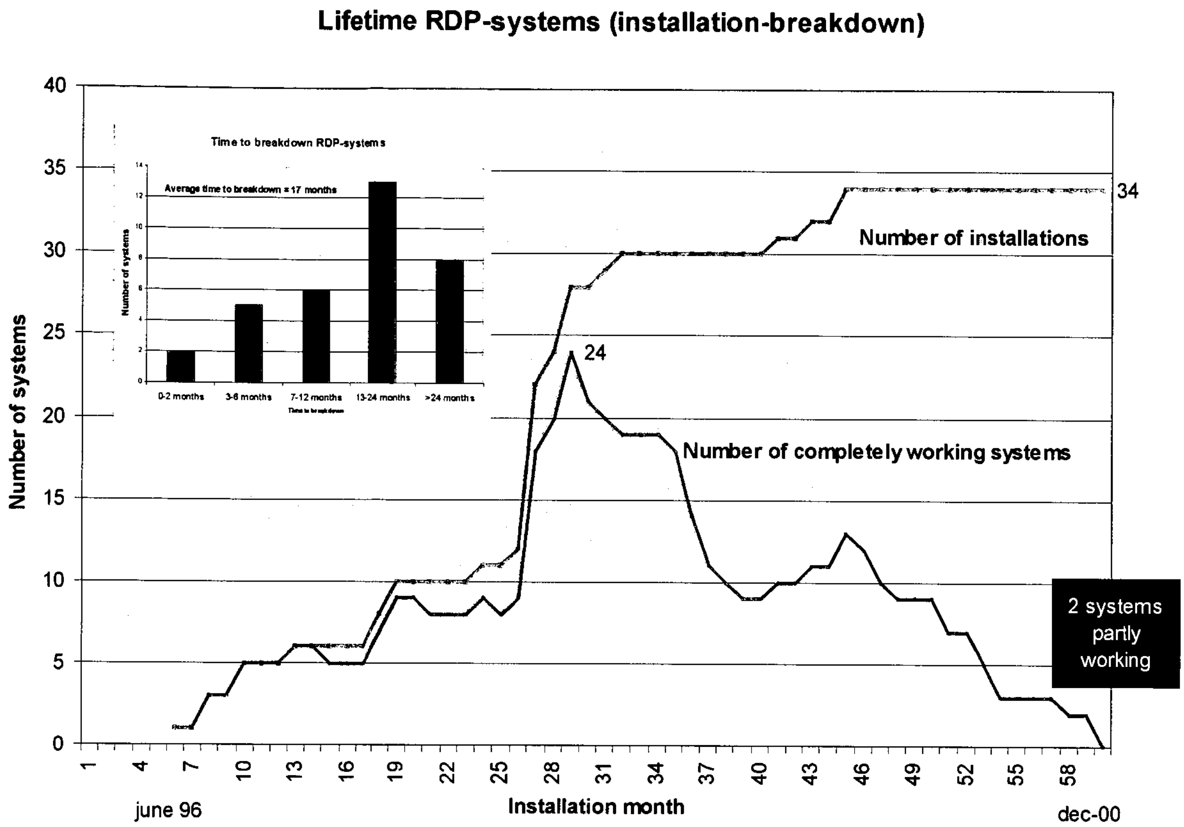
Problem	Frequency	Percent
Panels missing	35	73
Batteries missing	23	48
Inverter missing	3	6
Regulator missing	2	4
Panels defect	1	2
Batteries defect	4	8
Inverter defect	5	10
Regulator defect	1	2
Panels disconnected	5	10
Plugs not working	1	2
Unknown	3	6

Some systems had more than 1 problem.

<u>Conclusions technical performance RDP-systems:</u>

- Theft is the major problem of failure of the systems.
- Also defect inverters and disconnected solar panels by the users (not to be stolen) are an important cause of non functioning.

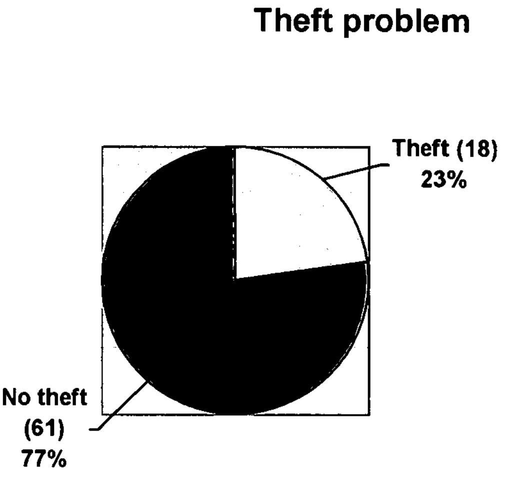
With the installation dates and dates of failure (when the dates were known by the users), a graph of the number of working systems at every point in time is made.



* Graph based on dates mentioned by the users. Some users had to estimate the date, so a difference of a few months from reality can occur. (The researchers suspect that no systems were installed after 1998.)
** Only systems of which installation date and break down date is known are used. (34 systems).

7.3 EU1-systems (schools)

Vandalism and theft problem.



Most systems were theft occurs do not work at all, in a few cases, the panels were rewired after theft, while in some cases the wirering was done is such a way that the system was able to partly function with a some panels missing.

Technical problems EU-1 systems:

Problem	Frequency	Percent
Panels missing	10	31
Batteries missing	1	3
Inverter missing	1	3
Regulator missing	1	3
Panels disconnected *	4	13
Fuse problem	2	6
Plugs not working	1	3
Lights +plugs **	3	9
Battery problem	1	3
Unknown	8	25

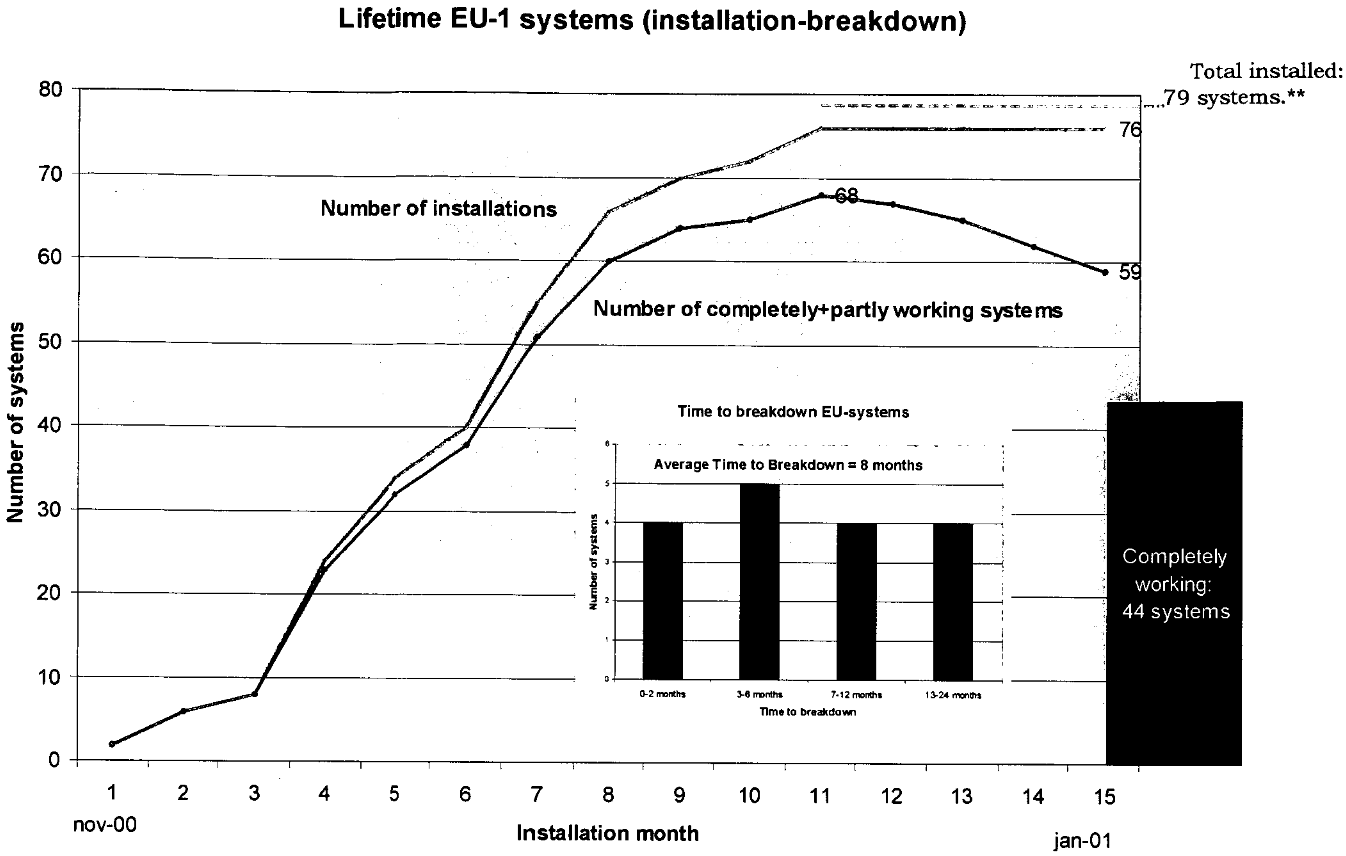
Of 1 system, everything was missing.

* In some schools, the panels were disconnected by the users because of fear that they would be stolen otherwise.
** The plugs only work when the lights are burning.

With the installation dates and dates of failure (when the dates were known by the users), a graph of the number of working systems at every point in time is made.

<u>Conclusions on the technical performance of the EU-systems:</u>

- Theft causes the failure in 23%, the other 61 systems have other technical problems.

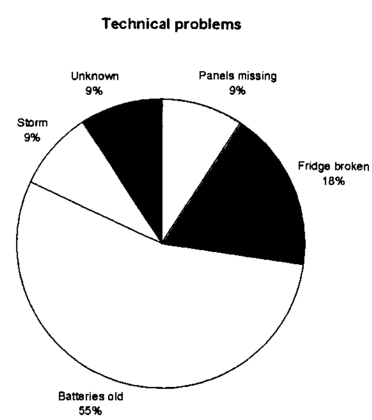


* Graph based on dates mentioned by the users. Some users had to estimate the date, so a difference of a few months from reality can occur.
** Only systems of which installation date and break down date is known are used. Of 3 systems, no installation date was known, of 6 systems no break down date was known.

7.4 IDT-systems (clinics)

Theft problem:
In only 1 clinic, a solar panel was stolen, but the system was still working.
In all the other clinics, theft was not an issue.

Technical problems:



Problem	Frequency
Panels missing	1
Fuse problem*	1
Fridge broken	2
Batteries old **	6
Storm ***	1
Unknown	1

* In 1 case, the automatic fuses were all out and the users did not know how to switch them on again. (was fixed during visit).
** When the lights go out when the sun is not shining for a while, the problem is defined as a battery problem. The lights in the nurse home go out first.
*** In 1 case, the array structure was bent due to storm, and wires were lose. (problem was fixed during the visit).

Conclusions technical performance of the IDT-systems:

- Theft is not a problem for the solar systems in the clinics. More then half the systems is still working completely.
- The major problem with the other systems is the age of the batteries (installed around 4-5 years ago).
- 2 refrigerators are not working anymore, of a 2 others the display did not work (but was till cooling).

7.5 General remarks of respondents

This paragraph contains some general remarks that users gave during the field research

1. *"We really need electricity and a TV to teach the children".*
2. *"We use the lights only when it is cloudy weather, the school is closed in the evening."*
3. *"We use the lights when its cold, they give some heat for the little children".*
4. *"We disconnected the solar panels and put them in a safe place, otherwise they will be stolen".*
5. *"We want real electricity, solar gets stolen too easy."*
6. *"We want grid electricity, because then we can use heaters and kettles, solar system is too weak."*
7. *"We called this telephone number [installer] that there was a problem with the system and they promised to come, but never showed up."*
8. *"On windy days, the grid electricity falls out, so it is better the have a solar system as well."*
9. *"We don't have money for a night guard or a big fence, the government should provide it."*
10. *"We want a solar system, because the grid electricity (card system) is too expensive. We also need a TV and a VCR very badly."[school with grid connection]*
11. *"It is very difficult to explain how a fish or a city looks like, if the children can't see it on a TV".*
12. *"Almost no one in the village has a job, so there is no money for the school".*
13. *"The school fee for the whole year is R10, and even that they hardly can pay".*
14. *"Can you explain me how the solar panels work, than I can teach the children".*
15. *"It was a good system, but now the lights go out in the nurse rooms".*
16. *"The police arrested the boy who had stolen the panels, and he went to jail for two years".*
17. *"Normally there is no theft and vandalism around here, only with the solar system".*
18. *"Can you imagine how it is to teach without lights, TV, a copy machine or even chairs where they can all sit on in a classroom that's much too small?"*
19. *"We have a problem with the community, because they want the lights on for 24 hours a day, and they don't understand it's impossible".*
20. *"They promised the grid electricity is coming, but we are waiting a few years yet".*
21. *"Do you know companies that can sponsor us with some computers or TV's, we don't have a budget for it but is very important".*

Chapter 8:

Analyses of the results

In this chapter, the results of the fieldwork will be analysed in detail. The differences between the programmes (school-clinics) and the reliability of the results will be discussed per factor.
The success of implementation will be analysed first (technical performance of the systems and user satisfaction), than all the factors that were investigated.

8.1 Success of implementation:

In general, it is clear from the results that the RDP programme is a failure, only 6% of the visited systems are working partly, all the rest is not working anymore after 3-5 year. Also in discussions with the involved parties, this programme is seen as not successful. The reasons for this will be discussed per factor. Fore the EU-programme, the success of implementation is higher, but still a lot of systems are not or partly working. If the rate of failure is not changed, a substantial part of systems will not be working in a few years time.
The clinics project is much more successful, so a lot can be learned from it for the schools programmes.

1. Technical performance:
In the RDP and EU programmes, theft of panels (RDP+EU) and batteries (RDP) is the main reason for the technical failure of the systems. Besides the theft problem in the RDP programme, the batteries have an expected lifetime of 2-3 years, so without maintenance, it is impossible that these systems will work for a longer time.
The inverters also cause some problems, in the RDP and the EU programme.
When the users disconnect the panels, which has obvious a large influence on the performance of the system, this must be linked to the theft and vandalism problem, as this is the reason for the disconnection.
In the clinics, the installed batteries start to fail because of their limited life-time, having a big influence on the satisfaction of the users, as they need the electricity to light their homes in the evening.
Some users declared that parts of the solar system never worked from the beginning (plugs, lights), although in the past programmes (RDP,IDT, EU), all solar systems had to be checked, before the hand over was done. Also the transport on the bad roads of batteries gave some problems (fell down, spilling the acid). (Louineau 2000).

Reliability of the results:
In most cases, a clear technical problem could be indicated, therefore a multi-meter, acid meter, and the technical knowledge of the researchers was used. In case of uncertainty, the problem was indicated as "unknown".

2. User satisfaction:
The impression of the researchers on the satisfaction of the users is twofold. Most users are satisfied with the solar system, because they see it as an important start for development and better ways to teach the children or treat patients. Even if the system is not working anymore, they sometimes declare to be satisfied, although there is a clear relation between the working of the system and the satisfaction.
Users sometimes react very sceptical on electrification by solar energy, indicate they need more electricity, but never use the system.

Because most users did not know what to expect from the solar systems and the application, satisfaction "covering a need" is very difficult to measure. Almost all users where the system was working (even partly) said they would recommend a solar system to a school or clinic without electricity.

Reliability of the results:
As most users indicated to be satisfied with the solar system (even when the system was not working), it is doubtful that these results are very reliable. Two clear reasons can be given for this: 1) the people in these rural areas are happy with every improvement, or attempt to improve their situation; 2) users expect that their answer (to two unknown white researchers) will influence their future situation.

8.2 Influencing factors:

1. Need of the user:
Most users say it is or would be very difficult to work without the solar system. This need is the largest at the clinics, because the nurses live next to the clinic, and the lights in their room are powered by the system. Compared to other facilities, there is no clear priority for electricity, especially in very poor areas where people lack every form of infrastructure. Most users need the application (TV,VCR, lights, plugs, medical equipment) of electricity, the source of the energy is not important. In some cases, especially in schools with small children, heating is needed a lot to teach during winter. Sometimes, the expressed need for electrical equipment (especially computers) seems to be their impression of the link with the developed world, and not a pure need for the artefact. No clear relation could be found between the need of the users and the success of implementation.

Reliability of the results:
Since the need is surveyed by presenting the respondents alternatives to chose between, a quite reliable result is expected. Sometimes there was the feeling hat the respondents gave electrical equipment a higher priority because they thought this could influence the future chances to receive this. As the need is specific to each school or clinic, it is normal that not one universal priority is found. The feeling of the researchers was that the expressed need for a computer was in a lot of cases an expression of the desire to belong to the developed world, more than the need for the computer itself.

2. Characteristics of the user:

Involvement:
It was found that the involvement of the users has no clear influence on the working of the solar system (even with very motivated users, systems were stolen, vandalised or broke down). But users with a completely working system, that really used the lights and other applications, were more motivated and involved than when the system was not working. It was not clear if involved users had a better working system, or that failure on the system causes less involved users.
There was also a big difference between the individuals, even on the same school or clinic.

Reliability of the results:
As this factor is investigated by asking linked items that could be observed or checked (keeping logbook, availability logbook, reporting of problems), the reliability of these results are high.

Knowledge:
The knowledge of the users is limited, as the users can seldom detect what is wrong with the system when a breakdown appears. In some cases, the lights were broken and the respondent reported the system to be broken and does not know what the problem is. Also the required maintenance of the batteries is not known by all users (67% knows the batteries have to be filled with distilled water). Most users have received a training after the system was installed and the limited usability (water cooking by a cattle is impossible), but knowledge on the working is very limited. The relation that less knowledge has a negative influence on the success of implementation was not found in the research.

Reliability of the results:
By asking questions about the maintenance and use of the system, the knowledge of the users could be checked in a reliable way. Also questions about the working of the system gave a reliable impression about the knowledge.

3. Environmental characteristics:
An environmental aspect that could be derived from the field research is the condition of the road, and the distance to the closest weatherproof road. For 39 systems the distance to the weatherproof road was more than 10 km. This makes it during rainy periods impossible to reach the schools and to do maintenance. To make maintenance possible during the rainy season a four-wheel-drive is required. The improvement of the roads takes a lot of afford and money, and is not likely to happen in the near future.
The absence of shops in the near environment (for 62 systems the distance is more than 20km) together with the absence of good public transport and personal cars makes it difficult for the users to purchase extra equipment or maintenance products.
Also the presence of criminal activities in the regions is a factor that is present in the region. The field research shows that in most cases only schools are victim of criminal activities, and personal belongings are left alone. Also it appears that in a lot of cases the users suspect some community members had a part in the criminal activities
The relation between the environmental aspects and the success of implementation could not be found. There was a relation between the crime in the region and the success of implementation.

Reliability of the results:
The distances the respondents answered will not be very reliable because most users had some difficulties with estimating. Were possible the answers were checked by observation. Also the condition of the buildings was observed.

4. Technical design:
The systems are designed in a way that in a developed environment, with sufficient maintenance, a good functioning of more than 10 years could be expected. As stated before the technical performance of the systems was not optimal. The main reason of technical failure was the theft of vandalism of the system. Also in some cases defects, not caused by vandalism or misuse, on the system were reported. In rural areas where knowledge can not be assumed, defect light, that had to be replaced were reported as a defect system.
The maintenance of batteries was not always executed by the users. Still no major failures on the working of the batteries was found, but there has to be noted that the age of the batteries was much less than the expected lifetime.
The design was never used to its maximum capacity, except on schools where the lights were left on during the night. The equipment to enlarge the use of the system (TV, VCR) was not present yet. It is not likely that the use of power will increase in the near future, as there is a lack of money to buy equipment.

All systems had more or less the same technical characteristics. At the RDP schools the improved car batteries can be used by the people in the rural areas at home. This made that those batteries are more often stolen than the large batteries of the EU and clinic systems..

Reliability of the results:
During answering these questions, the respondents mostly started telling what they really thought of the solar systems, also indicating the negative points, so the results will be quite reliable. As some users just wanted "more" or "bigger", it is discussible if the technical design of the solar system causes the unhappiness.

5. Product support and maintenance:
It is very clear that the maintenance structure as it was discussed in the policy was not executed. On the RDP schools no maintenance was executed, and it was not clear to the users who to contact in case of failure, although a number was indicated on the box where the batteries are installed in. After reporting failure maintenance was almost never executed. At the EU schools, two maintenance visits had to be done by the installer in the first year after installation. Most schools were visited during the first year, but for the users it was very unclear who visited the school. The repair policy of Eskom excludes schools where vandalism occurred from any form of maintenance.
The IDT project was visited and checked after installation. Also the structure was clearer as representatives of the hospital sometimes came to supply distilled water, and problems could be directed to the hospital.

Reliability of the results:
As it was clear from the interviews, no support and maintenance structure was in place at all, this is also clear from the results from the field research. Most items could be checked by observation (distilled water and lights in stock, water level in batteries, telecommunication facilities). The number of times someone checked the system or repaired it, is sometimes doubtful (when it was not indicated in the visitors book of the school or clinic, people tried to remind it). When the system was not working, and people were not happy with it, they tended to say that "no one ever came".

6. Ownership of the system:
It is not clear to the users who really owns the system. This is not surprising, as the systems were delivered for free, and there is no budget at all on local level. The systems were handed over to the schools and a document had to be signed, where was stated that the school was responsible for the system.

Reliability of the results:
A part of the users immediately said who they thought was the owner of the systems, but others waited until some possibilities were given and just made an uncertain choice. The conclusion that the users do not really know who the owner is, is reliable in any case.

7. Distribution of the responsibilities:
At the school and clinic level, there is no clarity who is responsible for the maintenance, there is also no clear procedure what to do when there is a problem. From the interviews of experts, it was clear that on all levels, there was a general feeling of evading responsibilities and not observing agreements. It is clear that this lack of transparency has an influence on the success of implementation. This was also the general impression during the research, and most interviewed experts that were involved in the implementation of the programmes, this was given as one of the main reasons for all problems.

Reliability of the results:
The same remarks can be made as for the ownership. The conclusion that there is no clear distribution of responsibilities is reliable.

8. Security:
Security is a major problem in the schools as they are desolated in the evenings, weekends and holidays. Since most schools do not have a good fence, and just a few have a night guard, theft is a major problem. The panels are installed next to the building, so it is very easy to reach them. It is clear that most panels or batteries are not stolen in a professional way but by local people, and destroyed during the steeling. Disconnection of the solar panels by the users also cause a lot of not functioning systems, better security would prevent this problem.
In the clinics, the security is much better, with theft being no problem there.
After being a victim of theft of vandalism, Eskom stops supplying any service to the schools. No spare panels will be installed, except the school is able to pay for them. The main reason to stop service and maintenance support is the possibility to supply local thieves from panels again and again.

Reliability of the results:
Most questions are straight forward and simple, so reliable answers are expected. Only the question on the level of crime in the area can be influenced very much by individual experiences of the interviewed. The effect of fence and night guard on theft is clear, but one can expect that it is a combination of more factors that have an influence on theft.

9. Training and informing the community:
Almost half of the users said not to be informed about the installation of the solar system, and during the field visits, it was the impression of the researchers that the communities were not informed about the systems at all. Especially during the RPD programme some respondents say that systems were installed during the summer holidays, without any notification before and without further training.
Most users got training when the system was installed, but just in a few cases there was a good general knowledge on the working and the maintenance. Some users were interested in more information and training, others just wanted the system to work, without knowing a lot about it.
Informing the community is very important as the respondents indicate community members to take a part in the vandalism and theft of systems.

Reliability of the results:
In a lot of cases, the training was given a few years ago, so the respondents had to remember the information, which can influence the reliability of the results. Sometimes more people were present during the training, or respondents did not know exactly who the trainer was.

10. Financial aspects:

At the level of schools and clinics, no budget is available for purchase or maintenance of the solar systems at all. Since the need for books, furniture, good buildings, equipment etc. is very big, the money available for the solar system will also in the future be very limited.
Also at the level of the departments, no budgets were available for maintenance in the past, although the need for these budgets was stressed in a lot of reports and involved parties. It is clear that the lack of budgets is one of the major reasons that there is no maintenance done in the past, influencing the success of implementation.

Reliability of the results:
Most schools and clinics are very poor, and do not have any budget for the solar system. All respondents were very open to talk about this, and were hoping that this could be changed in the future. Also in the interviews of experts (Eskom and the departments), it was clear that no budgets were available in the past at all.

Chapter 9:

Conclusions and recommendations

9.1 Conclusions:

1.The success of implementation of the RDP programme is very low: only 6% of the visited systems is still working partly, all the rest is not working at all. In the EU-programme, it is better (22% not working at all, 21% partly, 57% completely) but if no maintenance and anti-theft measures are taken, more systems will break down in the future. The clinic programme can be seen as successful, although 45% of the systems are working partly because the batteries should be replaced.

2. Theft is a major problem in the school programmes: 81% of the RDP-systems are not working because of theft and 23% of the EU-systems. In the clinics, theft is not a problem. A clear relation was found between the fencing, night guard presence and installation of the panels on the roof and theft. Also good burglar proof bars do prevent theft.

3. No functioning support and maintenance structure is in place, causing the bad performance of 19% of the RDP-systems, 32% of the EU-systems and 45% of the clinic systems that have a technical problem. When there is a technical problem with the system, most users report it, but there is no clear reporting procedure. Just a few systems were ever repaired after the problem was reported.

4. Schools and clinics have no budget to maintain the systems. Also the departments did not allocate any budget to pay for maintenance. As the foreign budgets were used to install as much systems as possible, no money was left for the maintenance of the systems or the monitoring of the projects.

5. There is no clear distribution of responsibilities on all levels, combined with a lack of policy. This is also the general reason that no good maintenance and support plan was ever designed and executed, no budgets were allocated, and lessons from past programmes were not used in the projects.

6. No detailed need study was executed in the schools programmes, leading to situations where the need of the users was not fulfilled by the system. In the clinics programme, a need study was done, but good communication and a TV was needed a lot.

7. Most users got a training when the solar systems were installed, but the general knowledge about the working and maintenance of the systems is very limited. The involvement and knowledge of the community is very limited.
As community members were involved in criminal activities, good and clear information to the community is needed to enlarge the involvement of the community.

9.2 Recommendations:

The recommendations are presented in four parts.

In Paragraph 9.2.1, the Product Life Cycle of the solar systems is discussed, and recommendations on each phase of the product life cycle of the solar systems, from the need analyses to the disposal, will be given. In Paragraph 9.2.2, recommendations on the service and support are made.
Paragraph 9.2.3 will focus on other, specific factors for implementation of solar systems in rural schools and clinics in South Africa. In paragraph 9.2.4, the recommendations on the policy that is needed on the electrification of schools and clinics with solar systems are presented.

9.2.1 Product Life Cycle of the solar systems

1. Need identification:
From the results it is clear that there is a need for applications that require electricity, resulting in a need for electricity. A detailed need analyses has to be done, to install the systems on sites were they are needed the most (a large secondary school will need lights in the evening more than a small primary school). The actual need for electricity changes over time, which makes it difficult to determine the exact present and future need for electricity. It must be clear to the users why grid electricity is not an option, so electric heating and permanent lights are not possible. Further research to determine the actual need is recommended.

2. Conceptual design:
After the identification of the needs of schools and clinics, possible alternatives to fulfil this need must be analysed. In the evaluated school programmes, one standard design was used for all schools. In the choice of these alternatives (grid electricity, solar-wind electricity, gas, or others) it is important to consider the results from the past projects. It is also very important to visualise all the costs over the complete life-cycle that an option will bring along as explained in Paragraph 4.4 as well as the practical circumstances (maintenance, delivery of gas bottles, etc.). In this decision phase, all the involved parties must be realistic and consider the impact on the budget that each option will have.

3. Detailed design:
When the decision is made to install a solar system, the system must be designed in detail, so that the need will be fulfilled and the user satisfied about this solution. In Appendix 1, a design procedure for solar systems is given, with an example for a school system. Because theft is a major problem for school systems, this factor is important to design the systems. Solutions to prevent theft of the solar panels and the batteries must be found. Paragraph 8.3 focuses on this problem.
It is important to realise that the need for electricity can increase, when a television is delivered and people get used to the possibilities electricity gives them (evening courses, cell phone charging, community meetings in the evening etc.).

4. Selection criteria where to install solar systems:

After a good need identification research is done, the decision criteria must be reviewed, to decide which schools and clinics will get a solar system. Also the kind of solar system can be different (schools and clinics can be divided in different categories, depending on the electricity need). These criteria must be detailed, and adjustable over time. For the past programmes, distance from the grid (or time until grid-electrification) and quality of the building were the main criteria. In the future, also the kind of school (age of the children) or clinic, and the need for electricity and the applications should be criteria.

5. Construction and installation:

The most important aspect of this phase is the training of the installers before installation and quality control after installation.

When anti-burglar bars will be used on the array to prevent theft of the panels, this can be done before installation on a central place, to simplify quality control. The pre-assembled array (completely welded), can be transported and installed as one part. Pre-assembly in general (battery-box, with all electric equipment) is better to control quality and enable faster installation in the field. (Adams 2001)

In the planning of the installation, the environmental aspects (distance from weather proof road) must be reckoned with, otherwise delays will be inevitable. More than half of the locations are situated further than 10 km from the weatherproof road.

6. User training:

At this moment 16% of the users never got training. All the staff members of a school or clinic should be trained how to use the solar system and do basic maintenance. They should also be able to report a problem, so a general idea of the working of the system must be available.

For this training, a good, not to complicated user manual should be available, with a lot of illustrations. In the case that the trained people leave the school or clinic, a possibility should be available to train new people. The maintenance personnel that visit the school or clinic can have an important role in this.

Also good educational information should be available, so that the solar system can be used as an educational subject in the schools. When a television and VCR are supplied, a training tape on the solar system should be supplied that can be shown to the students.

7. Use of the solar system:

From the training, it must be clear for the users how the solar system must be used in the correct way. To be able to understand the limitations of the system, a basic knowledge of how the solar systems works must be available. It must be clear to the users that they have a big influence on the duration that the system will work by doing the maintenance, reporting problems and using the system in the way it was explained.

8. Disposal:

When a renewable energy system is implemented, also the disposal phase of the system must be taken into account to assure the sustainability. Some parts of the solar system can be very harmful for the environment when not disposed in a proper way, but in the past policies and programmes, disposal of the solar system was never an issue.

The disposal of the different parts of the solar system will not happen at the same moment. It can also be difficult to plan the disposal of certain parts, as the lifetime can not be defined exactly. In general, a procedure for the disposal must be designed together with the maintenance procedure, of which it must be a part.

In the next paragraphs, the disposal of the solar system will be discussed per part.

The solar panels:

The solar panels have an expected lifetime of 20 to 25 years. No harmful substances are used in a solar panel (glass, silicium, aluminium). It can be disposed of trough the normal circuit of garbage. The aluminium frame can be sold to local scrap dealers.

The batteries:

The batteries are the most harmful parts of the system for the environment when disposed in an incorrect way.
In all the systems, lead-acid batteries were used. The lifetime of the batteries varies from 2-8 years. When the expected lifetime of the batteries of the RDP-programme is taken into account, all these batteries will be at the end of their life, meaning that 1340*16= 21440 batteries (modified automotive batteries) will be disposed soon. In the clinic programme, around 200*12=2400 batteries (flooded solar) will be disposed in the coming years. For the EU-programme, 12*1000=12000 flooded solar batteries will be disposed in 6-8 years.
If lead-acid batteries are improperly disposed of, such as dumped in a non-hazardous landfill or in an empty field, the lead and sulphuric acid can seep into the ground, contaminating the environment and the groundwater supply. (Topps)
The procedure for disposal of the batteries must form a part of the installation contract of the solar system. In practice, the old batteries can be collected when new batteries are installed, or when the site is visited for maintenance. The supplier of the batteries can be obliged to take back the old batteries for recycling, or include the price of recycling. But today (2001), very few countries have a recycling policy strict enough to include the cost for recycling in the selling price. A centrally managed project like the electrification of schools and clinics can be a very good example for recycling in Africa.

The inverter + regulator:

The inverter and regulator have an expected lifetime of 10 years, and most defects can be repaired by the manufacturer. (MLTDrives 2001)
When an inverter or regulator is irreparable, it should be collected during a maintenance visit, avoiding it being disposed in the environment.

The frame + battery box:

The frame on which the solar panels are placed, is galvanised steel, having an expected lifetime of more than 20 years. The battery box in the RDP programme was painted steel, in the clinics a hard wooden box is installed (both placed inside the building). In the EU-programme, a galvanised steel box is used, placed outside the building under the solar panels.
Since steel is not harmful for the environment, it can be disposed very easy, be re-used for other purposes, or sold to a local scrap dealer.

Fuses + wiring:

In each school and clinic, a fuse box is installed, and some hundreds of meters wire.
Whenever the school or clinic will be grid-electrified, most of the wiring can be used again, so disposal will not be an issue.

Light bulbs:

The light bulbs used in the schools are fluorescent tubes, expected lifetime is 12.000hrs. (Eskom 1999) In the clinics, compact fluorescent bulbs are used, with an expected lifetime of 10.000hrs. (Bulbco.com 2001)
Faulty lights must be collected during a maintenance visit, and recycled by specialised companies, as they contain mercury. Each bulb contains enough mercury to pollute 30000 litres of water beyond a save level for drinking purposes. (http:www.mercuryrecicling.co.uk, 19-06-01)

The refrigerator:

The refrigerators used in the clinics (Minus40, 12V, 90l), have an expected life time of 15-20 years, they are CFC free. Almost all defects on these refrigerators can be repaired by the manufacturer. (Minus-40 2001) When the fridge is irreparable, which will become clear when it is sent back to the manufacturer, he is responsible for the disposal.

Recommendations on each phase of the life cycle:

- A good need analyses has to be executed, especially for the schools, to adjust the system design on the need of the users.
- The conceptual and detailed design of the solar systems should be based on the need, and alternatives for a solar system should be evaluated (comparing costs and possible problems over the whole lifetime).
- The selection criteria of sites where a solar system will be installed must be reviewed, also type and size of school/clinic should be included, influencing the need for electricity and the applications.
- During the construction and installation, better quality control is needed. Pre-assembly should be done as much as possible to assure the quality. Installers should be trained properly.
- Every teacher and nurse should get a training on how to use and maintain the solar system and report problems. When a VCR is delivered, an educational tape on the solar system should be provided. A clear, simple manual is needed.
- A disposal procedure for the different parts of the solar system should be designed. Old batteries and light tubes should be collected.

9.2.2 Service and support lifecycle of solar systems

It is clear from the results that no good support and maintenance plan is put in place, causing a lot of the failures of the solar systems. To design a service and maintenance plan, all aspects are discussed in a structured way. More research is necessary to design the maintenance plan in detail.

9.2.2.1 Maintenance concept information

1. Levels of maintenance:

The first, and most important level of maintenance is at the site of the school or clinic itself. There, the preventive user maintenance has to be done (checking and filling the batteries, identifying the problems and report etc.). At this moment the knowledge about the lifetime of the battery and the required maintenance of the battery is limited under the users. Also more complicated corrective maintenance can be done on site: replacing fuses, batteries, inverter/regulator, solar panel, lights, plugs and switches. This has to be done by specially trained people. At this moment most users reported when the system has a problem, but no-one came to solve the problem.

Most of the broken parts (fridge, inverter, regulator, 2-way radio) can only be repaired by the manufacturer, because of the specific knowledge and tools needed. Therefore, the broken part has to be transported to the manufacturer. In the mean time, this part can be replaced by another from a central stock.

2. Repair policies:
The decision on which parts will be repaired, must be made during the design of the system. Especially in remote rural areas, it can be cheaper to replace a part by a new, then sending out a specialised contractor to repair it. Some spare parts must be available on district or provincial level to replace the broken part during the time of repair (refrigerator, 2-way radio, inverter, regulator).
Parts like batteries and broken solar panels can, in most cases, not be repaired so spares must be available and the old parts must be collected.

3. Organisational Responsibilities:
It is clear that in the current situation, the responsibilities for support and service are not clear and not respected by some institutions. Before new implementations are initiated, this problem must be solved completely. A clear policy should describe the responsibilities on each level (national, provincial, local, NGO, donors).

4. Logistic Support Elements:
The supply support should be set up on a district or provincial level, because of the large distances. Spares should be stored in a safe and well maintained workshop. A good communication network must be put up, using a database with the cell phone numbers of the teachers and nurses. Up to date information of all the stock should be in a database, as well as an individual file on each school and clinic.

5. Effectiveness Requirements:
Choices have to be made on the effectiveness of the maintenance. The maximum time between the report of a problem with the system and the repair, must be defined, and a control procedure put in place. At this moment there are no requirements on service time at all, resolving in systems being broken down for a very long time. It is very important to take into account the environmental circumstances (condition of the roads especially in the raining season) and holiday periods, which can influence the effectiveness dramatically.
The fact that most users have a cell phone, can be used to increase the effectiveness of the maintenance considerably, because direct communication with the users is possible.

6. Environment:
To put up a reliable service and support system, all environmental aspects must be taken into account: all the tools and spare parts must be able to withstand heavy rain, temperature changes, moisture, dust, mud and transport over bad roads. When one puts up a maintenance planning, no large delays can be tolerated. This is why the maintenance vehicles should be able to reach the sites in almost all weather and road conditions.

9.2.2.2 Maintenance structures:

Different options can be considered for the maintenance of the solar systems. The most important, common characteristic of all options, is that every option will cost money, and budget has to be allocated. Paragraph 4.4 made clear that the purchase of the solar systems is only the top of the iceberg, if the aim is sustainable implementation of a technology. Some options for the maintenance of the systems are given, further research is necessary to come to the best solution.

The maintenance of the systems can be split up in periodic visits to the sites (preventive maintenance), and corrective maintenance when a system breaks down.

The batteries that are used in the EU-programme are designed to work without maintenance (filling up the water) for 6 months, so every solar system should be visited two times a year, checking the battery level and the rest of the system. Every visit must be reported in central database.
The corrective maintenance must be well organised as well: the users must have a telephone number they can call every working day, to report the problem. Than, the technician must plan the visit and give feedback to the school/clinic when he will come (and not make empty promises like it is done at this moment). After the visit, the database must be filled in, giving the problem, so that a general overview is available. This can be very useful to evaluate the projects, and learn from the problems that occur.

Option 1:

The maintenance can be done by employees of the Department of Education, Health or Public Works. A this moment, no trained people are available to do this job, (IDT 2000) so people should be trained, or new people engaged. There is also no transport or tools available. It is clear that on the short term, this is not an option, on the long term, this can be considered (after training of people and setting up the infrastructure).

Option 2:

Contractors (or the installers of the system) can be recruited to do maintenance. They have the knowledge of the systems (it is their core business), tools and transport. A good evaluation system must be put in place to check the quality of maintenance and quickness of reaction for corrective maintenance. By tendering for the maintenance (with good quality control), the best price can be reached. The disadvantage of this option is that a very good communication and control system must be put up, not to lose the overview and ability to budget. An advantage is that the optimum in quality and price can be reached truth the competition between the contractors.

Option 3:

The maintenance is done by Eskom NGE. A central managed maintenance plan is set up to do maintenance on all the schools/clinics. The advantage of this option is that the knowledge, tools and transport are available, and that there is a central overview (if good managed). A disadvantage is the absence of competition, which can influence the price and quality.

Option 4:

Each school/clinic is responsible for the maintenance. With the new subsidy system for schools, each school will be responsible for its own budget. A local electrician could be paid from these funds to do the maintenance. However, at this point in time, almost no local electricians have knowledge of solar systems. Another disadvantage is that no overview is available of the condition of the systems, neither is the quality of the maintenance secured.

Option 5:

A combination of the options above can also be considered: the preventive maintenance can be done by the departments, or Eskom NGE, corrective maintenance can be done by a contractor.

Recommendations on service and support:

- A detailed maintenance plan must be designed, from the very beginning of the project, and budgets allocated.
- Every site must be visited twice, and a corrective maintenance structure put in place, with an up-to-date database of all visited sites and problems.
- The fact that almost all users have a cell phone, can be used to report problems.
- During the design of the system, decisions must be made on which parts will be repaired when they brake down, and which will be replaced by new ones. Stocks of spare parts must be available on district or provincial level.
- All environmental aspects should be taken into account during the planning of maintenance to prevent delays.
- One of the five presented maintenance structures must be chosen, to reach optimal quality, price and effectiveness.

9.2.3 Specific factors

1. Prevention of theft and vandalism:

It is clear from the results of the field research that the prevention of theft and vandalism must be a priority in future programmes. Some possible changes in design and implementation are presented, these are solutions that can reduce the theft problem, without claiming that the theft problem will be solved completely.

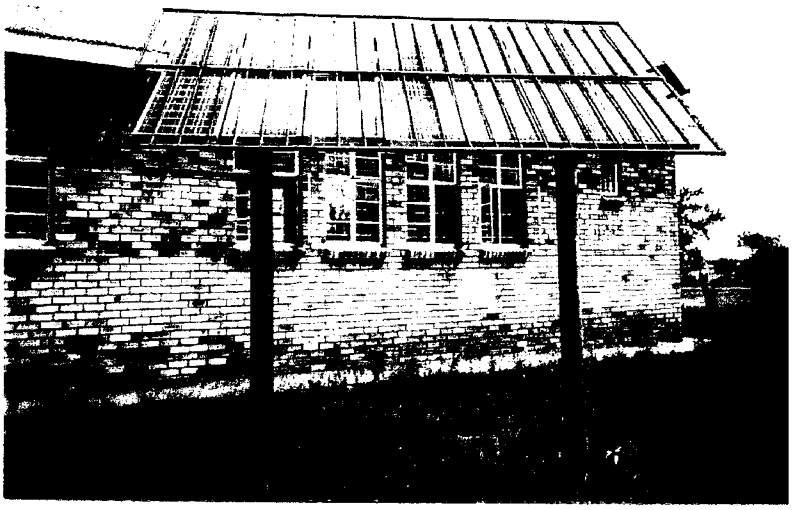
Solar panels on the roof:

Similar to the clinics, the solar panels can be installed on the roof of the schools, making it more difficult to remove them. Two long steel pipes can be used, bolted against an outside wall of the school. Barbed wire can be welded on the pipes, making it impossible to clime up.

Clinic with solar panels on the roof

Anti-burglar bars:

A steel U-profile can be welded around the solar panels, on the frame. The solar panels can only be removed by cutting the welding (and then a generator is needed), or destroying the panels. The EU programme will be upgraded with these bars. A good evaluation of the influence of these bars should be done, to learn for future implementation. This solution can be combined with placing the panels on the roof.



School system (RDP) with self made anti-burglar bars

Solar system near house of community member:

(Idea of J. Adams, Siemens)

The complete solar system can be installed near the house of a community member. This community member should be living near the school/clinic, and be appointed in a community meeting. The solar panels, batteries, regulator and inverter can be near his house, looked after 24 hours a day be the family living in the house. Also the maintenance should be done by the community member. The inverted power must be transformed to a higher tension (2000V for example), to reduce the losses in the transport line to the school/clinic. This power line can be much smaller than the standard power lines used by Eskom, making it less expensive. In the school, a transformer reduces the tension to 220V again. A detailed study of the costs of the transformers and power line must be executed to evaluate the costs of this solution. Also the legal aspects of this solution must be looked at (ownership of the system, responsibility in case of theft, etc.). To stimulate the involvement of the community member, some lights and plugs can for example be installed in his house.

Fence around the solar system:

From the results it is clear that only a very good fence (higher than 2 m), barbed wire and a gate with a good lock influences the theft. In most cases these good fences were combined with a night guard and panels installed on the roof (clinics).

Night watch:

Most clinics have a night watch, paid by the government, who stays at the clinic every night. This, in combination with the good fencing of the clinic, and the installation of the solar panels on the roof, seems to be the best solution against theft and vandalism. With this solution, also the building, the equipment and all things belonging to the school/clinic are guarded. The guard can also be trained to check the system, together with the teachers and headmaster.

Pilot projects in criminal environment:

The security measures mentioned above should first be tested in some pilot projects in areas with the highest theft and vandalism rate. This to make sure that the proposed measures will solve the problem.

<u>2. Ownership of the solar system:</u>

The difference between having to buy a solar system, or getting it for free can make a big difference in the involvement of the users to maintain and look after the system. Because of the high costs of a solar system, and the very small budget of rural schools and clinics, it is impossible to make the school/clinic pay for the purchase of the system. A possibility is to make the schools and clinics pay partly for the purchase of the system, or pay for the use of the system (per used kWh, or per month, or a combination).

<u>3. Involvement of the community:</u>

To get the community involved to look after and support the use of the solar system, it is important to inform them properly. Before the installation, a community meeting should be organised, to explain the community why the school/clinic gets a solar system, and no grid electricity, what the capacity of the system is, what all the uses are etc. Like it was seen on a few schools, some funds are collected by letting the community charge their cell phones, or watch television. These initiatives can also help a lot to make clear to the community what the benefits of a working solar system are.

Also good educational information should be given to the teachers together with a good manual, so that they can explain to the children (especially in secondary schools) how the system works. At this moment, it was experienced in the field that few teachers used the solar system as a subject to teach.

It must be clear to the community that vandalism of the system will be punished very severely (on 1 school, the 17 year old thieve went to prison for 2 years).

<u>4. Installation of a Battery Charging Station.</u>

In a report (Hochmuth 1997), it is recommended to upgrade the solar systems of schools and clinics with a battery charging station to make use of the excess energy. The price for charging a car battery in the rural areas is around R10 (experienced during field research). If a charging system for batteries is installed at the schools/clinics, the excess energy can be used, generating funds for the school/clinic. Looking at the use of the systems on the schools, it is clear that most systems are over-designed, so it must be possible to use this energy, especially during the weekends, holidays and periods besides the exam periods. It will probably also increase the involvement of the community, as the benefits of the system become very clear. Further research should be done to look at the possibilities of this interesting option.

Recommendations on specific factors:

- Good anti-theft measures must be taken on the school systems: placing the solar panels on the roof, installing burglar proof bars, building a good fence around the system/school, placing the system near the house of a community member and engaging a night watch are solutions, that will have an influence on the theft. Pilot projects should be used to see what combinations give the best results.
- The community should be involved more to look after the system by letting them taking advantage of the system (charging cell phones, batteries, watching TV etc.).
- A battery charging station can be installed, to use the excess energy and to get the community more involved.

9.2.4 Policy

It is clear that a detailed policy is necessary to make a success of future implementation of solar systems on schools and clinics. This policy must focus on the different levels that are involved in the implementation of the solar systems
It is important that a solar system is not purely looked at as a technical artefact, but it must fit in the educational and health care goals that are set on national level.
The different levels on which this policy has implications and should be involved are the following:

1. *National government departments*: The national Departments of Minerals and Energy, Education and Health are the main role-players. At this moment they only can give advise to the provincial departments, without obligatory rules.

   The White Paper on Energy Policy was approved by the government in 1998. This policy contains a very general guideline on the energy planning for the next decade. For the electrification of rural schools and clinics, a very promising direction is defined, although no concrete terms, numbers or responsible organisations are mentioned. Therefore, this policy can be seen as a start, but is not a working policy document for rural electrification.
   To assist the Government in the redirection of the National Electrification Programme an advisory body, the National Electrification Co-ordinating Committee (NECC), was established comprising the main institutional stakeholders. This new National Electrification Programme will be operational by 1 April 2001. (Kotze 2001) Provision is made for the schools and clinic backlogs of respectively approximately 17 000 schools and 1 000 clinics have been included (grid and non-grid electrification). This proposal on the grounds of the unsustainability of the current dependence on international grant funding is still under consideration at the NECC. (NECC 2000)

   It is at this level that a general, but detailed policy on the electrification of schools and clinics must be designed and monitored.

2. *Provincial government departments:* The departments in each of all nine provinces have a major authority. They should be involved in the design of the policy, and committed to budget as planned.

3. *Districts:* Each province is sub-divided in a number of districts, but there is a difference between educational and health districts. Depending on the strategy for maintenance of the solar systems that will be chosen, the districts can play a more or less important role. A possible co-operation between the health and the education programmes could be very cost reducing, as storage and education of maintenance personal can be structured on a common base.

4. *Non Governmental Organisations:* This is the management of the programmes (in the past Eskom and IDT), installers, consultants etc. As it is on this level that the actual installation of the systems and training of end users is done, the quality control is very important. This level is also the input for the monitoring and evaluation of the projects, so clear procedures must be available.

5. *Communities:* These are the communities that have to be involved when a solar system will be installed on a schools and/or clinic. As stated earlier, the involvement of the communities can have a great influence. How the communities will be involved, and what the goals are must be described in detail. As stated in (Cross 1995) p7: "One root problem is perceptions of development. The views of the government-donators-developers alliance are so far apart from the views of the communities that the two sides can rarely communicate without help."

6. *Individual users:* The teachers/nurses/ students/ patients. Analysing the need of the user, the training of the end-user and communication procedures must be designed and quality controlled.

A very important issue is the communication between the different levels, to be able to adapt the programme if necessary, and to keep a good overview of what the situation is on each level. A standardised database with location, school/clinic name, contact numbers, installation date, installer, system specifications, reported problems, etc. should be accessible on each level.

Further research is necessary to develop a policy for each level, as this is essential to manage the sustainable implementation of non-grid electrification.

Recommendations on policy:

- A clear, detailed policy must be designed for the electrification of rural schools and clinics with good communication and up-to-date information on the programmes.
- The implementation of this policy must be a requirement for new projects to be funded by foreign countries.

9.3 Future research

The aim of this research was to evaluate the past solar electrification projects to come to recommendations on the design and implementations for future projects. From the results, it is clear that there are a lot of problems with the past projects. The recommendations give the areas where changes can be made to improve the success of implementation on the long term.
However, detailed research on a lot of aspects is necessary.

1. How to identify the real need of schools and clinics for electricity, and a procedure to form categories on the quantity of electricity needed. Than the design of the system can be adjusted to the need.

2. The theft and vandalism must be studied in detail, to come to the best (and cheapest) solution.

3. A complete maintenance plan must be designed, and a choice made between the different options (see Paragraph 9.2.2.2). The expected lifetime of all parts must be looked at under field conditions, checking the expected lifetime promised by the suppliers (batteries, inverters, regulators, refrigerators).

4. The possible benefit for the whole community should be studied, optimising the use of the solar system (charging cell phones, watching television, evening classes, battery charging station etc.). Also ways to get the community involved can form part of this study.

5. A detailed study on the complete lifecycle costs must be done together with the maintenance plan, on which the departments can budget.

6. The integration of the implementation of the solar systems with other development efforts should be studied. Solar water pumping, evening classes, telecommunication, computer use etc. can form part of this study.

7. A clear policy must be designed, on national, province, district, NGO and user level for the sustainable implementation of non-grid electricity systems.

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APPENDIX

Appendix 1: Design procedure for solar systems.

(Source: [Siemens, 1998 #40])

Typical Appliance Power Consumption
(See appliance for actual power used)

DC	[W]
Ceiling fan	20
Refrigerator	50-70
Television (25cm)	45
Fluorescent light	5-13
Stereo/Tape player	100

AC	[W]
Fluorescent light	5-13
Cell phone charge	10
Refrigerator	90-150
Stereo	40
Television (48cm)	60-85

Daily DC Requirements

List each DC load (Watts)

Multiply by daily average use (hours)

Add to find daily DC load
Add 30%* of the total

The Sum is Your Average Daily DC Energy Requirement

Appliance	**W**	**x**	**h**	**=**	**Wh**
______	__		__		__

= Average Daily DC Energy Requirement ___

+ Allowance for battery and system losses (30%) ___

= Average Daily DC Energy Requirement ___

Daily AC Requirements

List each CC load (Watts)

Multiply by daily average use (hours)

Add to find daily DC load
Add 40%* of the total

The Sum is Your Average Daily AC Energy Requirement

Appliance	**W**	**x**	**h**	**=**	**Wh**
______	__		__		__

Average Daily AC Energy Requirement ___

+ Allowance for battery and system losses (40%) ___

= Average Daily AC Energy Requirement ___

Daily Power Requirement (AC+DC)
/
Daily Watt-hours per panel
=
Estimated Module Requirement

Daily Power Requirement
x
Reserve Factor (multiply by the number of days that the batteries must operate loads without solar charge.)
+
Safety Factor (30 % capacity reserve)
=
Required battery capacity

EXAMPLE FOR SCHOOLS:

AC Loads:	Lights (14x20W)	x 5hrs/day	=	1400 W
	TV (85W)	x 3hrs/day	=	255 W
	VCR (50W)	x 3hrs/day	=	150 W
	Cell phone charge (4*10W)	x 4hrs/day	=	160 W
Average Daily AC Energy Use			=	1965 W
+ Allowance for battery/inverter losses (40%)				786 W
Average Daily AC Energy Requirement				**2751 W**
Daily Power Requirement/Daily Watt Hours per panel*			=	2751/550
Number of required solar panels			=	**5 panels**

* Panels of 110Wp, in South Africa, area factor =5 [Siemens, 1998 #40]

Daily Power Requirement x Reserve Factor (4 days)	=	2751 x 4
	=	11004
+ Safety factor (30% capacity reserve)	+	3302
	=	14306 Wh
/ Voltage of battery bank	/	24 V
Required Battery Capacity	=	**596 Amph**

CONCLUSIONS:

- If the area factor is 4 (cloudy weather during more than a week, which was mentioned by some users), 7 panels are required.
- With a reserve factor of 4, the whole system can work without sun for 4 days, but this only for new batteries!
- The use of the lights for 5 hours per day, only occurs in the exam periods, so this is the worst case.

- In the EU-programme, 8 solar panels of 110W are used, and a battery capacity of 510Amph. One can say, looked at the mentioned hours of use in the field, that the systems are over-dimensioned a bit, but not very much.
- The fact that the systems are not used in the weekends, so can charge for 2 days and the 8 panels installed, means that an excess of electricity is available in most cases, that could be used for other purposes.

- Detailed research has to be done on the insulation in the different areas to define the correct area factor and reserve factor for the battery capacity.
  Also more research on the performance of the batteries through the lifetime has to be done.

Appendix 2: Aspects in questionnaire and questionnaire

A. ASPECTS IN QUESTIONNAIRE

Dependant variable: Success of implementation

Question number:	Aspects of Technical performance of solar system
15	Is the system working?
10-16	Working lifetime of system (Installation till not working since) ?
17	What is the problem of the system?
106	What are the general conditions of the panels?
111	What are the general conditions of the batteries?
112	What is the current from the array into the battery bank?
113	What is the voltage of the battery bank (display)?
114	What is the voltage of the battery bank (measured)?
115-116	What is the current stage of the batteries?
128	Are there any faults in the system?
130	What is the measured specific gravity?
19	Did the system have breakdowns before?
20	How often did the system have a problem?
131	What is the measured water level?

Question number:	Aspects of Satisfaction of user
62	Are you satisfied?
63	Why are you satisfied?
64	Does the system give enough electricity?
65	Do you think the system is good designed?
84	Would you recommend the system to another school or clinic?
88	Does the system meet your expectations?

Independent variables

Question number	NEED OF THE USER
86	What would you like to have in the school/clinic?
87	Would you be able to buy a pc, tv?
53	What are you using the system for?
90	How many hours are the lights burning?
92	How badly do you need the system?
93	What do you need the most?
97	What is the indicated need in after interview impression.
	CHARACTERISTICS OF THE USER
	Involvement of the user
11	Logbook/manual available on site?
12	What is the accuracy of logbook?
13	Can you or did you ever use manual
18	Is the problem reported?
69	Do you feel responsible for the system?
70	Do you check the system yourself sometimes?
74	Who was present at the training?
75	Do you know whom to call when there is a problem?
75	Who would you call when there is a problem?
78	Did you really want the system in the beginning?
84	Would you recommend the system to another school/clinic?
87	Would you be able to buy a PC, TV?
101	Is there a fence around the solar system?
131	What is measured water level in batteries
96	Motivation to use or maintain system of interviewed person
	Knowledge of user of system
29	Do you know where to get more distilled water?
30	Do you know what happens if you use normal water?
72	Do you know weather the system has a warranty period?
73	Do you know how to claim against warranty?
46	Do you know that batteries have to be replaced in 4-7 years?
58	Was there a lot of staff changes the last two years?
59	Was the new staff informed about the working of the system?
73	How long did the training take?
74	Who was present at the training?
75	Can you shortly explain how the system works?
77	Do you know who to call when there is a problem?
79	Did someone ever asked you if you wanted the system before installation?
91	Can you cook water on the system?
	General characteristics of the user
39	What sort of telecommunications do you have available?
45	Are you saving for replacement of the batteries or the inverter?
47	Are you saving for other repairs on the system?
48	Do you have a night guard?
54	What is the profession of person interviewed?
55	What time are you related to school/clinic?
56	What is the time planned to stay at school/clinic?
85	Do you know how to work with a computer?
98	Is system used a lot? (after interview impression)

Question number	ENVIRONMENTAL CHARACTERISTICS
	Condition/characteristic of the school/clinic
6	What are the numbers of pupils/patients per months?
7	Is there an alternative for lightning the school/clinic?
58	Was there a lot of staff change the last 2 years?
87	Would you be able to buy a TV, PC etc?
89	Is the school/clinic used in the evenings?
90	How many hours are the lights burning?
100	What is the general impression of the building?
101	Is there a fence around the school?
	Availability of alternatives
66	Do you have alternative fuels for lightning?
*	Are you connected to the grid?
	General characteristics
3	What are the co-ordinates of the school/clinic?
4	What province is the school/clinic located?
7	Distance from the closest electricity line?
8	Distance from the closest weather-proof road?
94	How far is the closest hardware shop?
95	Is there a lot of crime in the area?
99	What is the weather condition?

Question number	TECHNICAL DESIGN
10	What is the installation date of the system?
11	Is there a logbook available?
13	Is there a manual available?
28	Are there spare parts available?
41	Are parts stolen?
42	What parts?
43	Are parts replaced?
53	What other electrical equipment installed is installed?
67	Was the system ever upgraded
103	What is the number of solar panels installed?
104	What is the brand of the solar panels?
105	What is the power of each panel installed?
107	What is the brand of the batteries?
108	What type of battery is used?
109	What is the indicated battery capacity?
110	What is the nominal battery voltage of the whole battery bank?
117	What is the brand of inverter installed?
118	What is the nominal power installed?
119	Is the system enable to work with some stolen modules?
120	Are there 2 switches per classroom ?
121	Is extern display present?
129	How many litres of distilled water are available?

Question number	PRODUCT SUPPORT AND MAINTENANCE
19	To who did you report the problem?
22	How long did it take to repair the system?
23	Who does repairs on system
24	If nobody why not?
25	Who pays for repairs?
39	How often occurs preventive maintenance?
40	When for the last time?
77	Who would you call when there is a problem?
81-83	How many times did Eskom, the commission officer and the contractor visit your school?
131	What is the measured water level in batteries?
	OWNERSHIP OF THE SOLAR SYSTEM
68	Who is the owner of the system?
	DISTRIBUTION OF RESPONSIBILITIES
32	Who cleans the panels?
33	How often
34	Who checks the batteries?
35	How often?
50	Who paid night guard?
	Who trained the new staff members?
60	Do you feel responsible for the system?
69	Do you check the system yourself sometimes?
72	Who trained the staff?
74	Who would you call when there is a problem?
80	Who asked if you wanted the system?
81-83	How many times did somebody of Eskom, the Commissioning officer the contractor visit you school?
101	Is there a fence around the solar system?
	SECURITY
48	Is a night guard employed?
51	Are other security measurements?
101	Is there a fence around the whole property?
102	Is there a fence around the solar system?
122	Is the array security frame in place?
124	Is the new steel enclosure installed?
	TRAINING AND INFORMING
71	Was the staff informed about the working of the system?
72	Who explained it?
73	How long did the training take?
74	Who was present at the training?
75	Can you shortly explain how the system works?
	FINANCIAL ASPECTS
25	Who pays for the repairs?
44	Who paid for replacement of stolen parts?
47	Who pays the night guard?
87	Would you be able to buy a P.C., T.V or other?

SCHOOL / CLINIC SURVEY

Name :______________________________________

Village :______________________________________

District:______________________________________

---

1 School / clinic number — V1 [ ][ ][ ] — 1-3

2 Date — V2 [ ][ ][ ][ ] — 4-7

[ ][ ] Day [ ][ ] Month

3 GPS co-ordinates

[ ][ ] ° [ ][ ] ' [ ][ ] " S — V3 [ ][ ][ ][ ][ ][ ] — 8-13

[ ][ ] ° [ ][ ] ' [ ][ ] " E — V4 [ ][ ][ ][ ][ ][ ] — 14-19

4 Province — V5 [ ] — 20

Northern Province	1
Eastern Cape	2

5 Hour of arrival on site: — V6 [ ][ ][ ][ ] — 21-24

[ ][ ] H [ ][ ] Min.

6 Number of pupils/patients per month. — V7 [ ][ ][ ][ ] — 25-28

[ ][ ][ ][ ]

7 Distance from closest electricity grid (km). — V8 [ ][ ][ ] — 29-31

[ ][ ][ ] Hm (=100m)

8 Distance from closest weather proof road (km). — V9 [ ][ ][ ] — 32-34

[ ][ ][ ] Hm (=100m)

9 What source of water is available?

Mains reticulation	1	V10		35
Rain tank(s)	2	V11		36
Well/bore	3	V12		37
No water available	4	V13		38

10 Installation date of the solar system. V14 [ ][ ][ ][ ] 39-42

[ ][ ] Month [ ][ ] Year

11 Logbook available of the solar system on site? V15 [ ] 43

YES	1
NO	2

12 Is it accurate and regularly completed(ask to see it!)? V16 [ ] 44

YES	1
NO	2

13 Is there a user manual available on site? V17 [ ] 45

YES	1
NO	2

14 If yes, can you everything you need in the manual to use and maintain the solar system? V18 [ ] 46

YES	1
NO	2

15 Is the solar system working? V19 [ ] 47

COMPLETELY	1
PARTLY	2
NOT AT ALL	3

16 If no, since... V20 [ ][ ][ ][ ] 48-51

[ ][ ] Month [ ][ ] Year

17 What is the problem?

Panels missing	1
Panels defect	2
Batteries missing	3
Batteries defect	4
Inverter missing	5
Inverter defect	6
Regulator missing	7
Regulator defect	8
Fuse problem	9
Panels Disconnected	10
Unknown	11

V21		52
V22		53
V23		54
V24		55
V25		56
V26		57
V27		58
V28		59
V29		60
V30		61
V31		62

43 Were these parts replaced? V115 ☐ 154

YES	1
NO	2

44 Who paid for the replacement?

Eskom	1
Dep. of Health	2
Dep. of Education	3
School/clinic	4
Dep. of Works	5
Community	6
Other	7

V116		155
V117		156
V118		157
V119		158
V120		159
V121		160
V122		161

45 Are you saving for the replacement of the battery and the inverter/regulator? V123 ☐ 162

YES	1
NO	2

46 Did anyone tell you the battery has to be replaced after 3-4 years, the inverter/regulator after 10 years? V124 ☐ 163

YES	1
NO	2

47 Are you saving for others repairs on the system? V125 ☐ 164

YES	1
NO	2

48 Do you have a night guard? V126 ☐ 165

YES	1
NO	2

50 Who pays his salary? V127 ☐ 166

Community	1
Dep. of Health	2
Dep. of Education	3
Other	4

51 Are there other security measures? V128 ☐ 167

Lights on at night	1
Other:	2-5

52 When were the batteries replaced (if so)?

☐☐ Month ☐☐ Year FIRST TIME V129 ☐☐☐☐ 168-171

☐☐ Month ☐☐ Year SECOND TIME V130 ☐☐☐☐ 172-175

53 Electrical equipment.

		Nr Installed	Nr Working	12VDC	24VDC	220VAC	Educational /medical	Not educational/ medical	Both
1	Lights			1	2	3	1	2	3
2	Power outlets			1	2	3	1	2	3
3	Refrigerator			1	2	3	1	2	3
4	TV			1	2	3	1	2	3
5	Video			1	2	3	1	2	3
6	Sat. Dish			1	2	3	1	2	3
7	Overh. proj.			1	2	3	1	2	3
8	Computer			1	2	3	1	2	3
9	Other			1	2	3	1	2	3

V131			176-177
V132			178-179
V133			180-181
V134			182-183
V135			184-185
V136			186-187
V137			188-189
V138			190-191
V139			192-193

V140			194-195
V141			196-197
V142			198-199
V143			200-201
V144			202-203
V145			204-205
V146			206-207
V147			208-209
V148			210-211

V149		212
V150		213
V151		214
V152		215
V153		216
V154		217
V155		218
V156		219
V157		220

V158		221
V159		222
V160		223
V161		224
V162		225
V163		226
V164		227
V165		228
V166		229

54 Profession of person interviewed. V167 ☐ 230

Headmaster	1
Nurse	2
Student	3
Doctor	4
Teacher	5
Head nurse	6
Other	7

55 Education level of person interviewed. V168 ☐ 231

Primary	1
Secondary	2
Diploma	3
University	4
Other	5

56 What is the time you are related to this school/clinic? V169 ☐☐ 232-233

☐☐ Years

57 Time planned to stay at this school/clinic? V170 ☐☐ 234-235

☐☐ Years

58 What was the staff change the last 2 years? V171 ☐ 236

No staff changed	1
Some of the staff	2
A lot of the staff	3
Almost all staff	4

59 Was the new staff informed about the working and maintenance of the system? V172 ☐ 237

YES	1
NO	2

60 How was the new staff informed about the working and maintenance of the solar system?

By other staff member	V173		238
By principal/head nurse	V174		239
By contractor	V175		240
By Eskom	V176		241
By the Department	V177		242
Other:	V178		243
Other:	V179		244

61 Is the solar electricity used in the school/clinic? V180 ☐ 245

YES	1
NO	2

62 Are you satisfied with the solar electricity? V181 ☐ 246

YES	1
NO	2

63 Why, why not?

______________________ V182 ☐☐ 247-248

______________________ V183 ☐☐ 249-250

______________________ V184 ☐☐ 251-252

64 Does the system give enough electricity? V185 ☐ 253

YES	1
NO	2

65 Do you think the system is good designed for what you need it here? V186 ☐ 254

YES	1
NO	2

66 Do you have other ways of lightening the school/clinic?V187 ☐ 255

YES	1
NO	2

67 Was the system ever upgraded (e.g. more panels, batteries,...)? V188 ☐ 256

YES	1
NO	2

68 Who is the owner of the system? V189 ☐ 257

School/clinic	1
Department	2
Eskom/IDT	3
Community	4
Sponsor	5
Other	6-9

69 Do you feel responsible for the solar system? V190 ☐ 258

YES	1
NO	2

70 Do you check the system yourself sometimes? V191 ☐ 259

YES	1
NO	2

71 Did anyone ever explain to you how to use, maintain check the system? V192 ☐ 260

YES	1
NO	2

72 Who explained it? V193 ☐ 261

Eskom extension worker	1
Department	2
Installer	3
Local Government	4
Other	5-9

73 How long did the training take? V194 ☐☐☐ 262-264

☐ Days , ☐☐ Total number of hours

74 Who was present at the training?

Principal/head nurse	1
Some teachers/nurses	2
All teachers/nurses	3
Some community members	4
Community matron	5
District office personnel	6
Others:	7-9

V195		265
V196		266
V197		267
V198		268
V199		269
V200		270
V201		271
V202		272
V203		273

75 Can you explain shortly how the system works? (INTERPRETE ANSWER) V204 ☐ 274

BAD	1	2	3	4	5	GOOD

76 Do you know what to do when there is a problem with the system? V205 ☐ 275

YES	1
NO	2

77 Who would/did you call when there is a problem?

Eskom	1
Dep. of Health	2
Dep. of Education	3
District officer	4
Dep. of Works	5
Installer	6
Private company	7
Other	8
Don't know	9

V206		276
V207		277
V208		278
V209		279
V210		280
V211		281
V212		282
V213		283
V214		284

78 Did you really want the system in the beginning? V215 ☐ 285

YES	1
NO	2

79 Did someone ever ask you if you wanted a solar system? V216 ☐ 286

YES	1
NO	2

80 Who asked you if you wanted a solar system?

Eskom ext.worker	1	V217		287
Dep. of Health	2	V218		288
Dep. of Education	3	V219		289
District officer	4	V220		290
Dep. of Works	5	V221		291
Installer	6	V222		292
Private company	7	V223		293
Other	8	V224		294
Don't know	9	V225		295

81 How many times did the Eskom extension worker visit your school to answer your queries? V226 ☐ 296

☐ Times

82 How many times did the commissioning officer visit your school to answer your queries? V227 ☐ 297

☐ Times

83 How many times did the contractor (installer) visit your school to answer your queries? V228 ☐ 298

☐ Times

84 Would you recommend the solar system to another school or clinic? V229 ☐ 299

YES	1
NO	2

85 Do you know how to work with a computer? V230 ☐ 300

YES	1
NO	2

86 What would you like to have in the school/clinic? (1= first priority, 2 is second etc)

Television	1
Telephone	2
Computer	3
2-way radio	4
Other	5-9

V231		301
V232		302
V233		303
V234		304
V235		305
V236		306
V237		307
V238		308
V239		309

87 Would you be able to gain funds to buy a PC? V240 ☐ 310

YES	1
NO	2

88 Does the system meet your expectations in terms of what was set would be provided? V241 ☐ 311

YES	1
NO	2

89 Is the school/clinic used in the evenings? V242 ☐ 312

YES	1
NO	2

90 How many hours per week are the lights burning?

In the classrooms			
In the principal office			
In the clinic			
Outside			
In the nurses home			
Other:			

V243			313-314
V244			315-316
V245			317-318
V246			319-320
V247			321-322
V248			323-324

91 Can you cook water on the system? V249 ☐ 325

YES	1
NO	2

92 How badly do you need the system? V250 [ ] 326

Not need it all	1
Do not really need it	2
Would be inconvenient	3
Difficult without it	4
Almost impossible without it	5

93 What do you need the most
(1=need the most, 5=do not really need) Give priority!

A good road to school/clinic		V251		327
Good water facilities		V252		328
Electricity		V253		329
New/better building		V254		330
Computer		V255		331

94 How far is the closest hardware shop? V256 [ ][ ] 332-333

[ ][ ] Km

95 Is there a lot of crime in this area (theft-vandalism)? V257 [ ] 334

Never	1
Almost never	2
Happens now and then	3
Happens a lot	4
Very much	5

Observation:

School or Clinic Number ______________________

Time ______________________

---

99 What is weather condition? V261 ☐ 338

Clear	1
Partly Cloudy	2
Cloudy	3

100 What is the general impression of the building ? V262 ☐ 339

BAD	1	2	3	4	5	GOOD

101 Is there a fence around the whole property? V263 ☐ 340

NO FENCE	1	2	3	4	5	GOOD

102 Is there a fence around the solar system? V264 ☐ 341

NO FENCE	1	2	3	4	5	GOOD

103 Number of solar panels installed. V265 ☐☐ 342-343

☐☐ panels

104 What is the brand of the solar panels? V266 ☐ 344

Isofoton	1
BP	2
Kyocera	3
Shell	4
Siemens	5
Other	6-9

105 What is the power of each panel?
(read in the back of the panel) V267☐☐☐ 345-347

☐☐☐ Wp

106 General condition of the panels. V268 ☐ 348

BAD	1	2	3	4	5	GOOD

107 What is the brand of the batteries? V269 ☐ 349

FNB	1
Willard	2
Other	3-6

108 What Type of battery is used? V270 ☐ 350

Starter Battery	1
Flooded Solar	2
Gel Battery	3
Malt Battery	4

109 What is the indicated battery capacity? V271 ☐☐☐ 351-353

☐☐☐ Ah

110 What is the nominal battery voltage
for the whole battery bank? V272 ☐ 354

12 Volt	1
24 Volt	2
36 Volt	3
48 Volt	4
Other	5
Unknown	6

111What is the general condition batteries? V273 ☐ 355

BAD	1	2	3	4	5	GOOD

Switch off all loads (if possible).

112 What is the current from array into battery? (measure with clamp meter). V274 ☐☐☐ 356-358

☐☐☐ Ampere

Switch off array also.

113 What is the voltage of battery from the regulator display? V275 ☐☐☐ 359-361

☐☐☐ Volt

114 What is the measured voltage of the battery? V276 ☐☐☐ 362-364

☐☐☐ Volt

Switch loads and array back on.

115 What is the current battery state of charge -Level? As indicated by the charge regulator indicators V277 ☐ 365

Battery A

Full	1
Half full	2
Empty	3
Loadshed	4
Boost	5

116 What is the current battery state of charge -Level? As indicated by the charge regulator indicators V278 ☐ 366

Battery B

Full	1
Half full	2
Empty	3
Loadshed	4
Boost	5

117 What is the brand of inverter installed? V279 ☐ 367

ASP	1
Steca	2
MLT	3
Other	4
Unknown	5-9

118 What is the nominal output power installed? V280 ☐ 368

400 VA	1
500 VA	2
600 VA	3
800 VA	4
1200 VA	5
Other	6
Unknown	7

119 Is the array rewiring upgraded to enable system to work with some stolen modules? V281 ☐ 369

YES	1
NO	2

120 Are there two switches per classroom? V282 ☐ 370

YES	1
NO	2

121 Is the external display to provide user interface at distribution board installed? (EU and some clinics) V283 ☐ 371

YES	1
NO	2

EU Only

122 Is the array security frame in place? (EU-schools) V284 ☐ 372

YES	1
NO	2

123 Are the sub-array blocking diodes installed? V285 ☐ 373

YES	1
NO	2

124 Is the new steel enclosure around orange Control Gear Enclosure installed? V286 ☐ 374

YES	1
NO	2

125 Battery Fuse and holder replaced? V287 ☐ 375

YES	1
NO	2

126 Battery step for Iso-foton cells? V288 ☐ 376

YES	1
NO	2

127 Is the new user manual available? V289 ☐ 377

YES	1
NO	2

ALL

128 Are there any faults in the system ?

Panels missing	1	V290		378
Panels defect	2	V291		379
Batteries missing	3	V292		380
Batteries defect	4	V293		381
Inverter missing	5	V294		382
Inverter defect	6	V295		383
Regulator missing	7	V296		384
Regulator defect	8	V297		385
Fuse problem	9	V298		386
Other problem	10	V299		387
Unknown	11	V300		388

129 How many litres of distilled water are there still in stock?

☐☐ Litres

V301 ☐☐ 389-390

130 Measure the Specific Gravity: (SG)
(it should be about 1.100 for cells in a low state of charge, and 1.250 for cells in a high state of charge. For a battery bank all cells should be within 0.05. If they are not, then there is a problem, and this is what we want to identify!)

Cell 1	
Cell 2	
Cell 3	
Cell 4	
Cell 5	
Cell 6	
Cell 7	
Cell 8	
Cell 9	
Cell 10	
Cell 11	
Cell 12	
Cell 13	
Cell 14	
Cell 15	
Cell 16	
Cell 17	
Cell 18	
Cell 19	
Cell 20	
Cell 21	
Cell 22	
Cell 23	
Cell 24	

V302					391
V303					392
V304					393
V305					394
V306					395
V307					396
V308					397
V309					398
V310					399
V311					340
V312					341
V313					342
V314					343
V315					344
V316					345
V317					346
V318					347
V319					348
V320					349
V321					350
V322					351
V323					352
V324					353
V325					354

131 Measure the water level in battery **(<u>0% is empty reserve 100% is full reserve</u>)**

FNB EU batteries have a float indicator for cell reserve measurement. FNB clinic cells, willard cells and Isofoton cells are translucent, and the electrolyte reserve is indicated by markes on the cell casing.

Cell nr	**Percentage of reserve remaining**
Cell 1	
Cell 2	
Cell 3	
Cell 4	
Cell 5	
Cell 6	
Cell 7	
Cell 8	
Cell 9	
Cell 10	
Cell 11	
Cell 12	
Cell 13	
Cell 14	
Cell 15	
Cell 16	
Cell 17	
Cell 18	
Cell 19	
Cell 20	
Cell 21	
Cell 22	
Cell 23	
Cell 24	

V326			355
V327			356
V328			357
V329			358
V330			359
V331			360
V332			361
V333			362
V334			363
V335			364
V336			365
V337			366
V338			367
V339			368
V340			369
V341			370
V342			371
V343			372
V344			373
V345			374
V346			375
V347			376
V348			377
V349			378

To be filled in immediately after interview:

96 Was the interviewed person motivated to use and maintain the system? V258 ☐ 335

Not motivated	1	2	3	4	5	Very motivated

97 Does the school/clinic really need the system? V259 ☐ 336

No need at all	1	2	3	4	5	Very needed

98 Is the system used intensively in the school/clinic? V260 ☐ 337

Not at all	1	2	3	4	5	Used intensively

Appendix 3: Pictures field work.

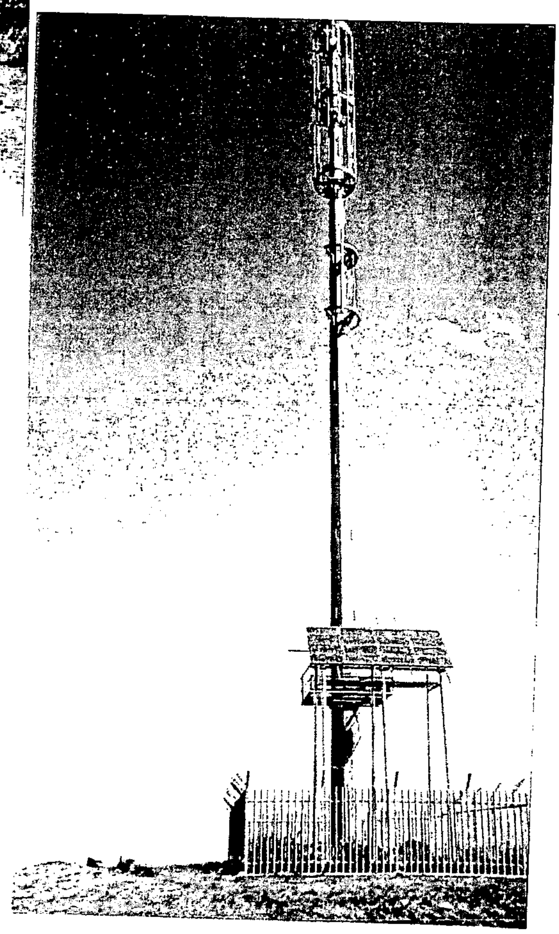
The environment:

Deep rural area in the Eastern Cape.
No electricity, good roads or other infrastructure is available,

Dirt road in the Eastern Cape, impossible to travel after rain.

Road after slight rain.

Weather proof road in the Northern Province.

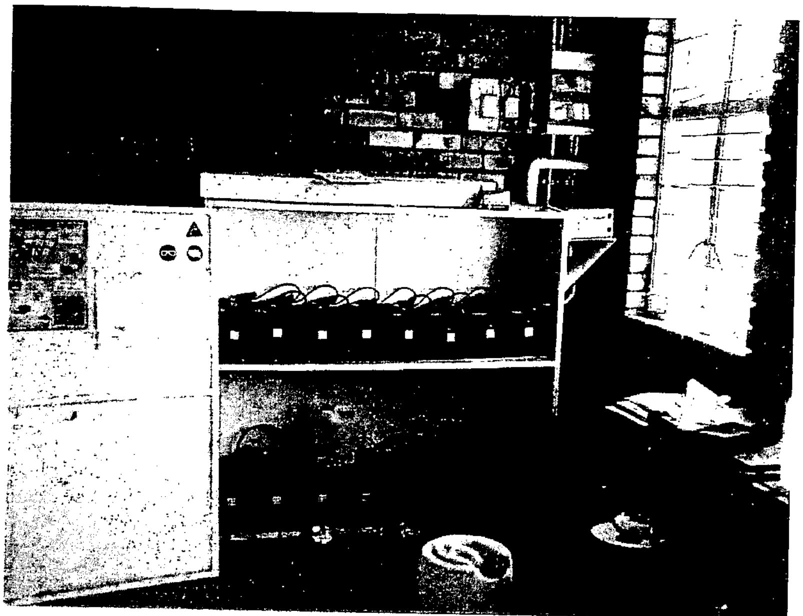


Telecom system in rural area.
Notice the fencing and high installation of the solar panels.

Clinic in rural area.
Telephone system

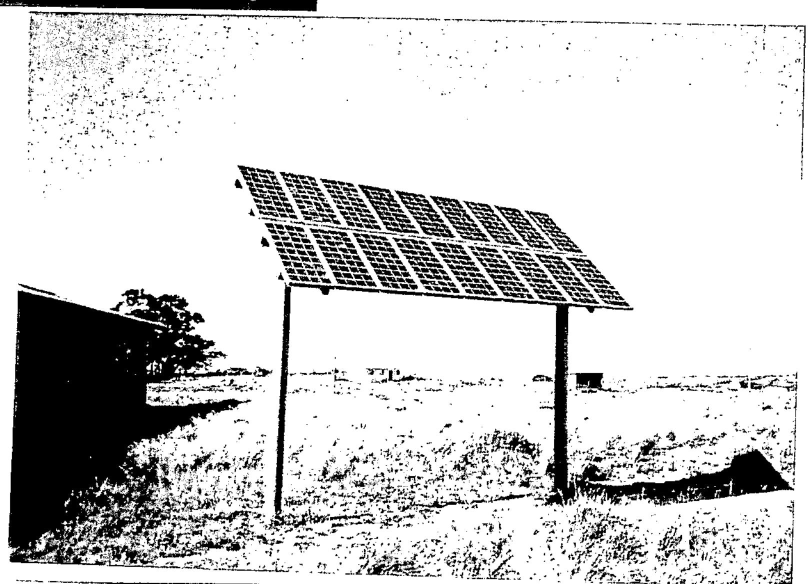
Solar panels electricity system

System components

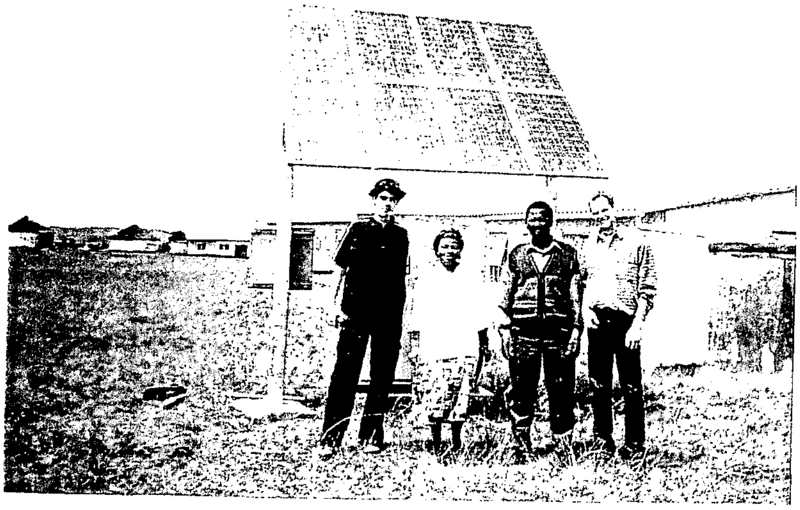


Battery bank of RDP-system. Situated in the back of a classroom.

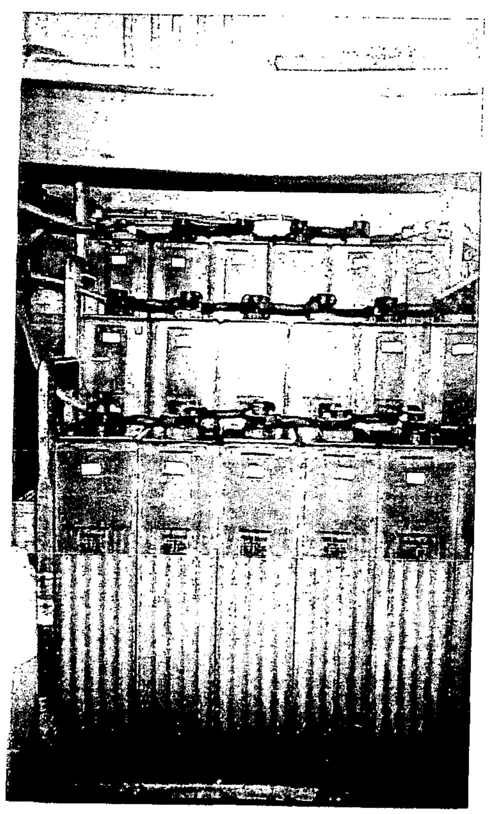
Solar panels (50Wp) of RDP-system.



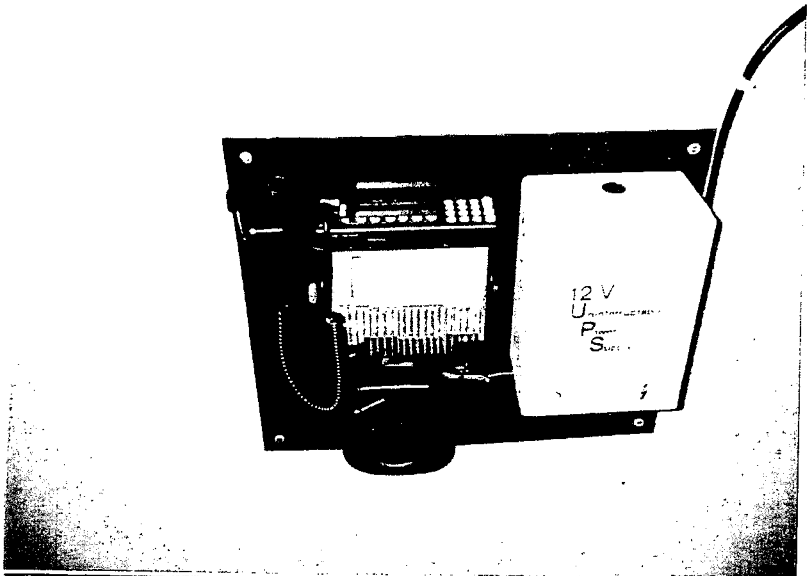
Battery bank of EU-system.



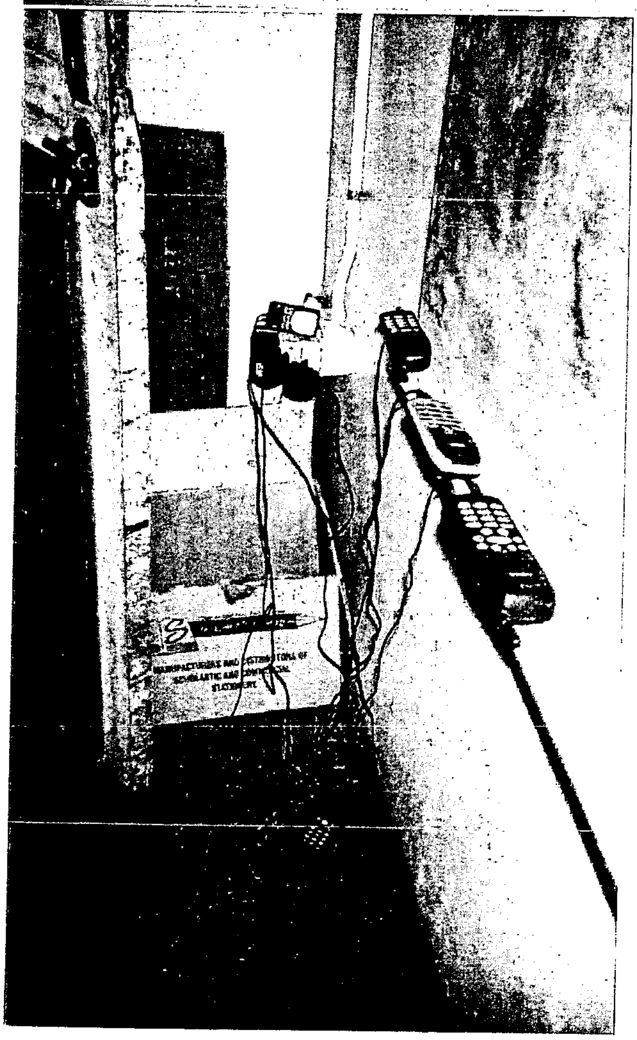
Working EU-system. 8 solar panels of 110Wp, Inverter and regulator in the orange box, battery bank in the grey box under the panels.



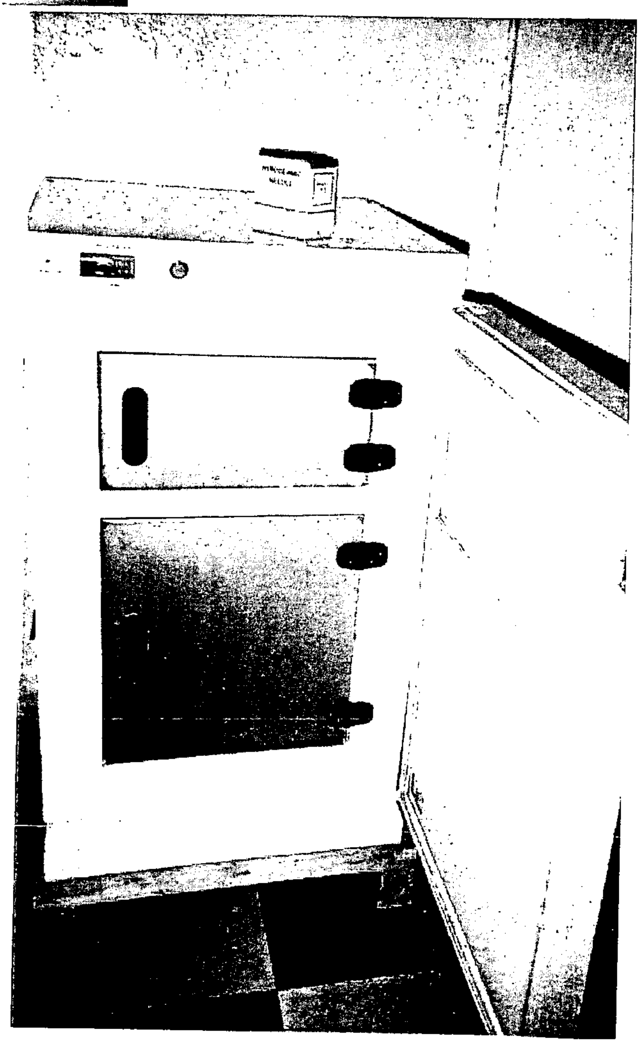
Battery bank of a clinic system.



2-way radio in clinic.

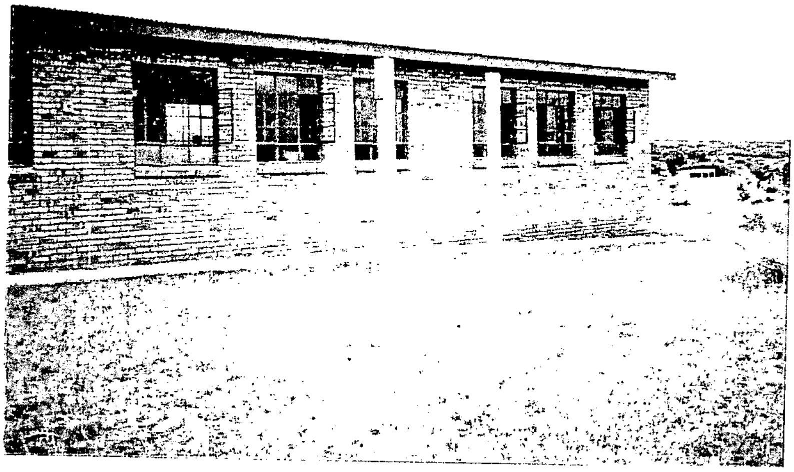


EU-system used to charge cell phones.



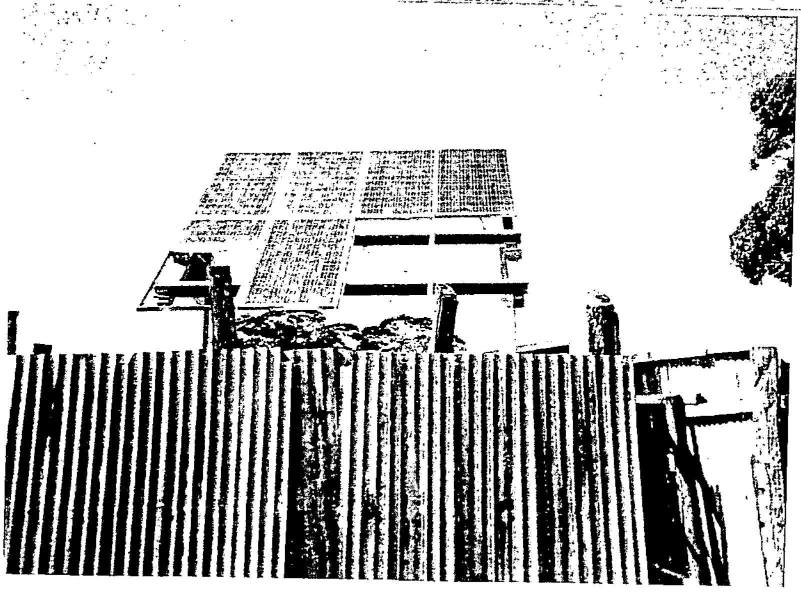
Clinic refrigerator. Ice pack freezing and cooling. 12V.

Vandalism and theft

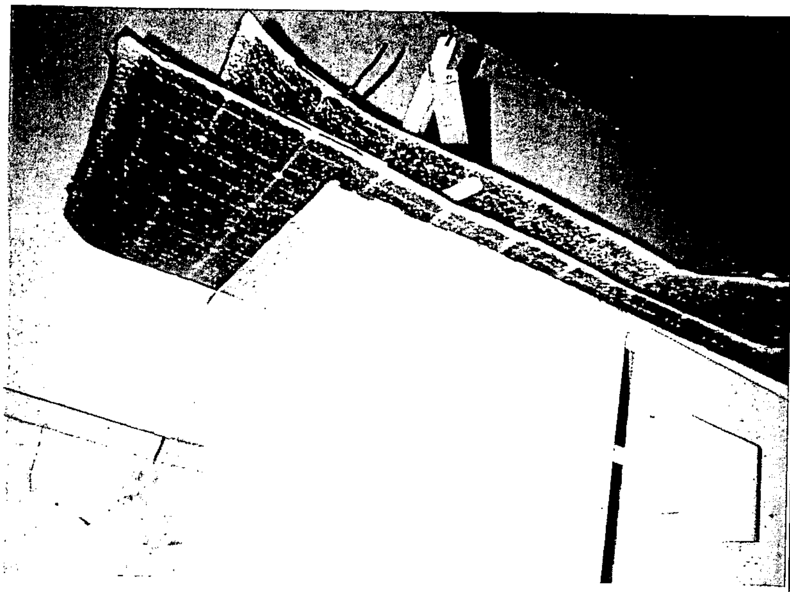


Solar panels stolen RDP-system. Only the poles remain.

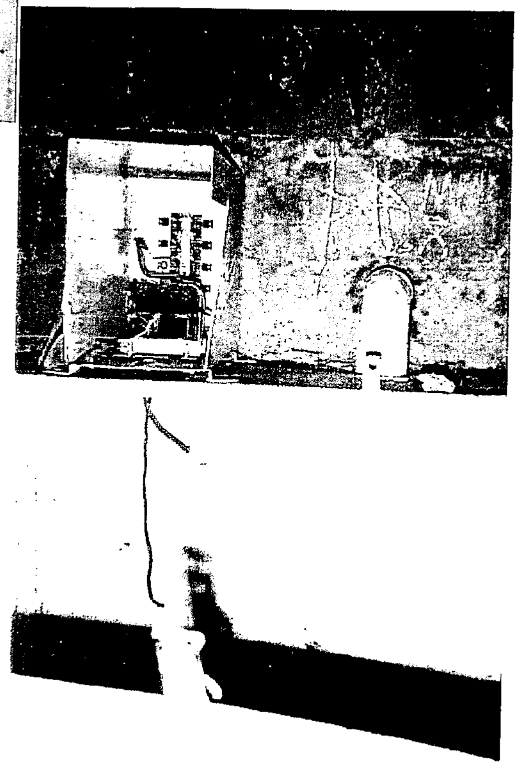
Solar panels stolen EU-system.



Solar panels stolen EU-system. The glass plate is pulled out of the frame.

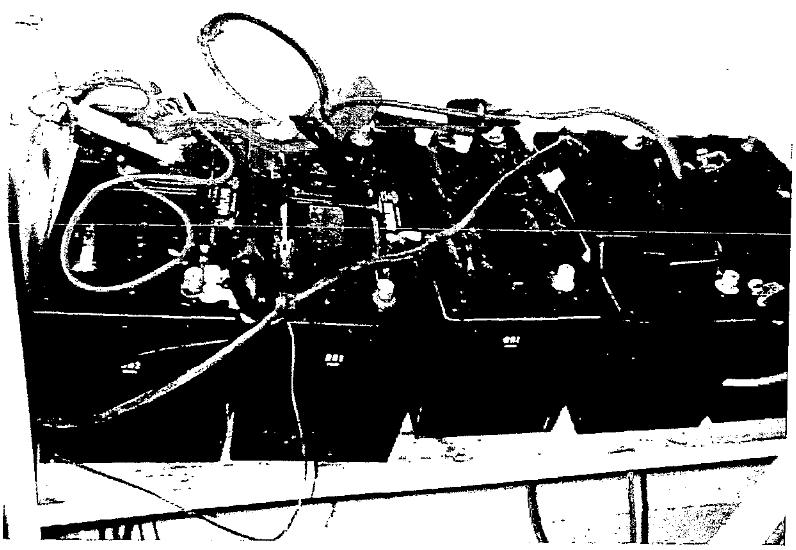


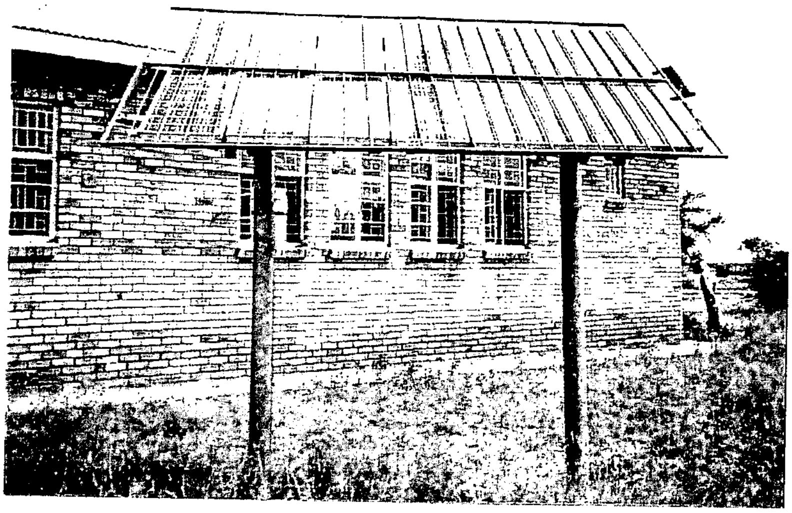
Stolen panels found back in the bushes.



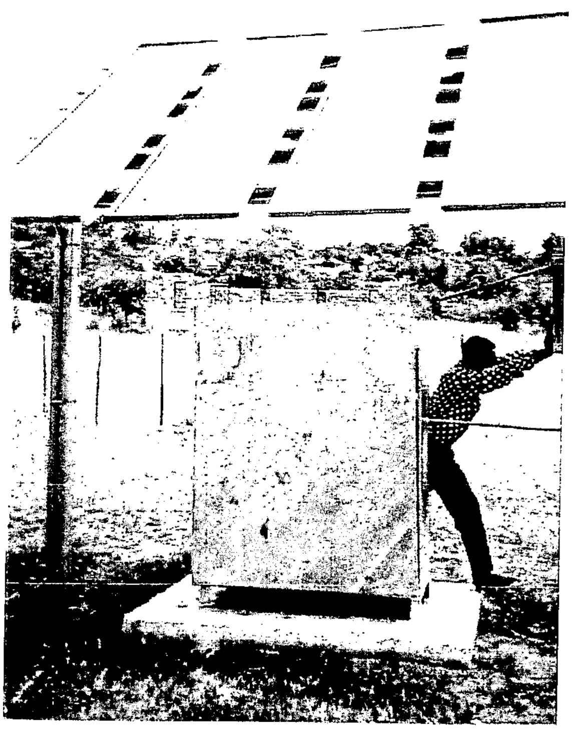
Vandalised inverter and stolen batteries RDP-system.

Vandalised batteries RDP-system.





Burglar proof bars on RDP-system, installed by the users.



Burglar proof bars on EU-system, installed by the users. U-bar around panels, welded on the frame.

Appendix 4: Life cycle cost of solar system.

The aim of this calculations is not to come to an exact amount to do maintenance on the solar systems in the future, therefore more research is necessary. The aim is to give a general impression of the life cycle costs of solar systems, making it clear that the purchase of the system itself is just the top of the iceberg, discussed in paragraph 4.4.
All costs are in Rand (Fl 1 = R 3, 132 on 05-2001)

Activity	*Budgeted cost per site 1995*	*Cost per site 2001 prices.*
Transport Cost per site: (this cost is calculated based on a round trip of 2000 km per week with a 1.8 LDV at R 2-83 per km and a total number of 10 sites maintained per week) Added 10% for overhead **Total 1**	2000km/10 schools *R 2,83/km= R 566-00 + *R 56-60* **R 622-60**	R 1103
Travelling time labour: (based on a team of one artisan and one skilled worker, cost for the team will be al follows) Artisan travelling rate per hour Semi-skilled worker travelling rate per hour At 24 hours per week estimated travelling time to visit 10 schools the labour travelling cost per school is calculated as: Added 10% for overheads **Total 2**	R55-00 + R15-00 R70-00 R70*24/10= R168-00 +R 16-80 **R 184-80**	R 327
Labour costs: (Based on a team consisting a artisan and a semi-skilled worker, 3 hours anticipated time per site in terms of the requirements for maintenance inspection) Artisan working rate per hour Semi skilled working rate per hour 10% added for overhead **Total 3**	R 95-00 +R 25-00 R 120-00 *3= R 360 +R 36-00 **R 396-00**	R 702
Total labour and travelling costs: T1 Transport Cost per site: T2 Travelling time labour: T3 Labour costs: Total visiting costs: **Total 5 travelling costs for 2 visits:**	R622-60 R184-80 +R396-00 R1203-40 **R2406-80**	R 4264
Hardware: Regulator (one replacement during 20 years) Inverter (one replacement during 20 years) Batteries (three replacements during 20 years) Additional costs (fuses, lights, water ,etc, every year)	R 300-00 R1200-00 R2500-00 R150-00	R532 + R2125 = R 2657 R 4429 (per bank) R 266

Source: [NGE, #94]

MAINTENANCE COST CALCULATION : EXAMPLE FOR SCHOOLS

Year	0	1	\2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Yearly cost		4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264	4264
Yearly cost		266	266	266	266	266	266	266	266	266	266	266	266	266	266	266	266	266	266	266	266
Battery						4429					4429					4429					
Inv+Reg											2657										
Total		4530	4530	4530	4530	8959	4530	4530	4530	4530	11616	4530	4530	4530	4530	8959	4530	4530	4530	4530	4530
Total*(1,1)n		4530	4983	5481	6029	13117	7295	8025	8827	9710	27390	11749	12924	14216	15638	34021	18922	20814	22896	25185	27704
Cumulative		4530	9513	14994	21023	34139	41435	49459	58287	67997	95387	107136	120060	134277	149915	183936	202858	223672	246568	271753	299457
Purchase	60000																				

Total Maintenance Costs: 299457

Yearly Maintenance Costs: 14973

Total Costs: 359457

Purchase/Total: 17%

Appendix 5: Background info for the reader.

This appendix is not supposed to be scientific, but is included to give the reader a broader picture on the experiences we had during the research. It can be read as a separate report, and there are some overlaps with the information that is presented in the report, for the correct information, the report has to be consulted.

The central issue of the research is to observe how solar systems work in a developing environment. Are there problems in utilising Solar systems in rural areas? Where occur the main problems? And what could be possible improvements for those problems?

Before we could execute this research, it was essential to have information about the physical environment the systems were placed in, and the political policy that caused the installed systems.
Being a foreigner, we knew very little about the situation and policy on electrification of South Africa. This had the advantage of having a new and fresh vision on the situation, but the disadvantage was that the time we needed to get a feeling for the current and past situation in the rural electrification field was considerable.

After arriving in South Africa, we had to focus on information about rural electrification, previous programmes, previous evaluations of rural electrification programmes, policy document about rural electrification, etc.
Discussions with experts gave us lots of answers, but the difficulty was to get correct and accurate information. The different parties were pointing out their perception, which was sometimes confusing. During these interviews, it became clear that no overview was available, and that political and other factors caused some extra problems concerning co-operation between the different involved parties.

It took us some time to get a picture of the different structures of the different departments, and the different responsibilities.
Electrification and maintenance of schools and clinics involves the Department of Minerals and Energy, Department of Education, Department of Health and the Department of Public Works.
South Africa is, especially compared to Belgium and The Netherlands, a very large country and a country where responsibilities are directed to lower authorities, like the provinces who have a lot of autonomy. This gave the difficulty that not all the information was present at the central departments.
All of the departments have their specific organisational structure and their specific responsibilities. For us it was sometimes difficult to get the correct information, as it sometimes was fragmented over the different departments and the different levels of the department.
The co-ordination between the different departments and authorities was not always as effective as desired. This had as consequence that questions remained unanswered after several interviews, because they were directed to the wrong parties, or were answered differently. This made it hard to judge the value of an answer.

After a month of interviewing and reading it was clear that a lot was written down, but real "hand on policy " was never developed, evaluation reports were scarce, and not easy to find.
Also to collect and derive correct information from earlier published reports was very difficult. Different reports gave different numbers, and pointed out a different perspective. This gave a broader picture of the situation, but was also very confusing at some moments.

In reports possible improvements and policy was found. This information was not always available with the responsible parties, or it was clear that the recommendations of these reports were never used.

After several discussions with all involved parties, the picture of the theoretical and paper picture was clear, and the set up of the field research could start.
With the knowledge we got from the interviews, the reports we read and our own sense we developed a questionnaire. At the Department of Minerals and Energy, we heard that the European Union was planning to execute a similar research. A co-operation could help both parties. For the co-operation the new derived questionnaire could be used.

A very difficult part of our research was to get the lists of schools and clinics that received a solar system. The DME, DoE and Eskom in Johannesburg (NGE) were not able to present us such a list. After some requests for information we received the lists of the schools from the Department of Education in King Williams Town, and the schools of the Northern Province were supplied by Eskom in Pietersburg.
In Pietersburg PC problems delayed the availability of the list as this information was only available on this computer. They had to reproduce the lists from their paper database.

After developing a questionnaire, a field trip to the Northern Province was done. The field trip was executed to test the questionnaire. Together with a fieldworker of Eskom Northern Province, we visited 5 schools in 2 days. The experience was very useful, and the questionnaire could be completed.
Also impressions we got from the days in the field gave us practical information to plan the field research later on, like the condition on the roads, the safety in the rural areas, etc. Also about the possible co-operation of the teachers to this research and the attitude of the local people in the rural areas towards foreign people.
During the fieldtrip we attended a community meeting. Although it was in Venda, (one of the South African languages) and not understandable for us, it gave a picture on how the communities are informed and how communities can influence the implementation and the use of a system.

At that particular meeting the issue was that the community wanted to have the lights on during the night, as a security measure, and Eskom (and the headmaster) wanted the available electricity to be used during the day for educational use.
A real solution was not accomplished, but Eskom made it clear that the lights were not supposed to be used at night.

In December, the Myeka High School near Durban was visited, where 3 solar installations are working, together with some computers, copy machine and via a modem, even internet was available. It was clear that the drive of the headmaster was the main reason for the success of this project.

After the number of schools and clinics that were installed were determined, we could prepare our sample. The sample size was based on the experiences and conversations with some people who visited these areas before. Also the practical execution of the research had to be planned very well. Hotels and camping sites in rural areas are very scarce. This meant we had to plan our trips from nearby cities. Because of the limited budget there was available, campings and caravan parks were chosen for accommodation during the nights.

To be able to plan our daily trips, it was essential to know where all schools and clinics exactly are situated. On the lists of schools we received the co-ordinates were indicated in some cases. This made it possible to develop a map, with some of the schools indicated, of the chosen regions.

The maps were made by HSRC. The making of the maps was also an experience for the mapping department. The final and right maps were ready just the day before the fieldtrip started.

During the first day of the first fieldtrip, in Nebo in the Northern Province, our first experience was that all the schools we visited had no solar system. After examination of all the lists we received we found out that those schools were on the initial list, but replaced by other schools.
The second day was more successful and several schools were visited during the following 10 days.

Our first impression was that the people in rural areas are very friendly, and helpful, but asking directions gave some surprising answers.
The general condition of the schools was very confronting for us, as some schools had only 3 classrooms for 200 children. People are very poor and unemployment rates are very high.
In some interviews we found out that the main income of communities exist of pensions of the elderly people in the village. What also surprised us that nevertheless the unemployment rate, help from community members to improve the situation in their community was very limited. Theft of solar panels was the main problem we discovered. Anti-burglars that were installed by local people prevented the theft in some cases, while in other cases the burglars were to weak to prevent theft.
The panels that were stolen were in most cases broken off the frame. No specific equipment as screwdrivers and other tools were used, which gave us the impression that there was no organised organisation behind the crime, but that local people were involved. Surprisingly we never saw panels on private property.

After the Northern Province we had a field trip with Mister John Adams of Siemens. In a two day trip, he showed us a school Siemens had supplied with solar energy, the solar village Falavhodwe and a water project that was powered with solar energy. The school's installation was not working, caused by theft of the panels. The other equipment was still in place (inverter, maintenance free batteries, datalogger etc.). The water project powered with solar electricity contained a new possible solution to the theft and vandalism problem. The installation was built in the garden of a community member. This normally prevents theft better than building panels on school property, normally closing at 15.00. The electricity is transferred through a 3 phase wire. The distance that can be reached through such a cable is limited. To make a longer distance possible, transformation to a higher voltage could be an option. In the case of the pump project, the assumed theft prevention was not optimal, as a few panels were missing on the day of the visit.

In the solar village we visited the day after, the providers of the panels had set up a maintenance structure. This was one reason the project had a larger sustainability. Also the large effort that was put into the enlargement of the involvement of the community, was a reason to create a larger sustainability.
Two schools and a clinic were also electrified. One school was vandalised (regulator boxes were stolen), and the clinic had problems with the batteries.

The field research in the Eastern Cape started a few days later than planned, caused by some car problems. The results of the Eastern Cape were very similar to those of the Northern Province, but the first impression was that fewer panels were stolen, but theft of batteries were often a problem.
The weather in the Eastern Cape plays a major role in the excitability of the research. Roads are very bad and inaccessible on rainy days. The days that we spend in the field were, with some exceptions, dry and most roads were accessible. After a total of 40 days in the field our sample was completed, and we could return home. After some more car problems we arrived in Pretoria where we could analyse the data and finalise our report. A presentation was held in Pretoria, to present the data, conclusions and recommendations of the research to the involved parties. To finalise the research a presentation will be held in Eindhoven, and the research will be defended.

Looking back at the project, we can say it was an unforgettable experience. Starting a research from the very beginning, organising the living in a country like South Africa, collecting information, executing field work from designing a questionnaire to analysing all the data, writing the report etc. Although not being ITOK students, the research in South Africa where the first and third world are extremely close, resulted in a project that we experienced as extremely instructive.