APPLICATION OF PHOTOVOLTAIC SOLAR ENERGY TO MEDIUM-SCALE INSTALLATIONS

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DECLARATION

I, Sandra Bezuidenhout, submit this thesis in fulfilment of the requirements of the degree of Doctor of Philosophy in Engineering. I claim that this is my original work and that it has not been submitted in this or in a similar form for a degree at any other university.

Signed by candidate

5th day of December 2001

ABSTRACT

Although South Africa has significant energy reserves, some 50 – 60% of the South African population is without access to electricity. Lack of infrastructure is one of the root courses of which energy supply forms an important component.

The energy sector is an integral part of the whole economy, and energy planning requires analysis of the links between the energy sector and the national economy. Local economy can be developed, if energy provision and supporting services are made available to rural areas. South Africa has, so far, developed and implemented energy activities without a solid base in energy policy and macro-economic planning. This has resulted in the situation where energy planning has taken place on a sectoral basis without much regard for socio-economic development objectives or inter-energy considerations.

With apartheid overthrown, South Africa experienced fundamental shifts resulting in significant changes in the energy policy. The election of a new government necessitated a review of the existing policy. South Africa is in need of an integrated energy policy framework, based on new social and economic imperatives relating to reconstruction and development in South Africa.

International experience is demonstrating the feasibility of photovoltaic electrification. An electrification programme for scattered communities in rural areas of the world could be the means of bringing about social, educational, economic and ecological revitalisation of the community. The objective should be to provide electrification that is adequate to their needs in the same degree as they would receive if they migrated to the cities. Providing a reliable source of electrification for communities without electricity connects them with the rest of the world through radio, television and telecommunication; offers water pumping, lighting, and studies at night, etc.

The South African government has targeted the supply of electricity to all rural schools and clinics as a key energy policy objective. An investigation and discussion regarding the existing non-grid schools electrification programme has been completed in order to understand the background to the study. During 1995 the South African utility Eskom started with a programme called Non-Grid School Electrification. Through the rural Schools Electrification Programme a significant number of schools have been electrified throughout South Africa using both grid and non-grid technologies. In order to address these 16 400 schools that are without electricity, the Department of Minerals and Energy and the utility decided to install stand-alone photovoltaic systems. This non-grid schools electrification programme is one of the biggest photovoltaic programmes in the world. The Department of Minerals and Energy and the utility, as the decision-makers, had decided on photovoltaic solar energy and therefore the author addressed the study in terms of what the utility implemented in the non-grid schools electrification programme.

The Non-Grid Electrification Programme has been studied and each step has been recorded. It is clear that the DME and the utility have been the decision makers without consultation with other stakeholders. A business plan was submitted for approval by the DME and was accepted by DME. The aim was to electrify 16 400 school by the end of 2000. An in-depth study has been done on the system design, system components, installation procedures, commissioning procedures and maintenance.

Appropriate renewable technologies and the life cycle cost analysis has been investigated and analysed for the suitability of PV versus other renewable options. The outcome was that photovoltaic systems are currently a mature and available technology to meet the demand for rural electrification. The significant benefits in terms of staff satisfaction and school operational effectiveness are among the main reasons for this choice, and these benefits are considered to outweigh clearly the extra initial cost when compared with diesel.

The study environment includes the following four phases:

- Phase 1 involved the compilation and review of relevant background data, interviews with staff of the key institutional stakeholders. The expected output was a report outlining key issues for the programme.
- Phase 2 involved assessment of the status of the already-installed school systems and the teaching staff's perspectives on them. It was proposed to select 48 schools in the Eastern Cape to be visited, and the views of the teaching staff at these schools were recorded and analysed. For this phase a questionnaire was drawn up and completed by trained interviewers.
- Phase 3 focused on 15 schools, selected from the 48 identified in phase 2. The approach was more in-depth to establish the effects of the school electrification programme on the schools and on the surrounding settlements. The main areas of focus were the levels of utilisation of the systems, the needs of the schools and communities, the impact of the system, and the supplementary infrastructure provided with the systems. For this phase a questionnaire was drawn up and completed by trained interviewers.
- Phase 4 was consolidation of the technical data obtained from the 15 schools identified in phase three.
- The conclusions of the different phases are discussed.
- The recommendations emerging from the research is consolidated into a final process for the application of photovoltaic solar energy to medium-scale installations.

The conclusions and recommendations showed that the level of utilisation of the systems were far below the *design* sizing. It can be argued that utilisation levels will increase in time but as the study was done approximately one year after electrification, the expectation would be that utilisation has stabilised. This being the case one of two conclusions can be drawn. Either the design was inappropriate (over designed) or community needs where not identified properly. In either of the cases better pre-electrification evaluation and selection will lead to more realistic input data that will result in a more appropriate design.

The study showed that *maintenance* and post installation attention was seriously lacking. In the schools where a completed technical evaluation could be undertaken lights were found inoperative, batteries were stolen, battery connections were loose, vandalism was experienced and batteries were found in a discharged state. If adequate maintenance were done problems such as these would never have occurred.

The recommendations make provision for improvement of the existing programme through the implementation of the proposed consolidated and robust process addressing three main problem areas as indicated by the research:

- Improved role-player interaction through the creation of a national policy
- Better system utilisation through more appropriate design supported by an improved pre-electrification evaluation and selection process leading to better prioritisation and statistical need analysis of schools
- Enhanced systems sustainability and reliability, through adequate maintenance of systems.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

AHC	Energy actually supplied by the solar panels
AHU	Energy used by the end-user
AHP	The potential energy available from the solar panels as if there were no electrical regulation
Cn	Battery capacity
EDG	Energy and Development Group
EDRC	Energy for Development Research Centre
EMIS	Education Management Information System
ESI	Electricity Supply Industry
GEAR	Growth, Empowerment and Redistribution
GIS	Geographical Information System
HSRC	Human Sciences Research Council
IC	Charge current (A)
IC+, IU+	Maximum charge and load currents
IDT	Independent Development Trust
IU	Load current (A)
NER	National Electricity Regulator
PV	Photovoltaic
RAPS	Remote Area Power Supply
R&D	Research and Development
RDP	Reconstruction and Development Programme
Rib Manager	Regional Implementation Body Manager
SADC	Southern African Development Community
SMME	Small, Medium and Micro Enterprises
TB	Battery temperature (in degrees C)
TB-, TB+	Minimum and maximum temperatures of the battery
TLC	Transitional Local government
UB	Battery voltage (V)
UB-, UB+	Minimum and maximum charge voltages of the battery
WEC	World Energy Council

1 BACKGROUND TO THE STUDY

1.1 INTRODUCTION

South Africa is fortunate to have significant energy reserves. This will enable South Africa to sustain high economic growth where grid electricity is seen as the most desirable energy supply and is a necessary input for technological and economic progress. However, despite the current excess in electricity generating capacity, some 50-60% of the South African population is still without access to this vital resource.

Many of the remote rural areas in South Africa do not have sufficiently well developed infrastructures to bring the necessary services to the communities living in these regions. The needs are vast and cover a broad spectrum, ie roads, energy supply, health care, education, water and sanitation.

Over the past few decades, electrification in most developing countries has been expanded rapidly and practically all the major cities and towns now have access to some form of electricity service. However, this is not true for rural areas, particularly in the less developed countries. In recent decades, the socio-economic development of rural areas in many developing countries has been regressing instead of progressing. This raises questions about the effectiveness of policies for the development of rural areas, particularly in the energy sector. Demands that could be satisfied in the past through the use of local traditional energy resources cannot be met at present, with the result that the quality of life of rural populations is deteriorating. The main reason for this is that traditional production systems, which were relatively stable and environmentally sustainable, are now becoming unsustainable as resources become more and more depleted owing to demographic pressures and their associated human needs. In rural societies, energy problems are aggravated because the greater part of the population lives below the poverty line, earning low, seasonal income. In order to survive, they are forced to confine their use of energy to traditional resources, such as fuel-wood, which are becoming more difficult to obtain.

During 1995/6 Eskom started with a project electrifying schools with non-grid electrification in South Africa. The ambition was to electrify 16 400 schools within the next five years. Looking at literature this is the biggest non-grid electrification programme in the world. The issue of rural electrification is very topical in South Africa. The schools electrification programme itself is neither a purely technical nor a purely commercial issue, as many political realities need to be taken into consideration - past, present and future.

The programme started in the Eastern Cape because Eskom had embarked on a pilot project at Jojweni in the Eastern Cape, where a school and a clinic were electrified with photovoltaic systems. At the school, three classrooms, the principal's office and the staffroom were electrified. The entire clinic was electrified, as well as the staff quarters. Refrigeration facilities were provided for the clinic. Eskom accepted this project as a sustainable solution for rural electrification. Another reason is that the Eastern Cape is seen as "the poorest of the poor" in South Africa and the Department of Education (DoE) in the Eastern Cape welcomed the support for such a school electrification programme.

The researcher was appointed as the Non-Grid Programme Manager in Technology Group, Eskom, and realised the impact that such a programme could have, not only in South Africa, but also world-wide.

1.2 PROBLEM STATEMENT

During 1995/6 Eskom electrified 1 200 schools with non-grid electricity in various provinces. Statistically progress was rapid, 890 schools were electrified in the Eastern Cape. However, before long problems began to emerge. For example the researcher noticed complaints been received about communities that did not want non-grid electrification, communities were not consulted in the process, schools did not apply for non-grid electrification, contractors started having conflict's with Eskom staff regarding the technical aspects, and the DoE did not maintain the systems. Various stakeholders questioned the sustainability of the programme. Systems were vandalised, theft occurred and nobody could say what the sustainability index of the project was at any stage. Eskom Distribution however also started claming that they do not support the project, which was an indication that something was going wrong.

The researcher realised that no evaluation had been performed on the process. Looking at literature there was not one single process that was applicable to the South African situation. The fact that South Africa received donor funding required that the programme be seen as a success world-wide. Eskom as the electricity utility in South Africa has a reputation in the communities for providing electricity and this needed to be maintained. In order for Eskom to remain part of such an initiative the process needed to be evaluated and it was clear that corrective recommendations were of vital importance. A project of this magnitude had to be successful and sustainable, especially from Eskom, the primary utility in South Africa.

There were also international influences. Donors such as the Norwegian Agency for Development (NORAD) and the Reconstruction Development Programme (RDP) have provided funding for the schools electrification program: NORAD donated R2 million in 1995, and the RDP allocated R56 million in the 1996 budget. Eskom did not contribute to the funding of this programme, the success of which was therefore dependent entirely on the beneficence of foreign donors, and/or allocations from the RDP. However, funds have not been forthcoming at the initially expected scale, which has hampered the programme. The fact that South Africa received donor funding required that the programme be seen as a successful and sustainable.

This programme is the biggest of its kind in the world. World-wide, lessons can be learned from the South African non-grid schools electrification programme. For all these reasons, it was realised that the lack of a systematic evaluation of the initiative was a serious lack, both for Eskom and for the country as a whole. The initiative also offers an opportunity to develop best practice, standards and policies in order to grade future projects both in South Africa and internationally.

After completion of the initial installations it was clear that no calibrated process or standard exists against which performance can be measured, making it virtually impossible to gauge the success or failure of the non-grid schools electrification programme. The researcher determined the need to undertake a more complete and scientific descriptive study of a selected portion of the non-grid schools electrification programme, specifically in the Eastern Cape. The results (a better understanding of the issues related to the programme) could then be used to develop a consolidated and robust process for the application of photovoltaic solar energy to medium-scale installations in South Africa.

1.3 PURPOSE AND FOCUS OF THE STUDY

The purpose of the study was to evaluate the non-grid schools electrification programme in the Eastern Cape to determine how to improve the process followed and increase its appropriateness. To achieve the purpose of the study specific technical and social aspects were investigated.

Technical aspects included:

- the evaluation of the technical and economic benefits of photovoltaic systems compared with other energy options
- determining whether systems that were installed in the schools are adequately designed to perform the identified functions
- examining how effectively the technology is being used by the teachers and the students

Social aspects included:

- exploring the pre-electrification process
- identifying to what degree the needs of the communities have been met
- exploring additional services that could be provided by the systems to enhance the possible benefits in a cost-effective manner
- indicating what impact the systems and their use are having on the activity in the schools

The study results were then utilised to establish a consolidated and robust process for the application of photovoltaic solar energy to medium-scale installations for future implementation in South Africa.

1.4 METHODOLOGY

The methodology followed included two elements:

- a descriptive study of the electrification of 890 schools in the Eastern Cape and
- the formulation of a consolidated and robust process for application of photovoltaic solar energy to medium-scale installations in South Africa.

1.5 MECHANISMS

Mechanisms applied are detailed in the following paragraphs.

1.5.1 Literature Survey

A literature survey was conducted regarding international energy policy, objectives, implementation and national planning. The problems experienced and the international perspective on energy options was discussed. International experience regarding photovoltaic electrification was examined at and applied in the study. South African energy policy, national planning, specific goals and policy problems were explored in relation to the developmental needs of the country.

Field Interviews

Interviews were conducted with stakeholders as well as teaching staff and pupils.

Questionnaires

Interviews were conducted with key stakeholders to solicit views on the non-grid electrification of schools in rural areas with particular reference to the following:

- Rationale and history of the programme
- Processes of identification and selection of schools
- Institutional role-players
- Principles of program ownership and community involvement
- Co-ordination mechanisms among the various stakeholders, especially service providers and implementation agents
- Financial and technical support
- Quality and capacity of facilities and services

Against the background of the information and insights obtained from the interviews with key stakeholders, a well-structured survey instrument was developed. Eskom's views and comments were incorporated to finalise the survey instrument to be used with the principles, teachers, pupils, and village residents.

Two *questionnaires* (Appendix B and C) were developed:

The *first questionnaire* (Appendix B) focuses on the school background – school principal/teacher. In this section the researcher sought to determine the insight of the principal and teachers. It is important to know how many classrooms, teachers and students there are. This was to determine how many students would benefit from electrification of the school. Community involvement is vital and can be determined by the replies from teachers to questions such as: Is the system still working? How many times do you use the system per day? Does the community use the system and for what? Testing the teachers' knowledge of the system also determines whether the teachers understand the technology.

Student's view's were determined by asking whether the electrification helped with their studies and in what way, and asking them to comment on other areas in which electrification could help.

The *second questionnaire* (Appendix C) focused on the teacher's and staff perspectives as well as community members. This was to determine the awareness and ownership of the systems, usage, operation and maintenance, impact and comparison with grid.

The following *sample stratification* principles were chosen to guarantee representation of the sample population and, by the same token, to ensure validation of the study findings and reliable conclusions:

- Categorisation of all the schools under: junior primary, senior primary, junior secondary and senior secondary.
- The Department of Education clustered the schools according to regions - namely Butterworth, Queenstown, Umtata and Kokstad - and the sampling of the 48 schools was to reflect the regional classification.
- It was also noted that the distribution of schools with NGE installations showed great disparities in terms of numbers, geographical location and distance into the hinterland. The sample stratification took these characteristics into account.

Structured Interviews

Given the distances travelled during the field survey, owing to the widely dispersed locations of the sampled schools, interviewers were recruited not only from the four defined regional localities but also, more importantly, from among those who know the areas well for purposes of logistics. Another crucial consideration in the recruitment and selection process was to have people with a basic understanding of interviewing techniques. All these considerations were to enhance timely and efficient administration and completion of the questionnaires.

Four interviewers were selected and trained, and they were allocated as follows:

- Two interviewers to cover the Kokstad region, which extends over the widespread, remote areas of Lusikisiki, Bizana, Mount Fletcher and Matatiele
- Two interviewers to cover schools in the Butterworth, Umtata and Queenstown regions, which extend over remote areas of Nqgamakwe and Engcobo.

The training of interviewers covered the following:

- Interview protocol
- Interview techniques and procedures
- Content and objectives of the survey instrument
- Logistics

Two workshops to familiarise the communities were organised, one in Queenstown and the other in Umtata. The initial plan was to organise only one workshop, ideally in Umtata, which is located centrally to the schools sampled for the survey. However, this original plan was changed as a result of observed concerns during the planning phase. Two workshops were therefore held to accommodate the articulated concerns and needs of the communities.

The workshop participants were educational officers, principals/headmasters, leaders of civic organisations and other stakeholders from the communities. The purpose of the workshops was to explain further the Eskom Non-Grid Schools Electrification Programme and the objectives of the planned survey. The ultimate goal was to win local support for the interviewers who were sent to different areas to administer the questionnaires.

1.5.2 Technical Data Collection

Of the 890 schools electrified with photovoltaic systems by Eskom Non-Grid Electrification in the Eastern Cape of South Africa, 15 schools were equipped with data logging equipment.

The reason for limiting the sample to 15 schools was cost. The cost for each system amounts to R10 000-00.

Specifications were clearly defined for this study to ensure the best possible results. Each site was analysed in detail in order to study the user profile and the photovoltaic system operation. On completing the data gathering process, a site report was produced summarising the essential information.

The data gathering performed by the data logger allowed conclusions to be drawn regarding the sizing of the installation and its use.

1.6 METHODOLOGICAL FRAMEWORK

In order to evaluate a project of this magnitude it is important to determine up front what key success factors should be used to evaluate success of the project. Key success factors will vary for different stakeholders. On completion of the study the researcher would expect the outcome of the study to demonstrate the following:

1.6.1 Department of Education

- Systems usage 3-4 hours daily for lighting, television, and video recording
- More study hours available for pupils after hours
- Improved student performance
- Well maintained systems, and there will be a schedule available for the maintenance of each school.
- Maintenance programme in place for the first level of maintenance as well second level of maintenance
- Prioritisation and statistical analysis of schools making electrification planning possible
- Greater teachers retention in the community because of the facilities available in the community
- Local Government will be involved in the process
- Accepting full responsibility for the ownership of the systems
- School applied for the non-grid electrification before installation
- Audio visual equipment available at the schools
- User education provided by the installer
- Awareness at all schools regarding non-grid electrification
- Education Management Information System in order to realise the impact of electrification and other commodities in the schools

1.6.2 National Electricity Regulator

- The development of an integrated rural development plan
- Implementation of new technology. The introduction of new technology will be in accordance with the non-grid electrification programme

1.6.3 Communities

- Technical and entrepreneurial skills development
- Extramural activities such as adult basic education, fundraising etc. available at schools
- Small, Micro and Medium Enterprises development
- Participation with Government, Department of Education, Eskom and other roll players for the electrification of schools
- Energy Committees making informed decision regarding the areas to be electrified
- The suggested needs of the school in order to design the appropriate system for the school
- The use of the school as a community centre.

- Improved community interaction with the school and ongoing fundraising initiatives.

1.6.4 Government

- Integrated energy strategy that promotes various energy sources
- Stimulate economic development
- Gained knowledge regarding photovoltaic systems in the field, broad database
- Integrated electrification planning
- Energy Database available showing the areas for grid and non-grid
- Observed synergy between all stakeholders. Government should be responsible for the overall planning of electrification of areas, and the participation of various stakeholders in the electrification process
- Clear policy regarding non-grid electrification areas In South Africa. Communities should know that they will only receive grid within the next five years. This should allow communities to make an informed energy choice
- Local black economic empowerment should be enhanced. The fact that the systems are easy to install should allow for Black Economic Empowerment to be developed within rural areas. This will ensure job creation.
- Training of local entrepreneurs to enhance job creation within the community. Meaningful income should be generated within communities because of the systems that are designed according to the needs of the community. This will allow for Small, Micro and Medium Enterprises size companies to be formed. Again this will show that Government is looking after growing business throughout South Africa

1.6.5 Service Provider/Utility

- Participation with other stakeholder should be visible such as roads, water, telecommunication
- Monitoring of systems should be able to determine the status of the programme at all times
- Best practises should be readily available
- Standards regarding the implementation available
- Gained knowledge regarding photovoltaic systems in the field, broad database
- Performance index should be 100%
- Measure load demand will be high
- Installations to produce the expected daily energy delivery
- Correct sizing of systems
- Utilisation high
- Internet design support
- Data collected during the pre-electrification process should be used for the design

- Tendering process should consider Black Economic Empowerment
- Post installation impact study
- Clear policy regarding non-grid electrification known to all departments in Eskom. Role clarity between the various line groups should be in place
- Cost effective systems
- High levels of community participation
- Feedback to Government regarding the programme and the success achieved

The methodological framework of the study included four phases. Phase 1 involved the compilation and review of relevant background data, interviews with staff of the key institutional stakeholders such as Eskom, Grid and Non-Grid Electrification, Department of Minerals and Energy, Department of Education, Eskom's regional section, Energy Development Research Centre (EDRC) and, Energy and Development Group (E+DG). The expected output was a report outlining key issues for the program. The results are discussed in chapter 6.

Phase 2 involved assessment of the status of the already installed school systems and the teaching staff's perspectives on them. It was proposed to select 48 schools in the Eastern Cape to be visited, and the views of the teaching staff at these schools were recorded and analysed. For this phase a questionnaire (Questionnaire 1 see APPENDIX B) was drawn up and completed by trained interviewers. The results are discussed in chapter 7.

Phase 3 focused on 15 schools, selected from the 48 identified in phase 2. The approach was more in-depth to establish the effects of the school electrification program on the schools and on the surrounding settlements. The main areas of focus were the levels of utilisation of the systems, the needs of the schools and communities, the impact of the system, and the supplementary infrastructure provided with the systems. For this phase a questionnaire (questionnaire 2, APPENDIX C) was drawn up and completed by trained interviewers. The results are discussed in chapter 8.

Phase 4 is a consolidation of the technical data obtained from the 15 schools identified in phase 3. Results are discussed in chapter 9.

1.7 CONTRIBUTION TO KNOWLEDGE

The researcher found weaknesses in the existing non-grid schools electrification programme caused by a lack of standards against which to evaluate the programme, a lack of selection criteria and application procedures for non-grid school electrification, inappropriate design of systems, and an overall lack of awareness and utilisation.

Through the identification of the above weaknesses, the researcher established the need for a scientific descriptive study regarding the existing non-grid schools electrification process. The researcher demonstrated that such a descriptive study would pave the way for the formulation of a consolidated and robust process, for future application of photovoltaic solar energy to medium-scale installations in South Africa.

1.8 STRUCTURE OF THE STUDY

Chapter I elaborates on the overall view of the Eskom non-grid school electrification project. The problem statement indicates the need for the study, its purpose and focus and the methodology for the study.

Chapter 2 describes the Non-grid Schools Electrification Programme in the Eastern Cape, South Africa, and the background to the project. The reasons for the programme and technical aspects are discussed.

Chapter 3 describes the impact of energy on development and the benefits to rural electrification.

In Chapter 4 an in-depth literature review that was conducted regarding international energy policy, objectives and national planning is presented. The problems experienced and the international perspective on energy options are discussed. International experience regarding photovoltaic electrification is examined. Equally South African energy policy, national planning, specific goals and policy problems, as well as energy experience is explored.

In Chapter 5 suitable technologies and the life cycle cost analysis for medium-scale rural electrification is discussed from a qualitative as well as a quantitative point of view.

Chapter 6 presents phase 1, which deals with the pre-electrification stage. The involvement and review of relevant data on the design, structuring, implementation, and mobilisation is explored.

In Chapter 7 phase 2 the assessment of the utilisation and impact of school systems, and teaching staff perspectives are discussed.

Chapter 8 follows with an in-depth analysis of the impact of school electrification as experienced by teaching staff, pupils, and parents. This forms phase 3.

Chapter 9 covers phase 4, a technical evaluation that verifies the data obtained from the previous three phases.

Chapter 10 presents the conclusions of the different phases.

In Chapter 11 recommendations regarding the provision of consolidated and robust non-grid electrification of photovoltaic solar energy to medium-scale installations is presented.

2 NON-GRID SCHOOLS ELECTRIFICATION PROGRAMME IN THE EASTERN CAPE, SOUTH AFRICA

2.1 INTRODUCTION

The Reconstruction and Development Programme (RDP) set the agenda for the first majority-ruled elected government in South Africa. The RDP is an integrated and sustainable programme, a people-driven process that aims to provide peace and security for all, build the nation, link reconstruction and development, and deepen democracy. The programme has five themes: meeting basic needs; developing human resources; building the economy; democratising the State and society; and implementation.

The Reconstruction and Development Programme's White Paper calls for all schools and clinics in South Africa to be electrified. Owing to the demographics in South Africa, Eskom cannot cost effectively grid-electrify all the schools and clinics in the country. The capital costs are too high, as discuss in chapter five. It is estimated that 19 300 schools (86%) and 2 200 clinics (47%) are unelectrified, and the RDP's White Paper provides that these schools and clinics should be electrified within the next five years.

Owing to the importance of providing schools with electricity, Eskom Non-Grid Electrification electrified 890 schools in the Eastern Cape by the end of 1995/6 with non-grid electricity, and photovoltaic in particular. Many pilot studies, extensive equipment evaluation tests and implementation strategies that have been done by Eskom clearly show that for the level of electrification being considered, PV technology provides a cost-effective and reliable solution. This research study will concentrate on the 890 schools and aims to contribute to the technical, social and process development of renewable energy in South Africa.

2.2 ESKOM GRID AND NON-GRID SCHOOLS ELECTRIFICATION PROGRAMME

2.2.1 Introduction

Eskom's responsibility in respect of the electrification of schools and clinics is for connection of the premises and metering of electricity consumption for grid schools. Internal wiring is the responsibility of the Ministry of Education. Eskom connects all the schools and clinics in its electrification projects to the electricity grid provided that the Department of Education or Health agrees to pay the recurrent costs. Schools in the five-year grid plan are planned in conjunction with residential electrification projects[1] The Independent Development Trust (IDT) has taken the responsibility for electrifying all the clinics outside Eskom's current project areas. This has been agreed between the Department of Minerals and Energy, IDT and Eskom Non-Grid Electrification (NGE).

2.2.2 Establishing the Eskom Non-Grid Electrification Department

Eskom Technology Group had a department that did research on alternative energy[2]. During 1992/3 a panel consisting of the Solar Energy Society of South Africa (SESSA), Energy for Development Research Centre (EDRC), the Department of Minerals and Energy, and Eskom decided that electrification of schools with photovoltaics needed to be researched. The panel decided that because of adult basic education in schools the solution would be to electrify three classrooms, the headmaster's office and the staffroom. At that stage funding was a problem, and R50 000 was available for the project. The funds available determined the size of the school to be electrified. This initiative led to the establishment of the Eskom Non-Grid Electrification Department in 1995.

The Eskom Non-Grid Electrification (NGE) programme began in 1995. Eskom's chief executive officer gave the non-grid schools electrification challenge to Eskom Technology Group and requested them to propose a solution. The Technology Group's senior management embarked on a pilot project at Jojweni in the Eastern Cape, where a school and a clinic were electrified with photovoltaic systems. At the school, three classrooms, the principal's office and the staffroom were electrified. The entire clinic was electrified, as well as the staff quarters. Refrigeration facilities were provided for the clinic. This project was presented to Eskom's chief executive officer and accepted as a sustainable solution[2].

This proposal to use photovoltaics to electrify rural schools was presented to the Department of Minerals and Energy. The Department of Minerals and Energy and Eskom NGE set the targets for the next five years. These targets were:

- 1996 - 1000 schools
- 1997 - 3200 schools
- 1998 - 4000 schools
- 1999 - 4200 schools
- 2000 - 4000 schools

Total: - 16 400 schools

Owing to the importance of providing schools with electricity, the Eskom Non-Grid Electrification Department undertook the task of implementing non-grid electricity systems where the grid network would not reach in the following five years. Eskom Non-Grid Electrification was appointed as National Project Managers by the government's RDP office, with the Department of Minerals and Energy as the co-ordinator of the programme. The funding for the first 1 000 schools was provided by the South African Government. However, in order to electrify the remaining 15 400 schools, international grant or loan funding was sought.

In the Eskom non-grid schools electrification programme, 1 000 schools were electrified in the 1995/96 financial year. The number was 245 for the 1997 financial year. This low number of schools for 1997 was the result of a funding problem experienced. The criteria for a school to be electrified with non-grid was that it should be three kilometres away from the grid and not be in Eskom's five-year electrification plan (Netplan). The reason for this was that every kilometre of grid extension costs Eskom R45000.00. This adds to the cost of grid electricity. Eskom Non-Grid Electrification did not have a set plan for the electrification of schools, but works from the Netplan in conjunction with Eskom's grid electrification department.

The Non-Grid Electrification programme[3] for schools was as follows:

- The Programme Manager set up a meeting with the Department of Education, the Department of Public Works and the RDP in the province. At this meeting the non-grid electrification programme was discussed in detail and a letter of support was obtained from the Department of Education for maintenance of the systems. This letter was important since the RDP provided only the capital cost of the system at a school; the community had to use this as a community-based project.
- The Regional Implementation Body Manager (NGE) arranged a community meeting with the Department of Education to prioritise the schools to be electrified in the province. There were no set criteria for the prioritisation of schools in a province. The Regional Implementation Body Manager (Rib Manager) together with the Department of Education then arranged a meeting with the communities involved. At this meeting the representatives of the Department of Education, parents, school-governing bodies, Transitional Local Council members and students were present. The benefits and disadvantages of photovoltaics were discussed, as well as the security of the systems. The communities had to give their approval for the installation of the system. At this meeting people with electricity experience/science and maths to standard eight or matric were recruited for training. The training was for installation and maintenance of the systems. These trainees had to be chosen by the community; Eskom NGE did not have a say in the selection process. Eskom set the criteria for the trainees. The training was done by Port Elizabeth Technikon in conjunction with the Small Business Development Corporation or Syncom. This training was subsequently stopped because the Department of Minerals and Energy felt that Eskom should not train installers.
- A fieldworker (NGE) draws floor plans of the schools (fieldworkers were technicians working in NGE). These floor plans were verified against the Eskom five-year plan and approval was requested from Eskom grid to continue the electrification of the schools. Approval was given in writing by the electrification (grid) department.
- Floor plans were sent to the NGE's national office (Johannesburg) to open a project and design the photovoltaic system.
- When the design was completed the project followed the procurement process in Eskom.
- After the order had been placed the contractor went to the site for implementation of the systems. The contractor had to train the principal or

teachers in how to do maintenance on the system, including cleaning the panels, topping up the batteries etc.

- The commissioning officer (NGE) commissioned the systems as per the commissioning standards[4] before the school was handed over to the Department of Education. On handover the school received a television set, a video recorder and an overhead projector.
- A post-installation meeting was arranged three months after installation so that the NGE staff could address any questions and problems with the teachers and the community. During this meeting an inspection of the school was done and the impact of the electrification on the students and teachers was discussed[1].

Eskom Non-Grid Electrification and the Department of Minerals and Energy had established that a suitable level of supply was to provide adequate lighting in three classrooms, the staffroom and headmaster's office for four hours a day. This was discussed with Eastern Cape Department of Education and accepted. In addition, 220 V AC power was provided to run a television set/video recorder and an overhead projector for two hours a day, as well as limited power for running a computer.

The direct benefits to about 400 pupils per school were realised immediately, while the longer term benefits from adult basic education programmes, including literacy training, business skills and material focused on upliftment of community lifestyles, will have an impact on many more people within communities.

The programme included employment of locally based contractors, who were identified and given specific training and work contracts for installation purposes. The programme also utilised local labour that would be employed by the contractors to assist in the installation process. In this way the projects were responsible for job creation in the rural communities.

2.2.3 Eskom Non-Grid Electrification Business Plan

When NGE was established in 1995, a consultant was appointed (Perry and Associates) to conduct an investigation into the way NGE should implement a business plan. Perry and Associates had to examine NGE's competitors, the advantages of such a programme, disadvantages, structural implications, step-by-step process and a rollout plan to be implemented by NGE. The findings of this study by Perry & Associates[5] showed that Eskom Non-Grid Electrification (NGE) should consider the following key steps in the strategy "to accelerate the implementation of the non-grid electrification programme to rural communities":

- To identify the overall size and scope of the non-grid electrification programme, and determine the practicalities and limitations facing Eskom Non-Grid Electrification
- To determine the "total" number of rural communities requiring electrification and identify those unlikely to be reached by the grid (potential for non-grid projects)

- To assess the electrification requirements of these rural communities, taking into account the technical, social and broad economic criteria.
- To identify the steps required to smooth the process of implementation and financing at regional government and RDP levels.
- To develop a "roll out" plan and focus for electrifying rural communities and to identify the logistics required to achieve this broad strategy.
- To develop a "step-by-step" process, from the point of community identification to the point of electricity availability, that was practical and cost-effective, while including the local communities and local suppliers in the process
- To explore the "pricing" potential (hand-outs versus subsidy versus buy-ins versus sponsorship trade-offs).
- To determine the structural implications with which Eskom Non-Grid Electrification was faced.

The business plan concentrated on the financial impact and no technical evaluation was conducted. The reason for this was because Eskom NGE decided with the DME to electrify the schools only with PV.

With the above as a recommendation the Non-Grid Electrification department business plan[6] made provision for the non-grid electrification of schools over four year period as shown in Table 1.

Table 1 Schools Electrification Business Plan

Year	Number of Schools
1996	1 200
1997	245
1998	2 000
1999	2 000
2000	2 000
Total	**7 445**

The cost per school in 1998 rand terms was R78 232.00.

During 1995/96, 890 schools were electrified in the Eastern Cape and 310 schools in other provinces. Although the total number of schools in rural areas to be electrified in South Africa is 16 400, the business plan makes provision for only 7 445 schools to be electrified. The question is what happens to the remaining 7 955 schools? According to Eskom NGE the remaining schools will be electrified once funding is available[1]. This business plan is a violation of the original plan, and should be of concern to the Department of Minerals and Energy and the Department of Education.

2.2.4 Community Participation and Objectives

The RDP calls for community involvement: communities and the government drive this programme. Communities will have to be more self-reliant and not expect government always to be the main contributor to the programme. During the apartheid era, community organisations emerged as a result of the needs of the system, and they could become a beneficial legacy if they could be converted into agencies for development of their communities. In rural areas these organisations are far less organised and need to be given direction. Such bodies already exist in the Eastern Cape but are in need of new parts to play in a changed political framework. International experience shows that development projects generally have more chance of being successful if they include community participation as a component[7].

People-driven development requires the beneficiaries of a project to have control over the project. It aims to build capacity in the process of implementing a project, rather than just delivering it. These interventions are very slow, as the starting point is determined by the existing capacity of the intended beneficiaries. The people determine which project to implement. Through implementation the capacity is increased, and so the parameters are set for the next project[7].

Studies done by Liebenberg[14] and Bedford[15] address some key issues relevant to school electrification, such as the following:

- System design may not be adequately influenced by potential energy requirements at schools.
- Given the capacity shortages (institutional and technical skills) of the Department of Education at the various administrative levels, the Department's involvement in the electrification programme has been fairly limited.
- The specific focus on electrification of schools and clinics constitutes a serious limitation to current programmes aimed at electrifying community facilities in rural areas.
- The current electrification programme does not provide for public lighting, water pumping, and Small, Medium and Micro Enterprises (SMME) - economic activities such as carpentry, sewing and knitting.
- The programme is driven primarily by the electricity distribution industry and by Eskom in particular.
- The lack of an effective collaborative framework for co-ordination of programme activities does not augur well for efficiency and capacity building.
- The link between community ownership of the programme and its sustainability needs to be strengthened.

It is evident that rural communities are part of the energy equation and should therefore have a right to take part in the decision making process.

2.3 TECHNICAL ASPECTS

The system design for the schools in South Africa is considered below. Components, installation procedures, commissioning procedures and maintenance will be addressed in this section.

2.3.1 System Design - South African Experience

South African schools are equipped with systems as illustrated in Table 2.

Table 2 Components and Estimated Duration of Daily Use in South Africa[(3)]

Application	Equipment	Power rating	Number of hours per day	Equivalent power consumption	Remarks
Classroom	8 neon tubes television video overhead projector	20W 100W 50W 300W	4 hours 1 hour 1 hour 1 hour	640Wh/d 100Wh/d 50Wh/d 300Wh/d	Power for equipment calculated for one classroom per school
Staffroom	2 neon tubes	20W	4 hours	160Wh/d	
Principal's office	2 neon tubes	20W	4 hours	160Wh/d	Dependent on size of office

The energy demand per school is illustrated in Table 3.

Table 3 Estimated Energy Demand of a School[(3)]

Application	Number	Power demand per unit (Wh/d)	Total power demand (Wh/d)
Classroom *	1	1 090	1 090
Classroom	2	640	1 280
Staffroom	1	160	160
Principal's office	1	160	160
		2050**	2 690

*Calculated with AC equipment use

** Battery cycle efficiency and inverter efficiency not taken into account

2.3.2 System Components

At schools in rural areas of the Eastern Cape, stand-alone photovoltaic systems have been installed to supply schools with electricity for lights, television, video and an overhead projector.

The system consists of the following components:

- Solar (photovoltaic) panels: the solar array, consisting of a number of solar panels, converts solar radiation into DC electrical power.
- Regulator: the regulator controls charging of the battery bank from the solar array, and its discharging by the loads. It also controls the load disconnection.
- Battery bank: this is the energy storage mechanism in the system. The batteries act as a voltage stabiliser, and minimise the effect of voltage surges on the system. The batteries also ensure that a constant voltage is maintained to the load.
- Inverter: changes 24V DC from the battery bank into 220V AC at 50Hz.

- Inverter: changes 24V DC from the battery bank into 220V AC at 50Hz.
- AC load: the inverter supplies switched socket outlets mounted on the walls with AC. Appliances with power rating less than the inverter maximum rating can then be used on the system as an AC load.
- DC load: 24 V DC is used for the lights[8].

An electrical schematic of a photovoltaic system for schools is given in Figure 1.

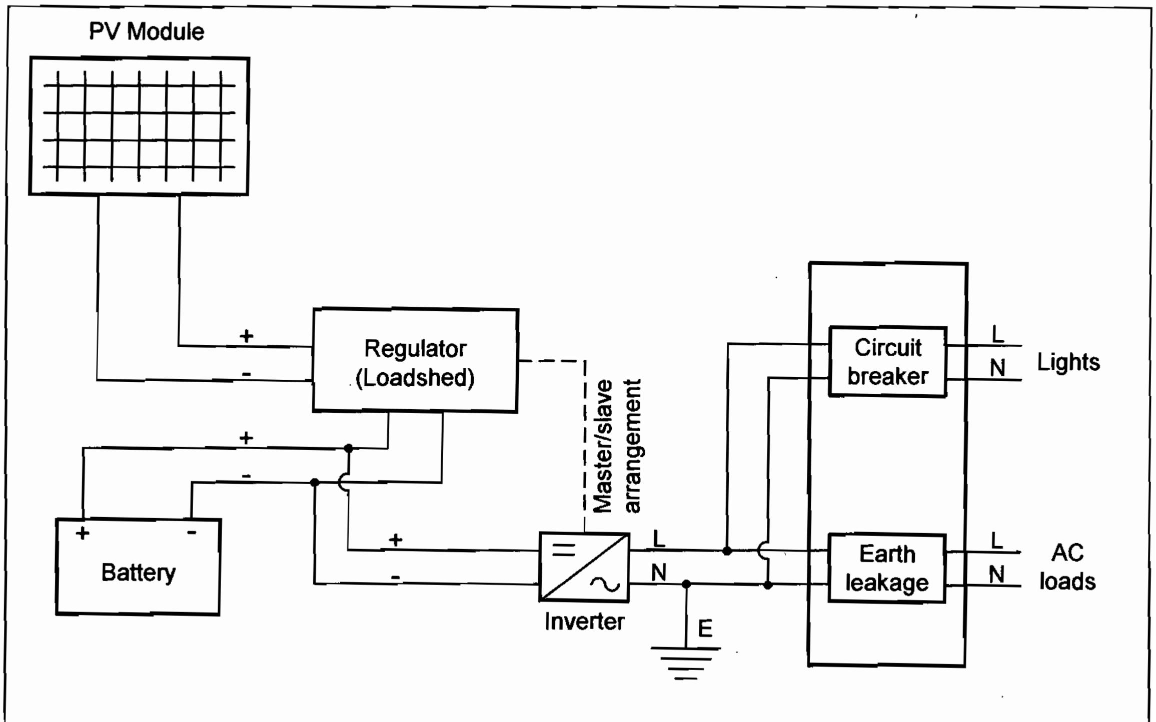

Figure 1 Electrical Schematic of a Photovoltaic System for Schools[(9)]

Photos of the installations are in APPENDIX A.

2.3.3 Installation Procedures

An analysis in the application field shows that poor quality installations and inappropriate equipment are problems. This has contributed to the spread of the false concept in some areas that photovoltaic systems "do not work". Until now there has been a noticeable absence of technical rules, specifications and standards to cover purchase, installation, performance and efficiency of photovoltaic systems, as well as the compatibility of different components. There is no consensus on the application of these requirements and this needs to be established.

In order to have a standard installation procedure for the electrification of schools in South Africa a detailed installation procedure[10] has been compiled by Eskom. The installation of photovoltaic systems consists of the integration of a number of activities that require different levels of skills and competency. The installation should be divided into three main sub-tasks:

- Erection of the photovoltaic module support frame, digging of trenches and installation of battery enclosures and distribution boards.
- Mounting and wiring of photovoltaic modules, interconnection between photovoltaic modules and distribution board, and installation of earthing and lightning protection.
- Installation and wiring of lights, switches and power sockets, and pre-commissioning of the system.

2.3.4 Commissioning Procedures

Before a school is handed over to the Department of Education, Eskom's commissioning officer has to commission the system. A copy of the checklist[11] shall be made and filled in by the responsible commissioning person. The parameters are described in the Commissioning Procedure, and the initial data on the system are gathered from the Commissioning Procedure document.

Unacceptable installations, or parts of these, have to be rectified before the systems are accepted and handed over to the school principal. The handover is to the school principal, who is a representative of the Department of Education.

The commissioner has to make certain that the principal and at least two other teachers understand the operation and maintenance of the system. The installer's responsibility is to explain the PV system to the principal and the teachers.

2.3.5 Maintenance

User education is essential for the success of a photovoltaic programme. Information and training in simple maintenance and safe operating procedures should be targeted at those persons who have primary responsibility for the system. Users need to understand that good operating practices minimise recurring costs and enhance battery life[12]. In order to ensure successful operation of the systems over the total lifespan, attention has been given to the maintenance requirements. A full maintenance schedule has been drawn up covering the *weekly* user maintenance, which includes:

- checking the system operating indicator lights
- check and clean the PV array.

Tasks to be performed on a *monthly* basis by the user includes:

- check the electrolyte levels of each battery

Tasks to be performed on an *as and when* required by the user includes faulty lamps.

The contracted maintenance service on a six-monthly basis includes[8]:

- maintenance of the PV solar array
- maintenance of battery bank

- maintenance of the regulator
- maintenance of the inverter
- maintenance of the luminaries
- maintenance of the distribution board
- maintenance of the wiring
- maintenance of the socket-outlets
- maintenance of the wall switches
- maintenance of the appliances
- circuit-breakers/relay contacts/earth leakage unit for system protection.

A complete routine procedure and maintenance logbook is required. Maintenance personnel record all data, the supplier of the system provides breakdowns and component replacements.

The periodic maintenance is to be undertaken by contractors trained to do such work, or by the Provincial Department of Public Works; in either case the funding for such maintenance will come from the Provincial Department of Education budget. Eskom Non-Grid Electrification[3] will monitor the effectiveness of the maintenance programme and make recommendations to the Department of Education, if changes need to be made to the programme.

Comparing the Tunisian experience (discussed in 4.4.1), maintenance is an important element of a photovoltaic programme and a maintenance procedure is essential to the success of the Eskom NGE Schools Electrification programme

2.4 EVALUATION OF THE ESKOM NON-GRID ELECTRIFICATION PROGRAMME

The Eskom NGE schools programme is one of the biggest programmes in the world, and an evaluation is needed to determine whether the process followed is cost effective and utilised effectively. World wide, lessons can be learned from the South African schools electrification programme.

The South African Government regards school electrification as a priority. The difference between Tunisia and South Africa is that Tunisia implemented the programme more slowly. South Africa implemented the programme without on-going evaluation of the project.

The Department of Minerals and Energy is the co-ordinator of the NGE programme and one of the requirements is an audit report done once a year for the Auditor-General, Department of Finance. The Department of Minerals and Energy appointed Eskom's internal auditors for this audit, which had to examine the technical process as well as the financial process that was followed by NGE. The audit was done specifically in 1996, and the Audit Report[13] identify the following key issues:

- The procedures for establishing area identification of schools have shortcomings that have, in the past, resulted in unnecessary cost and frustrations to communities and schools.

- The identification process performed by contractors must be guided by clear guidelines agreed upon by Eskom and the Department of Education. This will help to obviate Non-Grid Electrification of schools that should be electrified by other means.
- It was noted that schools identified for electrification should be checked carefully against Eskom's five-year plan to ensure that only schools outside Eskom's expansion plan are evaluated for non-grid electrification.
- The evaluation of tenders has not, in some cases, resulted in awards being made to the lowest technically approved tenderer.

Donors such as the Norwegian Agency for Development (NORAD) and the RDP have provided funding for the schools electrification programme: NORAD donated R2 million in 1995, and the RDP allocated R56 million in the 1996 budget, the latter funding being administered by the Department of Minerals and Energy. Eskom did not contribute to the funding of this programme, the success of which is therefore dependent entirely on the beneficence of foreign donors, and/or allocations from the RDP. However, funds have not been forthcoming as initially expected, which hampered the programme.

It is impossible to carry out functions such as project identification and preparation in the absence of reliable data. There is no legislation in South Africa that requires energy suppliers to provide data into a central database in order to facilitate comparison, integration and exchange. Liebenberg[14] and Bedford[15] argue that because of a lack of accurate demographic and planning information on the numbers of unelectrified schools, their location, including their locations in relation to the grid, and the nature of their energy needs, it is only possible to operate with estimates. Estimates of the number and percentage of unelectrified schools vary considerably, which also makes it difficult to assess the progress that is being made. It is essential to have reliable quantitative indicators for monitoring implementation and, later, for evaluation.

The results obtained in Tunisia, Brazil, Indonesia, Thailand, India, Argentina and from the South African schools programme show there is a definite need to evaluate the Non-Grid Schools Electrification Programme, and to compare results with other school programmes world wide. There is a clear absence of rules, specifications and technical standards that may regulate the purchasing, installation, performance and efficiency of these systems. Compatibility of the different components in a system need to be compared with each other to ensure that all the interfaces not only match each other, but improve the exploitation and use of the energy generated by this source. Literature is difficult to obtain because there is not much information available on non-grid electrification of schools world-wide. Therefore the following guidelines serve as a point of departure for this study:

- There is a need for electricity in rural schools in South Africa.
- Photovoltaic systems are a cost-effective way to fulfil the needs of the rural communities
- Through photovoltaic systems education can be enhanced in a rural community

- There are other needs that can be addressed by electrification systems

The questions being addressed are whether the non-grid electrification process followed is effective; whether the systems installed are of the correct sizing to meet the needs of schools and communities, and whether they are utilised effectively.

2.5 CONCLUSIONS

The Non-Grid Schools Electrification Programme has been described in this chapter, and the background to non-grid electrifying schools in South Africa. Owing the importance of the programme there is a need to evaluate communication with communities, the impact the systems are having on education, the use of the systems in order to ensure sustainability, and then to develop a process for non-grid school electrification.

In Chapter 3 the impact of energy on development and the benefits of rural electrification is discussed the suitable technologies and a life cycle cost analysis for medium-scale rural electrification will be discussed from a qualitative as well as a qualitative point of view.

3 ENERGY AND ITS IMPACT ON DEVELPOMENT

3.1 INTRODUCTION

While the upper income end of the market in many countries has used photovoltaic systems, such systems are ideally suited to address this remote-rural need in the South African context. Other renewables are available in South Africa but this study will only focus on photovoltaic. The high solar radiation levels, long distances between rural sites and low maintenance requirement of this equipment has proved that it is an economically sound choice for this application.

A wide range of school sizes and conditions exist in South Africa. A great number of schools in the rural areas have no infrastructure, too few classrooms and poor quality buildings. The recently introduced Schools Register of Needs chronicles[16] the situation regarding educational infrastructure in South Africa in more detail:

- The demand for classrooms outstrips the supply, forcing extreme learner to classroom ratios in many places, and schools without structures.
- A third of school structures are described as being in weak or very weak condition, in most cases requiring almost total structural renovation or demolition.
- At 24% of South African schools there is no water available within walking distance. At a great many of the schools where water is available, the quality is poor.
- Less than half of the schools in the country (43%) have electrical power supplied.
- At 13% of the schools no toilet or sanitation facilities of any kind are provided for scholars and teachers[16].

There is evidence that rural schools in South Africa are in a worse condition and have fewer of their infrastructural needs catered for than urban schools.

The national electricity grid will be connecting large numbers of sites over the next five years. It is estimated that of the schools already in existence and those that were build by the year 2000 there will be 26 000 requiring electrification, 16 000 of which will not receive grid electricity in this five-year period. In order to address these 16 400 schools the Department of Minerals and Energy and Eskom Non-Grid Electrification (NGE) decided to install stand-alone photovoltaic systems. The benefits of providing even a limited supply of electricity to a school are multiple and will have an impact on the educational opportunities in the communities by offering the following:

- Lighting available for after hours study
- Lighting for adult basic education classes
- Access to improved teaching methods (TV, video and overhead projector)
- Community use of school as a meeting place

The current electrification programme is focused primarily on conventional grid extension, while more cost-effective and appropriate technologies may be overlooked owing to an inadequate national guiding policy framework and a lack of data

3.2 RURAL ELECTRIFICATION – GLOBAL VIEW

Energy is a key to development world-wide. There are about 2 000 million people in the world, mostly in rural areas of the developing countries, without access to electrical energy from a central power grid.

The demand for energy is seen to accompany economic development. Electrification is necessary but not a sufficient condition for development. During 1980 the consumption of commercial energy in Western Europe was established at a relatively high level; in the USA, substantial periods of growth were combined with very high consumption levels. In Asia, starting from a low consumption level, the increase was as high as two or three times the population growth rate.

3.3 BENEFITS OF RURAL ELECTRIFICATION

The goal of rural electrification is to bring about increased economic growth, development, higher income and improvement in the quality of life of the people living in the regions to be electrified. Electricity by itself does not bring about economic development, or create new sources of income. Electricity is one of the delivering mechanisms to satisfy basic needs.

A number of socio-economic indicators characterise developing areas, a few of which are the following:

- High unemployment and low, often erratic, income, typically acquired from day to day, necessitating household budgeting on the same basis
- A low standard of health, influenced by a variety of environmental and other factors, with high fertility and mortality rates as related characteristics
- Limited access to basic services, including housing, water, sanitation, energy supply, health care, education and other support structures
- High urbanisation rates, and large scale population migration, especially urban-rural circular migration as well as inter-household migration
- A social structure with a large proportion of female-headed households and single parent families
- Informal housing and squatter settlements, which are seldom conducive to domestic efficiency, resulting in further degradation of household livelihood[17].

This section presents a summary of the benefits of rural electrification. Most are qualitative rather than quantitative. It is difficult to measure quantitative benefits because of their nature, the length of time that elapses before benefits manifest themselves, and the intervention of other factors.

Table 4 Potential Benefits of Rural Electrification[18]

TYPE OF BENEFIT	BENEFIT	MECHANISMS
Social and educational	Improved living standards Reduced burden on women Improved communication Household and community lighting Improved education Improved water supply Greater urban/rural equity	Access to appliances, time saving Less effort spent collecting wood Access to radio and television Better quality light, reduced crime Lighting in schools, evening classes Use of electric pumps Increase in living standards Employment opportunities
Health and environmental	Reduced pressure on natural woodland Less smoke from indoor cooking fires Improved services in clinics and hospitals Reduction in birth rate	Less fuel wood collection Use of electricity for cooking and heating Refrigerators, lighting, communications Higher standards of living
Economic	Improved agricultural productivity Increase in employment Greater number of enterprises Financial savings to users Foreign exchange savings	Irrigation, use of agricultural machinery More businesses, growth in agriculture Opportunities, access to equipment Electricity replaces expensive fuels Electricity replaces paraffin and diesel

3.3.1 Social Benefits

Electricity has long-term social benefits. Improvement in the quality of rural life could motivate more people to stay in the rural area. Improvement in the standard of living would lead to a drop in the birth rate, and electrification would obviously contribute. Access to television would lead to a better-informed rural population, because they could identify with the country as a whole[19].

Women collecting wood have less time for preparation of food, farming, child minding, home crafts, education, socialising and recreation. Women and children are now spending more time collecting fuel-wood, which is not as plentiful as in the past. Owing to a scarcity of wood, women have to cover bigger areas and it is affecting more and more people. In addition, people are forced to use low-quality biomass fuels such as agricultural residues and animal waste, which results in a lowering of their standard of living. Removal of too many trees in an area threatens the local ecology and food production potential of the area for the local people.

Studies in India and Colombia have found that lights encourage adults and children to read at night. This might lead to an above average growth rate of electricity connections in villages where the literacy is high. Owing to electrification, teachers move to communities with electricity, thereby providing the infrastructure for increasing rural literacy in the long term. Rural electrification can be both cause and effect of rural literacy.

3.3.2 Health Benefits

Burning of agricultural residues and animal waste, particularly on open fires, is a health hazard for those (women and children) exposed to the smoke. Respiratory ailments from combustion of fuel in confined spaces, accidental burns, loss of life through fires, and eye strain from reading or studying in poor light are caused by forms of energy used at present.

Since women walk such long distances to collect wood, the tendency is to collect bigger headloads and make fewer trips during the week. This imposes extra stresses on women's physical well-being. Spinal damage might occur.

3.3.3 Environmental Benefits

Fuel-wood collection exacerbates deforestation and soil erosion. In many regions of the world the rate of consumption of fuel-wood far exceeds the rate of addition to supply through the growth of trees. The social cost of having to rely on fuel-wood is in the time and effort required for its collection, and the impact this has on family life and on the potential for economically productive activities. According to Gander it is estimated that several hundred million man-hours are spent on collecting fuel-wood in South Africa every year. Wood itself is becoming a commercial commodity in rural areas, creating severe economic hardship for the poor[20].

3.3.4 Economic Benefits

One of the most persistent claims for rural electrification is that it can induce industrial growth in otherwise lagging, low-income rural economies. The evidence from developing countries does not support this claim. Rural electrification has not, by itself, triggered industrial growth or regional development. In certain circumstances, however, it has supported growth led by a dynamic agricultural sector[21].

Without agricultural growth, the use of electricity in rural areas remains low, and many of the expected economic benefits of electrification have not been realised. The World Bank's[22] 1994 Rural Electrification Policy Paper states that investment in rural electrification is economically justified only when the emerging uses of electricity are strong enough to ensure sufficient growth in demand to produce a reasonable economic rate of return on the investment.

Rural electrification does not reduce poverty by helping the poorest rural people. Most of the direct benefits of rural electricity go to the wealthier people. Even when rates are low, potential consumers cannot always afford the initial connection and household wiring. Once connected, the amount of electricity consumed, and therefore the benefits derived, depend on the ability to buy electrical equipment, such as light fittings, television sets, fans, water pumps and motor-driven machines. Evidence from Indonesia[22] suggests that the poorest 25-50% of the population could not afford electricity, even if a connection were to be financed through power company loans. Direct observation tends to support this supposition for most countries with a per capita rural income of less than $200 per year[22].

Rural electrification reduces rural poverty through a general rise in rural income derived from productive uses. And - again with the exception of irrigation - these productive uses of electricity appear to come about only when other factors are already raising rural and national per capita income, as has been the case in Malaysia and Thailand[22].

Although rural electrification schemes in Asia have generated substantial economic benefits, they have had a dismal cost recovery record, even without taking into account off-peak load generation costs. The capital and operating cost of generation, transmission, and distribution are significantly higher for rural communities than for urban; rural tariffs have been at best equal to, and in many cases much lower than, urban tariffs generally. Only 10 to 50% of the economic cost is recovered. Therefore, rural electrification has usually been highly subsidised, either indirectly by urban industrial users, or directly by government allocation[22].

3.3.5 Specific Reference to Institutional Benefits

The role of education and literacy in rural development is important. There is a positive correlation between a nation's level of literacy and its socio-economic development. Literacy and education are fundamental to a society that is advancing to higher levels of development and more complex labour patterns. Several studies have found a strong relationship between rural electrification, income, and education. There is a strong relationship between access to electricity and higher levels of literacy. These two variables are also associated with income, and it is possible that wealthier households that could afford a connection were better educated in the first place. Results suggest that electrification and education programmes are complementary and that electricity could, at least, facilitate the effective implementation of literacy[23,24].

The supply of electricity to rural schools, clinics and hospitals is often a high priority for governments. The South African government has targeted the supply of electricity to all rural schools and clinics as a key energy policy objective[25]. This policy is advocated for the simple reason that the benefits are likely to be high, and to be evenly distributed in the community.

During 1993-4 the Independent Development Trust (IDT) in South Africa announced that R55 million had been allocated for rural electrification. In KaNgwane and Venda 14 clinics were earmarked for photovoltaic systems and implementation of these systems was completed by August 1994. This has not been seen as a photovoltaic initiative, but as part of an integrated electrification approach. Eskom came into the process at national level. The Independent Development Trust (IDT) initiative involved Eskom in system maintenance, and opened up the possibility of Eskom being responsible for supplying photovoltaic systems as part of their normal business.

The implementation process for the IDT clinics was as follows:

- Careful assessment of energy needs at the clinics
- A professional approach to system design, project tendering and selection of contractors
- Testing of critical components, especially refrigerators
- Planning of user training
- Participation by Eskom, particularly in maintenance[26].

3.3.6 Underestimating Benefits

Rural electrification may not have been an engine for economic growth, but it has provided significant benefits. Many of the benefits have been underestimated, for three reasons:

- Where tariffs are far below economic cost, and demand is constrained by non-price factors, conventional rules of thumb for establishing the demand curve often underestimate the benefits that consumers derive from electricity. The most common error is to assume that the observed consumption level represents a point on the demand curve, when in fact it may be far below the demand curve because consumption is being held down by inadequate supply.
- The economic benefits of electricity may be difficult to measure on the basis of the cost of the substitutes. For instance, because electric lighting provides an order of magnitude improvement over lighting by candle and kerosene, electric light is much more than a simple replacement for kerosene.
- Even if a substitute for electricity is deemed to exist (as in the use of diesel pumps for irrigation, for example), micro-economic rate of return may be flawed for two reasons. Firstly, observed consumer behaviour and underlying prices are often distorted by taxes, subsidies, and lack of information about access to rural credit. Secondly, assumptions about rural electrification and its substitutes that may be valid for a small project, taken in isolation, do not necessarily apply to a large rural electrification programme: diesel fuel may not be available, and prices and benefits may differ[22].

3.3.7 Adverse Effects on Rural Electrification

Electrification has an important and efficient productive use. It stimulates economic growth through increased productivity in rural areas. The assumption that rural areas are characterised by poverty, deprivation and vulnerability, and will be transformed primarily through economic growth, has been much debated in recent years.

Fluitman[1] found that, where people have access to electricity, socio-economic development does not necessarily depend on electricity. Fluitman concluded that the benefits of rural electrification, including the social benefit, tend to be overestimated and the cost underestimated.

There is not much credible evidence[23] to support a direct connection between rural electrification and social benefits. Investment in schools, water supply, health services, and roads may have substantially more direct impact on literacy, population growth, rural-urban migration, and other social benefits. The cost of rural electrification outweighs the small and insubstantial social benefits. Money spent on other rural development, or on alternative energy programmes, could improve rural productivity and quality of life more equitably and effectively.

Most studies evaluate the social and economic impact of electrification separately, ignoring the possibility of relationships between the two. Changes in productivity, employment and size of a local economy can be measured, but social impact is significantly harder to quantify.

Rural electrification might cause regional imbalances in socio-economic development. A study completed in the Philippines found that "the contribution of electricity to the development process depends on the level of development of the area, the availability of capital and other financial and human resources as well as on the implementation of programmes, which stimulate the use of power". Similarly, in a study[23] done in India, it was found that the use of electricity lagged behind the set target because of a lack of capital, no banking loans, insecurity of markets for products, and an unreliable supply of electricity.

3.3.8 International Energy Policy

Rural electrification requires a substantial investment and therefore often requires government involvement. Most developing countries are pursuing rural electrification as a part of their developmental efforts. This implies that there are significant advantages to examining rural electrification issues in the context of overall national policy objectives. It is important to recognise that rural electrification problems cannot be considered in isolation, but must be analysed in the general socio-economic and energy sector matrix in which they are embedded. The limited use of electricity in rural areas and low consumer demand mean that rural electrification often needs to be subsidised by the governments of developing countries, since it is doubtful whether rural electrification could be self-supporting in many countries, even in the future[24,27,28].

The success of a rural electrification policy should be developed within a framework that is:

- holistic - in the context of the national economy;

- realistic - based on the actual capacity of the government, especially in terms of the managerially skilled manpower, and financial and physical resources available; and
- participative - with particular attention being paid to design, implementation, and monitoring of programmes and projects to ensure maximum popular involvement and distribution of benefits in rural areas[27].

3.4 OVERALL SOUTH AFRICAN SITUATION

To be specific, in the early 1990's only a third of the population[29] had access to electricity. Most of the country's 30 million black people had no supply of electricity. This energy inequality was a direct consequence of apartheid. Separate development for the black population meant that millions lived in nominally self-governing "homelands", which were cut off from many of South Africa's resources.

In South Africa, 40% of the population resided in metropolitan areas in 1995. It is expected that by the year 2011[30], 44% of the total population could be living in metropolitan areas. Urbanisation is important for the development process. Migration from rural to urban areas changes the pattern of needs and therefore the demand for energy and for specific energy carriers. Urbanisation could be slowed if living conditions were improved in rural areas, such as creation of job opportunities and provision of energy options. Considering the unemployment in South Africa, development of the rural areas is important. Rural development would stimulate economic growth, which in turn would create job opportunities. Slowing of urbanisation would curb slums and crime in urban areas.

3.4.1 Schools Electrification in South Africa

The Reconstruction and Development Programme (RDP) in 1994, was an agreed programme of the Government of National Unity to address the many social and economic imbalances of the past. The RDP addressed issues such as housing, job creation, education, health, electrification etc. Eskom[31] at that stage responded and had stated its commitment towards the RDP to ten outputs, to be achieved by the year 2000, pertaining to the RDP. These included:

- Further reducing the price of electricity
- Electrifying an additional 1 750 000 homes
- Contributing R 50m per year to the electrification of schools and clinics and other community development activities
- Protecting the environment
- Financing the above from local sources and from overseas development funding.

Eskom started with research on alternative energy during 1993[2] During 1992/3 a panel consisting of the Solar Energy Society of South Africa (SESSA), Energy for Development Research Centre (EDRC), the Department of Minerals and Energy, and Eskom decided that electrification of schools with photovoltaics needed to be researched. The panel decided that because of adult basic education in schools the solution would be to electrify three classrooms, the headmaster's office and the staffroom. At that stage funding was a problem, and R50 000-00 was available for the project. As a result of budget constraints, the funds available determined the size of the school to be electrified. This initiative led to the establishment of the Eskom Non-Grid Electrification Department in 1995.

Based on the literature studied the following conclusions are drawn:
- There is a need for electricity in rural schools.
- Photovoltaic systems are a cost-effective way to fulfil the needs of the rural communities
- Through photovoltaic systems, education can be enhanced in a rural community
- There are other needs that can be addressed by electrification systems

3.5 CONCLUSIONS

Chapter 3 has elaborated on the overall view of rural electrification globally as well as the South African situation.

In Chapter 4 a literature review is conducted regarding international energy policy, objectives and national planning. The problems experienced and the international perspective on energy options is discussed. International experience regarding photovoltaic electrification is looked at and applied in the study. The South African energy policy, national planning, specific goals and policy problems are discussed. South African energy experience is discussed as well as the current South African situation.

Eskom had decided on photovoltaic solar energy and therefore the author addressed the study in terms of what Eskom implemented in the non-grid schools electrification programme. It is vitally important for the South African Government and Eskom to address the following challenges:
- What benefits/disadvantages do photovoltaic systems offer over other energy options?
- What are the immediate needs of the communities in the areas of health care, education, and other services?
- Is the provision of a limited electrification photovoltaic supply meeting the needs of the institutions?
- Are the systems optimally utilised?
- What are the guidelines followed for electrification of schools?

The above questions are answered in this study to support the hypothesis of the viability of photovoltaic systems.

4 ENERGY STATUS QUO – INTERNATIONAL REVIEW AND SOUTH AFRICAN EXPERIENCE

4.1 INTRODUCTION

The conditions in which the population of developing countries live must be taken into account when dealing with any aspect of development. When discussing social and economic factors, questions should be asked about population growth and family planning. The effects of population growth have been widely discussed during meetings at the Earth Summit[32] (Rio de Janeiro 1992), the 15th WEC Congress, the World Conference on Population and the World Conference on Human Development. These effects constitute a serious threat to lasting development, especially since extensive investments will have to be made to cover the needs of the population, and it will be impossible to raise the necessary funds if present social and economic trends continue. The funds are needed to build the essential infrastructure and to fulfil the inevitable energy demand generated by economic growth.

The developing areas of the world house most of the world's population. The complexity of the problems arising from population growth in developing countries is greater in rural areas, where the greater part of the population lives. Questions relating to population have to deal with the central issue of energy for rural development. Rural communities in many developing countries are often unlikely to have access to basic services, as these require a minimum level of energy input.

Energy is a requirement for development, and without energy most of the world's population would be deprived of the right to development and the well-being everyone desires. The impact of energy availability on the lifestyle of communities results in many linked benefits, from improved material standards of living to access to education and health care. This leads to demographic transition, which takes place once a country begins developing; a transition that leads to reduction in fertility, infant mortality and population growth rate.

Unfortunately, this link between energy and population is not taken into account when development perspectives are analysed in the traditional way. The link is even less apparent when dealing with rural development. It is often obscured by the dominating idea that rural electrification should be used to substitute other forms of energy, which are used effectively in rural areas (fuel-wood, biomass, kerosene, or other commercial forms of energy).

If the link between energy and the development of productive systems in rural areas continues to be ignored, considerable time will be lost with serious consequences for the development prospects of rural populations. This will encourage rural communities to emigrate towards urban centres, increasing the problems of hardship and poverty. It is important to stabilise communities in their own areas, where they should have access to certain basic services. This approach is often seen as inadequate, especially when a flourishing rural economy offering employment and stable income to the rural community is lacking. Injecting energy into productive systems in rural areas could bring this about. An adequate institutional framework with appropriate financial measures could achieve this. Stabilising rural communities in their own areas through the development of productive systems would ensure the creation and fulfilment of a growing energy demand, dictated by economic activity and the need for improved lifestyles.

The economics of energy are concerned with the availability of energy resources and their relation to economic activity. The developing world will provide an increasingly important fraction of world energy demand, and its economic growth will be influenced and complicated by increasing competition for world energy resources.

It is difficult to define the term rural electrification precisely, because it is interpreted and used with wide variations in different countries. Frequently, rural electrification programmes[33] are defined in terms of local administrative units, mainly for convenience of implementation. The Indonesian government used the kabupaten (or provinces) as the basic geographic unit, broken down further into three types of rural agglomeration: swasembada, swakarya, and swadaya desa (villages). Such rural communities range from groups of 10 or more houses to small towns of over 40 000 inhabitants. In Sub-Saharan Africa and the poorer countries of Asia, rural electrification means bringing the supply to sizeable towns where 10% of the local population will take a supply. In Thailand or Jamaica, rural electrification means bringing a supply to small villages or farmhouses.

In South Africa, almost 60% of the population do not have access to domestic electricity. In the rural areas of some provinces, only 8% of the population have electricity in their homes. Formerly black towns and cities are still today partly unelectrified, or have only recently been electrified. The result is that these towns have no industries and few businesses. If we look at the overseas experience, and consider the high unemployment figure in South Africa, it is evident that bringing electricity to those South Africans who do not enjoy its benefits must be a national priority.

Extensive discussions are taking place on the funding of electrification, tariff policy, the process of national electrification planning, and the role and policy of grid and non- grid technologies. The current system is exceeding the targets for household connection as originally published in the Reconstruction and Development Programme[34] Neither the planning nor the financing process is transparent, and concerns are being expressed that scarce resources are not being used optimally.

Electrification is, by its very nature, a process guided by technical and financial considerations. But electrification is not an end in itself, as it affects the quality of life of millions of people.

4.2 POLICY

The limited use of electricity in rural areas and low consumer demand mean that rural electrification often needs to be subsidised by the governments of developing countries, since it is doubtful whether rural electrification could be self-supporting in many countries, even in the future[24,27,35]. The cost of renewable electricity generation schemes needs to be compared with the cost of central grid generation. Renewables have been shown to be technically feasible, and the prospects are excellent for renewable energy technologies to become competitive with conventional sources of energy during the next few decades. Renewable technologies will enter the market at a slow pace because the private sector will not invest in large volumes of commercially available renewable energy technologies, as this would usually not be cheaper than conventional energy options.

The success of a rural electrification policy should be developed within a framework that is:

- holistic - in the context of the national economy;
- realistic - based on the actual capacity of the government, especially in terms of the managerially skilled manpower, and financial and physical resources available; and
- participative - with particular attention being paid to design, implementation, and monitoring of programmes and projects to ensure maximum popular involvement and distribution of benefits in rural areas[27].

4.2.1 International Policy

4.2.2 Objectives

The objective for developing countries should be to upgrade the quality of energy planning, policy analysis and management, which have been neglected, especially in the rural areas. The emphasis in energy planning and policy analysis is on detailed and disaggregated analysis of the energy sector, its interaction with the rest of the economy, and the main interactions within the various energy subsectors themselves. Attention needs to be given to enhancing effectiveness of the implementation of rural electrification policy

4.2.3 National Planning

In national planning and policy-making the need is to ensure the best use of scarce resources in order to further socio-economic development efforts and improve the quality of life. If rural electrification is to improve the well-being of the rural masses, it should be designed to meet specific objectives. Rural electrification projects must make greater benefits available to the national and the rural population as a whole. These benefits might take diverse forms, ranging from improvements in economic efficiency and productivity, resulting in an increase in material output and income to less tangible gains such as improvement in the quality of life, or reduction in rural to urban migration. Rural electrification policies should address the issue of more equitable distribution of these benefits, especially to the poor. Subsidies given to rural electrification projects are made on the assumption that the principal beneficiaries will be low-income households[39].

Rural electrification has been promoted since 1950 as a major force for development of the rural areas in the Third World. The expectations, particularly in the 1960's and 1970's, included rapid economic growth and improvement in the quality of rural life (especially of the poor), increasing use of electricity for productive activities (in agriculture, industry and commerce), modernisation, and other social changes. Such hopes were not surprising, given that rural electrification has played a significant part in the developed nations. Rural electrification is seen as a key to development, and planning for such a programme must consider all the available options, including new and renewable technologies. Some energy policies consider matters such as rural productivity, decentralised generation of electricity, and postponement of rural electrification programmes in countries with extremely low levels of Gross National Product[63,27].

Sceptics[63,27] point out numerous problems that might interfere with the optimistic scenarios. Many of these difficulties have materialised. Difficulties that plague rural electrification efforts in many developing countries include scarcity of capital, high cost and poor quality of supply, disappointing load growth, low benefits and productivity gains, and perverse distribution effects, with benefits favouring the rich rather than the poor.

Advocates of rural electrification[63] believe that once an area is electrified the number of rural industries will expand and the quality of products improves. The effect may not be felt immediately, but over a longer time the availability of an electrical service will lead to the growth of rural industries.

Experience has shown that, firstly, rural electrification is a tool for national socio-economic development and should be treated like any other policy instrument. This tool should be closely co-ordinated to meet national objectives and goals.

Secondly, an integrated rural development approach has proved itself in many instances. Electrification alone is unlikely to entail development automatically and could, in fact, be costly and ineffective. A set of infrastructure services would be much more likely to result in greater benefits and welfare improvements through synergistic effects. A comprehensive package should include the following:

- Growing agricultural services and inputs
- Rural and agricultural credit
- Irrigation
- Incentives for small business and evidence of a growing number of productive uses on farms and in industries
- Reasonable roads and transport

- School and educational facilities
- Hospitals and health care facilities
- Rural markets
- Potable water
- Communication facilities
- Entertainment
- Electricity support services - including electrical equipment, appliance maintenance, house wiring, etc.

Thirdly, rural electrification must be analysed within an integrated framework that includes rural energy, the broader power and energy scene, and the overall macro-economy. Rural electrification and rural development are intertwined, and rural development itself is only one aspect of overall national development. Purposeful investment designed to accelerate the rural development process invariably leads to sudden and massive injections of external resources into traditional agricultural communities, often straining their relatively fragile structure and overwhelming their capability to absorb the surplus effectively and adjust to change. Careful sociological analysis is important in helping to ease human problems, smooth the structural and institutional adaptation process, and prevent disruption.

Fourthly, the dynamic nature of rural electrification is a key to successful implementation. The institutional framework, load forecasting, design and planning of networks, operation and maintenance practices, methods of financing, assessment of socio-economic benefits, cost, and other aspects must be tailored to the often rapid evolution and growth of rural loads and the grid that serves them. Concentrating on the start-up is just the first phase, and constant attention must be paid to financing and maintaining the level of services to electricity consumers in the project area over a long period, as load growth continues[63,27].

4.2.4 Specific Goals

Specific goals to be included in a typical national, integrated energy policy are:

- Determining the energy needs of the economy (especially the rural sector) and meeting them to achieve growth and development targets
- Choosing the mix of energy sources to meet future energy requirements at the lowest cost
- Minimising unemployment
- Conserving energy resources and eliminating wasteful consumption
- Diversifying supply and reducing dependence on foreign sources
- Meeting national security and defence requirements
- Supplying the basic energy needs of the poor, the bulk of whom are rural
- Saving scarce foreign exchange
- Identifying specific energy demand/supply measures to contribute to possible priority development of special regions (particularly rural or remote areas) and priority sectors of the economy

- Raising sufficient revenue from energy sales to finance energy sector development
- Attaining price stability and
- Preserving the environment

4.2.5 Policy Problems

In 1980, lending agencies[36] were sceptical about whether rural electrification was either economically sound, or beneficial to the rural populations it was designed to help. Funding for rural electrification from lending agencies such as the World Bank was cut. Third World countries forced the World Bank and US-AID jointly to review existing projects[36]. Decisions to fund rural electrification projects were based largely on economic efficiency.

It is not hard to be daunted by the scale of the problem of providing energy services to the world's rural population. Some 50% of the world's population[37] lives in rural areas of developing countries, and more than two thirds of these households (around 2 billion people) do not have access to electricity. Many government programmes have attempted to extend energy supplies to rural areas in order to redress this situation.

The weaker the utility's financial state, the more important it is for it to focus its rural electrification efforts on areas where a reasonable financial return can be obtained. As the network builds up and the number of profitable consumers increases, it eventually becomes possible to relax the electrification criteria on social and equity grounds and to provide electricity to the financially less rewarding areas. If the utility's resources are expended early where an adequate rate of return cannot possibly be achieved, the utility becomes progressively weakened financially, managerially and operationally, and the overall progress of rural electrification is jeopardised.

4.2.6 South African Energy Policy

Objectives of the Reconstruction and Development Programme

The Reconstruction and Development Programme (RDP) has been responsible for many national development initiatives. Although the RDP emphasises the number of houses to be electrified, the gains from investment in energy infrastructure in rural areas must be measured by the benefits that are delivered. Rural electrification should be seen as a contribution to development and growth.

More recently the RDP had been positioned in the government's new macro-economic strategy entitled: Growth, Empowerment and Redistribution (GEAR). Although this strategy placed more emphasis on economic growth (6% per annum) and job creation (400 000 new employment opportunities), to be achieved by the year 2000, it retained key elements of the RDP such as redistribution of income, meeting basic needs, development of human resources, and democratisation.

The government's Reconstruction and Development Programme (RDP) is aimed at the upliftment and empowerment of disadvantaged people and communities. Electrification is a crucial element of the RDP, since it is well known that one of the most effective ways to improve people's quality of life is to give them electricity. Social change is imperative in South Africa, and this will improve the quality of life of the people. The role of electrification in the process is as follows:

- Millions of women in rural areas will not spend four to six hours a day collecting firewood
- The high incidence of lung disease, especially in children, caused by the combustion of coal, wood, paraffin etc, will decrease
- The loss of dwellings, and injury as a result of burning, from fires caused by paraffin stoves and candles will decrease
- Education in schools will improve because of the use of electricity for lighting, audio-visual equipment and computers
- Health services in clinics will improve owing to better sterilisation equipment, cold storage of medicines and food, and use of electrical tools and equipment
- Electrical energy will be used to perform income generating tasks, e.g. welding, baking, sewing
- Entertainment

The energy sector has both economic and social functions, in that it powers productive activity and provides basic energy services for households. The energy sector therefore has the potential to contribute to economic growth and employment creation, as well as providing an important component of social infrastructure for households. The RDP target[34] for electrification is 450 000 new household connections per annum. Starting in 1994, this means that by the year 2 000 a further 2.5 million houses were electrified, affecting the lives of about 17 million more people. This required a concerted effort of planning and deployment of the resources required for implementing a programme of this magnitude.

The role of the National Electricity Regulator (NER) in the electrification programme is in monitoring electrification targets to ensure that the RDP targets are achieved. It is not the responsibility of the National Electricity Regulator to set the targets, or to achieve them. The NER is there to co-ordinate the setting of targets by communities themselves, to marry these with national targets and priorities, and to ensure that obstacles that may inhibit electrification are identified and removed in good time.

The South African Government established a company called Renewable Energy for South Africa (REFSA) in 1996 to facilitate finance for the electrification of rural areas. In areas where the grid will not reach, photovoltaic systems can supply needs that are peculiarly electrical in nature and of a low energy intensity, including lighting, television, radio, telecommunication and refrigeration. Photovoltaics could supply these services effectively in areas that would not be regarded as priorities for electrification via the grid. The Department of Minerals and Energy disbanded Refsa in 1998, and is now looking at providing the service itself.

National Planning

It is a widely held view that the key to South Africa's future, including the correction of historical social and economic imbalances, is one of sustainable economic growth. The economic growth rate aspired too, was at least 6% per annum by the turn of the century.

Clearly, economic growth is strongly dependent on the availability of adequate, affordable and reliable energy to meet the needs of society at domestic, industrial, business and commercial levels. The South African Government[38] is committed to the promotion of access to affordable and sustainable energy for small businesses, disadvantaged households, small farms, schools, clinics, rural areas and a wide range of other community establishments. As provided for in the South African Constitution, the State must establish a national policy that will ensure that the national energy resources are adequately tapped and developed to cater for the needs of the nation. Energy production should therefore be available to every citizen at an affordable price. Energy production and distribution should not only be sustainable, but should also lead to improvement in the standard of living for all the country's citizens. The State should ensure that energy is produced and used with maximum efficiency at all times.

The energy sector is an integral part of the whole economy. Energy planning requires analysis of the links between the energy sector and the national economy. Such links include:

- the input requirements of the energy sector, such as capital, labour and raw materials
- energy sources such as electricity, fossil fuels, petroleum products, and biomass; and
- the impact on the economy of policies on availability, prices and taxes, in relation to national objectives
- environmental resources such as clean air, water, and space.

The second level of integrated national energy planning treats the energy sector as a separate entity composed of sub-sectors such as electricity or petroleum products. This permits detailed analysis of each sector, with special emphasis on:

- interaction between the different sub-sectors;
- substitution possibilities;
- resolution of any resulting policy conflicts, such as competition between paraffin and electricity for rural lighting; between wood fuel and paraffin for cooking; between natural gas, bunker oil and coal for electricity production; or between diesel and petrol for transportation.

The third is the planning in each of the energy sub-sectors. The electricity sub-sector must determine its demand forecast and long-term investment programmes.

Local economy can be developed, if energy provision and supporting services are made available to rural areas. South Africa has, to date, developed and implemented energy activities without a solid base in energy policy and macro-economic planning. This has resulted in the situation where energy planning has been done on a sectoral basis without much regard for socio-economic development objectives, or inter-energy considerations. The government reassessed the situation through proposed restructuring of the electricity industry and development of a national policy[39].

Specific Goals

In 1985 a Draft White Paper on Energy Policy of the Republic of South Africa[40] was published. This draft dealt with renewable energy sources, with the following aim:

"To develop and utilise to the optimum those renewable energy sources that have the greatest potential in South Africa, e.g., biomass, hydro-electricity, solar and wind energy in order to extend the life of the non-renewable energy sources."

The White Paper on Energy Policy, published and accepted by Parliament in 1986, led to a number of institutional and policy changes. The objective of the energy policy as found in the White Paper[41] is:

"to ensure, by means of an appropriate energy management plan, both the adequate and uninterrupted provision of energy and its efficient utilisation in order to promote the optimum economic and social development of the Republic of South Africa in particular, and of all countries in Southern Africa, in general".

However, a revised national focus has been identified as a high priority need. In 1995, the Minister of Mineral and Energy Affairs requested the International Energy Agency to conduct a policy review for South Africa. This extensive and authoritative report[55], released in May 1996, contained the following main recommendations:

- A balance needs to be obtained between policy consultation and action.
- The energy governance system needs to be reviewed and should ensure transparency.
- Since the Department of Minerals and Energy (DME) does not have the capacity for its policy analysis, development and implementation responsibilities, it needs to be strengthened.
- Gathering of energy statistics is poor and requirements include an appropriate legislative framework.
- RDP priorities of electrification, supplies of traditional fuel, low-smoke coal provision to inland urban areas, and housing energy efficiency require focused support.

- Active participation in Southern African Development Community activities is required.
- Government support for research and development (including technical development) is required.
- An integrated industrial energy efficiency programme needs to be introduced.
- A residential and RDP housing energy efficiency programme is required.
- The pollution control regulatory system needs to be upgraded.
- An integrated approach needs to be taken to reducing township air pollution.
- An explicit national electrification strategy is required.
- The structure of the electricity distribution sector needs to be rationalised.
- Competition needs to be introduced in to the electricity sector in the medium term.
- Regulation of the liquid fuel sector and intervention by the State need to be rationalised. Subsidies for liquid fuels need to be phased out.
- The future of Mossgas needs to be decided.
- Offshore oil and gas exploration terms need to be reviewed and clarified.
- The role of Soekor, the State exploration and offshore licensing agency, needs to be assessed.
- A simple economic regulatory structure is required for piped gas.
- Renewable energy requires significant public support.

The Draft White Paper[42] prepared in November 1996 by the Department of Minerals and Energy was not accepted. South Africa was in need of an integrated energy policy framework, based on new social and economic imperatives relating to reconstruction and development in South Africa.

In 1998 the Department of Minerals and Energy published a Draft White Paper on Energy[38] for South Africa. Stakeholders were asked for their comments by the end of July 1998. The Draft White Paper has the following five objectives:

Increasing access to affordable energy services

- Government will promote access to affordable energy services for disadvantaged households, small businesses, small farms and community services.

Improving energy governance

- Governance of the energy sector will be improved. The relative roles and functions of the various energy governance institutions will be clarified, the operation of these institutions will become more accountable and transparent, and their membership will become more representative, particularly in terms of participation by blacks and women.
- Stakeholders will be involved in the formulation and implementation of new energy policies, in order to ensure that policies are sympathetic to the needs of a wider range of stakeholder communities.
- Co-ordination between government departments, government policies, and the various tiers of government will be improved in order to achieve greater integration in energy policy formulation and implementation.

- Government capacity will be strengthened in order to better formulate and implement energy policies.

Stimulating economic development

- Government will encourage competition in energy markets.
- Where market failures are identified, government will intervene through transparent regulatory and other carefully defined and time-delineated mechanisms, to ensure effective delivery of energy services to consumers.
- Government policy is to remove distortions and encourage energy prices to be as cost-reflective as possible. To this end, prices will increasingly include quantifiable externalities.
- If subsidies are required, these should be implemented transparently in order to subject them to normal political forces.
- Energy taxation will continue to remain an option in the government's fiscal policy, but will be exercised with more consideration for the economic and behavioural impact of such policies.
- Government will work towards an investor-friendly climate in the energy sector through good governance; stable, transparent, regulatory regimes; and other appropriate policy instruments.

Managing energy-related environmental impacts

- Government will promote access to basic energy services for poor households, in order to ameliorate the negative health effects arising from the use of certain fuels.
- Government will work towards the establishment and acceptance of broad national targets for the reduction of energy-related emissions that are harmful to the environment.

Securing supply through diversity

- Given increased opportunities for energy trade, particularly in the Southern African region, government will pursue energy security by encouraging a diversity of both supply sources and primary energy carriers.

The above five policy objectives form the foundations of South Africa's new energy policy.

Policy Problems

The National Electrification Forum[38] was established in May 1993. After concluding its discussions, the National Electrification Forum presented a set of recommendations to the cabinet in the second half of 1994, leading to establishment of the National Electricity Regulator early in 1995. The National Electrification Forum also developed financial models of various scenarios for the national electrification programme. This information was used by RDP drafters to establish a national electrification target of 2.5 million household connections by the end of 1999. The RDP further suggested that all the schools and clinics should be electrified as soon as possible. As a contribution to the RDP, Eskom had set itself the target of delivering 1.75 million household connections (300 000 per annum), assuming that municipal distributors would be responsible for the remainder.

The National Electrification Forum subsequently dissolved, leaving the task of drafting a new electricity regulatory bill to an advisory committee on electricity legislation reporting to the Department of Minerals and Energy.

The National Electricity Regulator (NER) subsequently attempted to rationalise the electricity distribution industry through its first licensing round. The Electricity Supply Industry (ESI) was requested to consider rural electrification. This was to be implemented by applying for licences to generate, transmit and distribute electricity. This initiative failed to result in any effective rationalisation and, in the absence of a clear policy framework, the National Electricity Regulator turned to the government for direction. An internal government committee, known as the Electricity Restructuring Interdepartmental Committee examined recommendations for restructuring of the distribution industry.

The Electricity Supply Industry (ESI), as part of the public sector, bears responsibility for the electrification programme. In striving to achieve electrification targets, the ESI will no doubt be faced with many challenges. Two areas of concern are the following:

- Non-payment - If the consumers do not pay for services, the electrification programme will be impeded and the suffering of those who are deprived of the benefits of electricity will be prolonged. The principle of no electricity without payment will have to be accepted by everyone.
- Electrification beyond the plug - Plans to make electrical appliances more affordable and accessible to South Africans in the lower income groups will have to be developed. Only then will electricity make a difference in people's lives, and electrification can then help in the upliftment and empowerment of people[34].

Whereas the progress on electrification is commendable, one must be realistic about the constraints that lie ahead:

- As the electrification programme progresses, it will become increasingly difficult and more costly to electrify homes, owing to remoteness from the grid and lower density of dwellings in the rural areas.
- Escalating costs may curb the rate of electrification.
- The funding requirements of the programme are considerable.
- Changes in local government structures have placed a considerable burden on their resources and their ability to provide infrastructure, including electricity, for the traditionally disadvantaged communities.
- Non-payment poses a threat to the sustainability of the electrification programme.

These constraints are not insurmountable. They call for careful planning and innovative strategies to curb capital and operating costs, to obtain low cost funding and encourage the sensible use of electricity. The electricity distribution industry must be restructured appropriately to optimise the use of scarce resources, and to meet changing needs of all the electricity consumers efficiently and effectively.

4.3 ENERGY OPTIONS

4.3.1 International Options

Despite the vast majority of developed countries having enjoyed grid electricity for many years, there are some remote parts where grid power is unavailable and where non-electrified rural houses can be found. For example, the total European population living without electricity in 1988 stood at 1 100 000 people[43], more than 95% of whom were low-income earners living in isolated areas of Mediterranean countries. Since this represents less than 1% of the total population of Europe, it could appear negligible. However, in photovoltaic terms it represents a potential market of 60 MWp in economic competition with grid extension, which is more than significant. Access to electricity is widely accepted as a general right in the context of European policies, so many programmes promoting photovoltaic rural electrification have been implemented since the early 1980's[43].

Many renewable energy systems have benefited from developments in electronics and material sciences, and other technological advances. Renewable energy equipment, being modular in many cases, can be constructed in modern factories, where it is easier to apply modern manufacturing techniques that facilitate cost reduction.

A renewable energy solution could include some or all of the following[49]:

- A diversity of energy sources, depending on the region. Electricity could be provided by various combinations of hydroelectric power, wind, solar-thermal, photovoltaic, biomass, geothermal and diesel
- Efficient use of energy supplies in all industrial and household sectors
- Biomass would be widely used. At the moment biomass is used inefficiently and contributes to deforestation
- Intermittent renewables could provide as much as a third of the total electricity requirements cost-effectively in most regions, without the need for new electrical storage technologies
- A renewable-intensive energy future would introduce new choices and competition in energy markets
- Most of the electricity produced from renewable sources could be fed into large electrical grids and marketed by electric utilities[44]

In the following paragraphs renewable energy options are discussed.

Biomass

The main sources of household energy used by rural communities at present, and those that will be in use for a long while to come, are traditional energy sources derived from biomass (fuel-wood, charcoal, agricultural residues and animal waste). Collection is the responsibility of women and children. In the developing countries, biomass fuels provide 80% of the primary energy used in rural areas. This is a traditional pattern and is owing to the low-income levels and ready availability of biomass fuels. Collection of biomass fuels is a non-monetary activity, but it is costly in terms of time, effort and environmental damage. Transition from biomass fuels to fossil fuels and electricity appears to be a basic feature of economic growth. This transition is more evident in urban than rural areas, and is dependent on income and existing supply infrastructure.

A study commissioned in 1992 by the United Nations, for the 1992 Conference on Environment and Development, found that if crops were grown specially for biomass purposes, the equivalent of 55% of today's total world energy use could be met via biomass by 2020. It has been found that 13% of the world's energy is provided by biomass, and in developing countries biomass currently supplies approximately 36% of the energy used. It provides virtually all the fuel used by about 2.5 billion people who live mainly in rural areas, and this represents 45% of the world's population[45].

Although biomass is a renewable source, much is used currently in ways that are neither renewable nor sustainable. Natural woodlands provide most of the supply and have deteriorated to a point where households have trouble obtaining sufficient fuel-wood. Firewood all over the developing world is becoming scarce, and women and children are forced to spend more time collecting it. Crop residues and animal dung are burned in coal stoves.

Biomass has provided electricity for many years with conventional steam-turbine power generators. In regions where low-cost biomass fuels are available the existing conventional steam-turbine technologies are cost competitive, although these technologies are comparatively inefficient in the small sizes used for most biomass electricity production.

Performance of the biomass electrical systems can be improved by adapting to biomass advanced-gasification technologies originally developed for coal. Biomass is a more attractive feedstock for gasification than coal because it is easier to gasify and has a low sulphur content, so expensive sulphur removal equipment is not needed. In the United States there is a biomass capacity of more than 8 000 MW_e[44].

Hydro-Generation

Hydropower is used primarily for electricity generation. Total world production of hydropower increased by 6% from 1994 to 1995 (from 205.2 million tonnes (mtoe) of oil equivalent to 218.5 mtoe). World hydropower capacity is estimated at some 600 000 MW, of which about 3% comprises hydro-schemes (ie less than 18 000 MW). Almost two thirds of world production of hydropower is in industrialised countries and small hydro-schemes account for just below 4% of the total production[45].

In the developing world, hydropower potential is still largely unexploited. At least 50 000 MW[45] of possibly exploitable hydroelectricity resources exist in Africa. Europe and North America are the only regions where there have been substantial developments, and by 1980 North America and Europe had developed 59% and 36% of their hydropower potential respectively, whereas Asia had harnessed just 9%, Latin America 8% and Africa 5%. Hydroelectric power is also generated in pumped storage schemes. Although these systems run at a net energy loss, they benefit from cheap off-peak tariffs and better load use. Pumped storage schemes are the only practical means of storing electric energy in commercial amounts. In 1970 the total of pumped storage capacity installed in the world was just more than 50 000 MW, whereas the present total is nearly 100 000 MW.

Wind Energy

The world's wind generating capacity connected to the utility grid increased from 1 020 MW in 1985 to 4 880 MW in 1995. This is 33% up from 3 680 MW in 1994. The US led the world with a capacity of 1 650 MW at the end of 1995, but Germany was closing in fast with 1 130 MW, Denmark was third with 610 MW, and India fourth at 580 MW. Altogether Europe had 2 500 MW of wind power capacity at the end of 1995: a nearly threefold increase on 860 MW in 1992[46]. There seems to be a lack of detailed knowledge of the true capacity of wind potential to contribute to the world's energy resource base, owing to the very site-specific nature of the information required. However, it has been established that sufficient sites are available in Europe to meet additional electricity consumption requirements of the former European Community, if necessary.

Over the past ten years, the cost of wind power has come down, mainly as a result of improved equipment production methods, and better siting and maintenance scheduling. Technical improvements, such as the development of advanced materials to provide lighter, stronger components, could reduce the cost further[45].

The benefits of wind electricity depend on the characteristics of the utility system into which it is integrated, and on regional wind conditions. Analysis concluded that wind systems have greater value if numerous generating sites are connected, because wind power fluctuations from a system of turbines installed at many widely separated sites are likely to be less than at any individual site[44].

The World Bank[47] is attempting to reorientate lending programmes to include small renewables, while government foreign aid programmes, including US-AID, are becoming active in promoting non-polluting renewable technologies. In Indonesia, a US-AID/GEF sponsored wind energy programme has a budget of $3.3 million for island and non-governmental development projects. In Russia, a US-AID/MFE rural electrification pilot programme worth $2 million is in progress. In Brazil, the World Bank/PAPP has funded a $400 million municipal development programme to install wind turbines for pumping water. In Mexico there is a CFE/APS $2 million project for hybrid village electrical systems in Baja and Sonora. Table 5 indicates the world market for small wind turbines.

Table 5 World Market for Small Wind Turbines[47]

Application	1995 M£/year	2005 M£/year
Remote homes	2.8	70
Telecommunication	1.5	14
Village/rural electrification	2.1	280
Miscellaneous remote site loads	1.4	14
Drinking water and irrigation water pumping	0.7	70
Oil well pumping	0.1	20
Refrigeration	0.1	4
Desalination	0.1	4
Totals	**8.8**	**476**

Photovoltaic

Photovoltaic systems are based on photovoltaic cells, which transform solar energy into electricity. Solar photovoltaic cells are semiconductor devices usually made of silicon. A complete photovoltaic system may include a photovoltaic array, a storage battery, a regulator, an inverter, the module supports, and a variety of cables, clips, connectors, switches, junction boxes, lights, equipment and other small parts[48].

The most common type of photovoltaic cell is the crystalline silicon cell with an efficiency of 12–13%. Crystalline cells are made from high-purity silicon, which is melted and cast into a crystal, sliced into thin wafers and doped with impurities such as boron to give them the required electrical properties. Thin conductors are deposited on them to provide contacts. A series of cells are interconnected to provide a photovoltaic array.

Amorphous silicon is a cheaper but less efficient cell where silicon is deposited as a thin-film in a vacuum chamber onto a glass or other substrate. Conductive layers and connections are attached to the substrate and into a protective glass layer.

Developments include thin-films produced from compound semiconductor materials. A typical material is that based on copper indium diselinide (CIS). This material will be in the polycrystalline state with crystals of 1-5 microns in diameter. There are a number of variations of these materials with gallium being substituted.

These thin-film cells have a thickness of approximately 2 microns, compared with the 300-micron thickness of the silicon cell. Thin-films can be made in any size, whereas silicon wafer cells are limited to the maximum size of the crystal. Thin-film can have different sizes and shapes, and mass production is possible[49].

World-wide photovoltaic sales are about 50 MW_e annually. The main problem preventing the widespread use of photovoltaics is the high cost of manufacturing the sheets of semiconductor materials needed for power systems. Photovoltaic electricity costs 25 to 35 cents (US) per kWh at present.

Despite their high cost, photovoltaic systems are cost-effective in many areas remote from utility grids, where alternative sources of power are impractical or costly. Since photovoltaic systems are modular, the cost can vary considerably. As the modular price decreases, the cost of the balance of system components such as batteries becomes increasingly significant. Small, grid-connected photovoltaic systems may be competitive today, when distributed generation has particularly high value. Many such niche applications will provide early markets for photovoltaic systems. As photovoltaic prices decrease, markets will expand rapidly[44].

Problems that face photovoltaic rural electrification are:
- funding; and
- skills at the village level: managerial and technical
- high cost
- lack of understanding and acceptance.

The cost of photovoltaic systems compared with grid supply will be examined, and the conditions of location and demand under which photovoltaics are viable will be identified.

When considering photovoltaic systems for an area, the least-cost solutions should be considered. Grid electrification should not prejudice the use of photovoltaic systems.

Solar Thermal

Solar-thermal electric generation systems use solar energy to heat fluids that drive turbines. Such systems typically concentrate sunlight with mirrors that follow the sun. Dispatching is possible because the heated fluids can be stored comparatively inexpensively. Since the systems use conventional power turbines, backup power can be provided simply by burning natural gas or other combustion fuel to heat the fluids when sunlight is not available.

The capacity of commercial systems now connected to utility grid totals 350 MW_e. Most of these systems are in California and were constructed in response to financial incentives offered in the 1980's. As in the case of wind, continual engineering refinements have led to steadily improving efficiency and declining cost.

A state of the art solar-thermal electrical system would produce electricity for about 9.3 cents (US) per kWh. This cost is significantly higher than that of baseload electricity in most regions. However, the value of solar-thermal electric power is enhanced by the fact that output varies directly with sunlight and therefore correlates well with peak electricity demands[44].

Diesel Generators

Throughout the developing world, millions of small privately owned generators are running on diesel, gasoline, or LPG. They are used to supply electricity to households, small factories and workshops, businesses, bars, restaurants, hotels, schools, hospitals, health clinics, pumping stations, etc. They usually deliver an alternating current supply and provide power for lights, television, power tools, electrical appliances, pumps, grain mills, and many other applications.

Energy efficiencies for the smaller generator sizes are about 15 to 20%[48], yielding a consumption of 0.5 to 0.6 litre/kWh of electricity produced. The working life depends on the quality of the unit and how well it is maintained, but about 2 000 hours is typical of the smaller gasoline units.

In Pakistan and Yemen[48] diesel generator supply systems have been installed. The cost to each connected consumer is about $300 in both cases, as may be seen from Table 6. It is also worth noting that both these diesel systems, under the conditions shown, are operating at a small fraction of their output capacity. A variety of daytime loads, as well as additional evening consumption, could be accommodated at no extra investment cost. If, for example, the average consumption per customer were to double, it would cause the delivered electricity cost to drop to between $0.25 and $0.30/kWh (1996).

The service provided by the diesel system offers a high degree of flexibility for households and the community. There is effectively no technical constraint on the appliances that could be used, or on the total monthly consumption at individual household level[48].

Table 6 Breakdown of Costs for Small Diesel Supply Systems in Pakistan and Yemen[(48)]

Assumptions/system elements	Pakistan		Yemen	
	Quantity	Unit cost	Quantity	Unit cost
Number of consumers	50		50	
Consumption/consumer	25 kWh/m		25kWh/m	
Diesel generator cost		$400kW + $160		$450/kW + $200
Fuel cost		$0.173/litre		$0.22/litre
Civil works		$580		$1.000
Distribution network		$2.900		$2.500
Repair and maintenance		10% of investment		10% of investment
Annual operating costs		$700		$740
Line of generator	8 years		4 years	
Interest rate	10%		10%	
Connection cost		$2/consumer		$52/consumer
Size of diesel generator		20kW		20kW
Daily operating time		6 hours		6hours
Daily production		40 kWh/d		40 kWh/d
Annual fuel consumption		7.116 litres		7.116 litres
Investment cost		$285/consumer		$306/consumer
Cost/kWh		$0.35kWh		$0.51kWh
Annualised cost of systems		$105/consumer		$151/consumer

Grid Electrification

Electricity will remain the fastest growing energy carrier, in spite of sustained efforts to improve demand management, end-use efficiency and conservation in some countries. The World Energy Council (WEC) expects investment in electricity to account for a third of all energy investment in the period to 2020[50].

Demand for electricity is projected to grow by 19 trillion kWh to 2015, nearly doubling present electricity demand. Over the past two decades, electricity consumption throughout the world has grown by 3.4% per annum, compared with 2% annual growth in total end-use energy consumption. As efforts are made to reach rural populations, and as electricity continues to penetrate end-use energy markets, electricity consumption world-wide is expected to grow at an annual rate of over 2.6%[51].

Table 7 illustrates that the United States is the country with the highest net generating capacity (760 427 MW), followed by Japan (212 913 MW).

Table 7 Selected Electricity Supply Statistics - world, 1993[(51)]

Country/Region	Net maximum capacity of generating plants, MW[1)]	Total production of electricity, GWh[2)]	kWh per capita
Region			
World	2 976 011	12 261 589	2 206
Africa	81 837	340 468	501
Asia	763 090	3 290 127	980
Country			
Australia	37 206	163 557	9 284
China	175 194	839 453	719
Germany	114 294	525 721	6 513
Japan	212 913	906 705	7 281
South Africa	35 315	177 100	3 927
United Kingdom	68 455	323 029	5 843
United States	760 427	3 145 892	12 308

Geothermal Energy

There have been developments in the use of medium temperature geothermal water for power generation using binary cycle plants. At the beginning of the 1990's, world geothermal electricity capacity was established at almost 6 000 MW, representing a small but not insignificant "niche" at around 5,6 million tonnes of oil equivalent.

It has been estimated that the geothermal energy in the upper 5 kilometres of the earth's crust is equal to approximately 40 million times the energy contained in the world crude oil and natural liquid gas reserves. In principle geothermal energy could be tapped nearly anywhere on earth. About 34 countries now use some form of underground energy. In Mexico, Nicaragua, Italy and China, geothermal energy is being investigated as a means of meeting rural electricity demands. Geothermal energy provides heating and hot water for more than 85% of Iceland's needs. In New Zealand, the Wairakei and Ohaaku geothermal power stations produce 8% of the national electricity company's generating capacity. Geothermal power generates 11% of Keyna's electricity, while Ethiopia has untapped reserves[45].

4.4 EXPERIENCE

4.4.1 International Experience in Various Countries

Urban areas in the world are growing at a much faster rate than its overall population. This is owing to declining availability of per capita income in rural areas, shrinking economic opportunities in rural areas, and more opportunities and superior services available in urban areas. By the year 2025, the urban population will have increased to 61.1% of the global population.

In the following paragraphs, experiences from Argentina, India, the United States, Thailand, Indonesia, Brazil and Tunisia will be discussed. The lessons to be learned from these countries are valuable when considering the growth of demand in South Africa.

Argentina

In Argentina[52] the aim is to supply 300 000 private users and 6 000 public services (schools, health centres, civil services, police stations, drinking water services etc.) with rural electricity. These areas have low population density, and there is no possibility of any expansion of the existing grid. This programme entails the following:

- Electrification will be done mainly through photovoltaics, wind turbines, and microhydro and diesel driven generators
- The total investment in the programme is US$314 million, which will be paid for by private users, provincial states and national subsidies. This programme calls for shared responsibility
- This programme will be open to public bidding, and the bidding will be won on technical background and financial solvency.

The results expected are that a minimum level of electrical service will be rendered, but that this will still be enough to meet lighting and social communication needs. The private company that is delivering the service should show good financial performance on a minimum subsidy.

One specific photovoltaic pilot project, called Baldes de Leyes, was implemented in San Juan Province to examine the real opportunities offered by solar technology, to design optimally adapted photovoltaic systems, and to implement from the technological transferring experience. Baldes de Leyes is an isolated area located in an arid environment, 160 km to the east of San Juan City.

An interdisciplinary team was assembled to take an integrated socio-technical approach. People from the village, craftspeople, professionals, scientists, entrepreneurs, and official organisations were involved in order to adapt technical solutions to the human needs of that rural ecosystem.

The assumptions of this project were as follows:

- That technology would be adapted to human needs, not humans to technology. The highest priority would be given to people's needs and wants, and respect for their opinions and values would take precedence over the project's objectives and time frames.
- A photovoltaic technology triangle was identified as a key element for successful development and delivery of the technology, i.e. the interrelationship between the one who generates it, the one who transfers it, and the one who uses it.
- Experience has shown that user participation is essential to ensure that the project is driven by demand rather than simply by supply, and that for this to occur a participatory approach is essential.

The roles, responsibility and involvement of users in the project were as follows:

Stage 1

The idea of utilising solar energy for rural communities was the central point of the project and was shared with the community. An interdisciplinary team was formed, in which the villagers accepted their participatory role. Data gathering and analysis were carried out. The limitations and performance expectations were discussed with the community, and local support and technical capabilities were identified.

Stage 2

There was collaborative participation from the start. A community demonstration photovoltaic system was designed and managed by the community so that buying into the project could be achieved. A photovoltaic system was installed in the chapel. This was a communal meeting place and everyone in the community could observe the new technology. Social activities were organised and confidence was gained in the new technology. The community made an evaluation before giving any acceptance. The systems designed were based on the needs of the community and on their daily activities.

The roles and responsibilities were clarified by defining each user and outsider's role. Cost and ownership were defined beforehand. Regular payment for maintenance was negotiated. User acceptance was determined at this stage and a formal contract was signed.

The users were involved during installation; local technicians were selected by the community and trained in basic theory and practice during the installation process, and women, youth and children were given training. Educational material and instruction manuals were specially prepared.

Stage 3

During this stage the local impact of the new technology was monitored. There was an increase in organisation and capacity building. Reinforcement was done through demonstration and diffusion.

India

The Indian government has a large-scale power generation initiative under the central and State governments, which includes a transmission and distribution network controlled by the government. Attention has been given to electrification in each five-year plan, but despite this the government has failed to achieve the desired quantitative and qualitative standard for electrification. Only 27% of rural households have been electrified and the shortage of power has led to unreliability of the power supply. Strategies have been implemented for operation, ownership and the distribution network. The government encourages small- and medium-scale generation, as well as large-scale generation, under private and joint sector participation. In rural areas, decentralised power systems based on "new and renewable" systems are encouraged. Solar photovoltaic energy systems are introduced as a decentralised form of power-generating unit to meet peak demand in the urban areas[53]. In India, a cross-section of 44 decentralised power-generating units from Calcutta Urban Agglomeration have been surveyed.

The Indian[54] experience shows that strategies focusing on concentrated deployment instead of on widespread deployment are what are required. Such an intensive approach would allow greater emphasis to be placed on giving post-installation attention to the installed devices.

United States of America

Renewable Energy in the United States was spawned during the 1970's when oil embargoes, rising energy prices, and concerns about increased pollution raised questions of the nation's continued dependence on fossil fuels. As world oil prices increased by 300%, renewable energy sources became a national priority. The Federal Government provided investment tax credits, and research and development funds of about $718.5 million in 1980. Private industry took advantage of this and came up with new and renewable technologies and applications. Consumers' interest in renewable energy sources provided political support for the Federal incentive programmes and laid strong foundations for an industry that grew rapidly[51,55].

Thailand

In Thailand[56] the grid-connected renewable energy electricity generation concept has been well researched and the government supports the concept.

In 1974, the oil crisis greatly stimulated serious endeavours related to the development and introduction of new and renewable energy. The first photovoltaic application in Thailand dates back to about 1976. However, nearly 300 panels were installed, with no record of their performance. Photovoltaic (PV) was used for telecommunication repeaters and signal repeating stations.

Two hybrid stations and one PV station were set up to demonstrate a grid support concept. The first station in Sa Kaeo province, about 200 km east of Bangkok, consists of 20 kWp crystalline modules, a 100 kWh lead acid battery, 20 kW grid interface inverters, switchgear, metering facilities, and data gathering facilities. A total of 114 MWh of electricity has been delivered to the grid during the past seven years.

The second station is located in Phuket. It is a wind hybrid station in the Andaman Sea about 900 kilometres south of Bangkok. This station has 8 kWp crystalline modules, a 140 kWh lead acid battery, 30 kW grid interface inverters, switchgear, metering facilities, and data gathering facilities. PV power is fed to the local 33 kV distribution grid along with six small wind generators of 42 kW combined capacity. A total of 83 GWh of electricity has been delivered to the grid during the past five years.

A third station is located in Chiang Mai, about 700 kilometres north of Bangkok. It consists of 14 kWp crystalline modules, a 60 kWh lead acid battery, 7.5 kW grid interface inverters, switchgear, metering facilities, and data gathering facilities. PV power is fed to the local 22 kV distribution grid. A total of 25 GWh of electricity has been delivered to the grid during the past two and a half years[56].

The fourth station, a photovoltaic hydro hybrid, is planned for Kanchanaburi, about 200 kilometres from Bangkok. Thin-film modules may be used in this installation, since the cost of thin-film can be reduced to meet the target cost through mass production, while the efficiency and stability have been improved.

The advantage Thailand has is that half the components of the system can be produced in the country, and with its well-established electronics industry Thailand is in an excellent position to co-operate with neighbouring countries to develop non-grid systems in remote villages[56].

Indonesia

The rural areas of Indonesia are sparsely populated, and supplying grid electricity would be a capital-intensive exercise.

Photovoltaic technology was started in 1978, by the Agency for the Assessment and Application of Technology (BPPT)[32]. The first system installed was a 5 kWp photovoltaic water-pumping irrigation system. A 25 kWp desalination/ice-making plant for fishing villages followed.

Various systems, totalling 3 MWp, have been installed including water pumping, small-scale photovoltaic television repeater, public television, medical care, radio communications and individual solar home systems.

The Indonesian Government's policy is to use alternative energy to promote the saving of conventional energy and to raise the standard of living of the rural population. Photovoltaic is an attractive choice for energy in rural areas. Solar radiation in Indonesia is high and uniform at ± 4.5 kWh/m^2 per day.

The first village in Indonesia to be supplied with photovoltaic electricity received it in 1989. This programme was such a success that the government decided to install a million solar home systems (1993 - 1998).

The criteria for photovoltaic applications are:

- equal shares of having electricity in rural areas, and
- utilisation of energy sources that are available locally.

In Indonesia the government makes the investment, and the households pay a monthly contribution. The local co-operative does maintenance of the systems and batteries[33].

Those who are progressing from kerosene and candles are generally satisfied with the superior service provided by a photovoltaic system. Continued satisfaction depends on informing customers properly in advance about what photovoltaic systems can and cannot do. Customers must also be properly trained in how to use and maintain the systems[32].

Brazil

In Brazil[32], underdeveloped communities felt they did not have access to the conventional energy system and were never intended to receive the service.

Equipment was installed gradually and with care. Each community and each technology has to be analysed, and all this must be done at a pace that is sufficiently fast to ensure motivation and political/institutional interest, but slow enough to have leeway for correction without deviating from the basic project. By keeping this balance it is possible to give governments and society time to adapt to the new culture.

Tunisia

The Tunisian Government traditionally accords high priority to its basic education programme. The budget of the Ministry of National Education is more important than that of any other ministry[57].

This educational programme touches rural areas, which are characterised by a high percentage of the people living on isolated, scattered small farms, especially in the west and the northwest of the country.

When examining the experience in Tunisia, it is found that in some regions (eg Sidi-Bon-Zid in central Tunisia) almost all of the rural population lives in dispersed settlements. Under these conditions, even in the long term, about 250 000 rural families will have no chance of being connected to the national grid.

Owing to this structure, a large number of small isolated schools are found in the rural areas. Electrification of these schools by the electricity grid is extremely costly. These generally comprise two houses (one for the director's family and one for the married teachers), two or three classrooms in the school, and the house of the school warden. The cost per kilometre of cabling amounts to about 15 000 - DM.

Some efforts have been made to equip schools with small diesel generators. The results were mainly negative, however owing to a lack of maintenance and spare parts, and high running costs[57].

An analysis done by the Tunisian National Energy Agency proved that there were clear economic advantages in equipping schools with small decentralised photovoltaic systems in preference to diesel generators and grid electricity.

This analysis also showed that in some respects equipping the teachers' and directors' houses with solar systems was at least as important as equipping the classrooms with them. Several teachers, being accustomed to urban standards, refused to work in isolated places without any opportunity for access to the media (especially television) and appropriate lighting. It was decided, therefore, to install photovoltaic equipment in order to satisfy the "basic needs": lighting, television and radio.

Table 8 shows the different components and estimated duration of daily use in Tunisia.

Table 8 Components and Estimated Duration of Daily Use in Tunisia[(57)].

Application	Equipment	Electric power	Number of hours/use per day	Equivalent of power consumption	Remarks
Classroom	2 neon tubes	25 W each	2 hours/d (in winter only)	100 Wh/d	Nominal power of tube: 36W reduced owing to ballast
House of director or teacher	3 neon tubes 1 TV set 1 radio cassette	18 W each 15 W 3,5 W	3 hours/d 5 hours/d 4 hours/d	162 Wh/d 75 Wh/d 14 Wh/d	
House of school warden	2 neon tubes	1,8 W	4 hours/d	144 Wh/d	

The total energy demand of a typical school is estimated in Table 9. The demand for the school itself is only 300 Wh/d; the rest of the system is mainly for the teachers' residence.

Table 9 Estimated Energy Demand of a School[(57)]

Application	Number	Power demand per unit (Wh/d)	Total power demand (Wh/d)
Classrooms	3	100	300
House of director	1	251	251
House of teachers	1	251	251
House of warden	1	144	144
Total			946
50 Wp module @ 45^0 (Wh/day)			150
Required number of panels			6

It has been calculated that under the conditions in north-western Tunisia, with an inclination angle of 45^O a photovoltaic panel of 50 Wp will deliver an average of 150 Wh/d. The total demand of a school is 946 Wh/d (see Table 9. The number of panels per school can therefore easily be determined as 6, as each with an area of $1m^{2.}$

First Technical and Socio-Economic Results in Tunisia

It was found[57] that the users (in the school electrification programme as well as in other programmes to equip farmhouses) accepted this new technology and generally used it properly. Cutting off the electricity by the charge regulator (to protect the battery) was noticed mainly in the first period of use and in times of extremely low sunshine (some weeks in winter).

Unfortunately, the systems are not used during the period of highest energy availability because of the three months' holiday in summer. It is most important for the school wardens to undertake the necessary maintenance (especially checking the electrolyte level in the batteries) during this period. It was found that in order to encourage the wardens to do these tasks, it is important to have them participate in the programme. Solar, a special pilot programme for electrification of the wardens' houses by photovoltaics, was established.

Evaluation of a year's experience of solar home systems in the first seven primary schools equipped proved that the systems for the classrooms were somewhat underexploited: four months of the year and two to three hours a day.

The following options for improving this situation were discussed:
- Replacement of the photovoltaic systems for the classrooms with conventional pressurised paraffin lamps. This solution was excluded after discussion with the teachers, owing the to risk of fire and poor luminosity.
- Installation of portable lamps with tubes of low energy consumption. This technology was installed in six schools in the Tairowan region (central Tunisia). The advantage was that teachers living some distance from the

school could use these lamps to light their way to and from school. One of the problems was that the performance of these lamps was characterised by an unsatisfactory lighting time for about 2 or 3 of the lamps installed. The short life of the neon tubes was owing to a lack of protection of the lamps against deep discharging. This alternative was abandoned.

- The possibility of making better use of the energy offered: Some schools use cassette-players for the pupils. Other forms of education (eg through the use of slide projectors) are possible, on condition that the special materials can be acquired. Therefore, a power point was installed in each classroom to power the equipment.
- Installation of "mini-centrals": Some types of charge regulator allow the branching of up to four solar panels of 50 Wp each. In the case of a director's house that was situated close to the classrooms, the panels of his house and of the classrooms could be branched to only one charge regulator. This allows the director to consume more energy for himself in times of low energy demand. In the subsequent programme carried out in El Kef (33 schools), it was found that this solution could be applied in only a small proportion of cases (10%).

Although the systems generally work well, a regional repair service is needed. For the first pilot phase (seven schools in the El Kef region) the Tunisian National Energy Agency assumed within its "Special Energy Programme" all the maintenance and service works by a trained crew of technicians. Phase two (equipping 33 isolated schools in the region) was combined with training programmes for private electricians, and teachers who had not had a technical education. The regional authorities have decided to organise a repair and maintenance team themselves.

The school programme in the El Kef region constitutes only part of a bigger programme, in which 110 solar home systems have been installed since June 1989. Since then, intervention of the repair team has been necessary in 40% of the cases, owing to failure of the system components. The reasons were most often the following:

- Failure of the ballast's electronics owing to humidity infiltration, dust or insects.
- The electronics of some types of ballast had been destroyed by the lamp not being switched off immediately after failure, or before removal of the neon tube.
- Heating-up of some charge regulators at times when the battery was completely charged was noticed. This effect even damaged the electronic components in some types of regulator.
- Manipulation by some users (e.g. trying to bypass the charge regulator to "repair" it in the event of failure, or to use the system as a charger for another battery).

4.4.2 South African Experience

The South African economy is highly energy intensive, but because of primary mineral extraction, large coal resources, a synthetic liquid fuel industry based on coal and natural gas, energy prices are among the lowest in the world, and a low level of efficiency is experienced in the use of energy. Energy consumption has grown rapidly over the past 40 years. The demand for energy has risen in line with the GDP, but at a lower rate, which is characteristic of developing countries. After the democratic elections, the South African Government intended the South African economy to become less energy intensive and to move towards downstream industries with higher employment and value-added components[58].

Industry is by far the largest energy consumer[58] (44%), followed by transport and households (21% each). The commercial and agricultural sections are relatively small. Direct use of coal and liquid fuels provide roughly equal proportions of final energy use, followed by electricity (22%), although the use of biomass (19%) - mainly in the form of firewood - is extremely important to a large section of the population[58]. If this could be expressed in terms of cost, quite different results would be obtained, mainly because of different energy tax and levy regimes.

South Africa's energy sector is characterised by the following:

- The country has a relatively high-energy intensity, partly because of the structure of the economy and partly because of the inefficient use of energy.
- Provision of energy at low cost has been a policy focus for a long time, and has led to the creation of energy intensive export industries.
- The energy sector is mainly coal-based, as about 75% of primary energy is obtained from large indigenous and relatively low cost coal resources.
- Crude-oil imports account for only 11% of primary energy demand.
- The electricity system is integrated at national level and has a capacity of about 40000MW. About 8 000 MW of this capacity consists of older and mothballed power stations, which are surplus to present requirements. No new capacity is expected to be required before 2005.

South Africa produced 171 297 GWh[38] of electrical energy in 1995. Eskom generates 96% of this and transports it over the national transmission network to distributors country wide. More than 400 distributors, mainly municipal electricity departments, supply electricity to end customers. Eskom is also the largest single distributor in the country in terms of energy sales for final consumption. All electricity utilities are subject to regulation by the National Electricity Regulator.

Eskom generates virtually all the country's electricity (96%), and supplies most of the remaining consumers. The electricity supply industry (ESI) in South Africa is structured in three layers, as shown in Figure 2

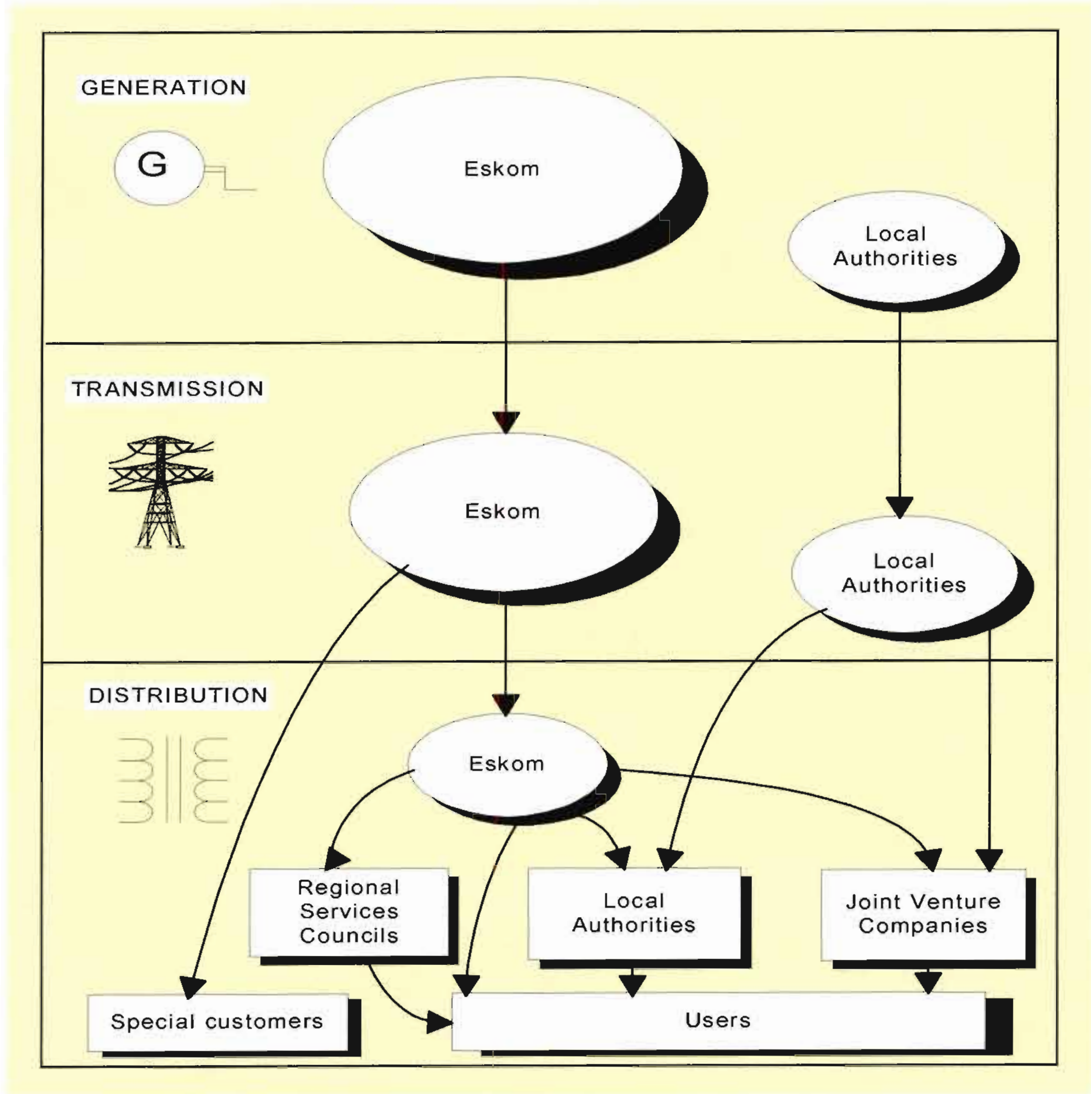

Figure 2 Structure of the Electricity Supply Industry in South Africa(59)

The Draft White Paper[38] indicate that Eskom will be restructured into separate generation and transmission companies initially held by a single holding company. This has become necessary for Eskom as a preparatory step to further changes in the electricity supply industry. The restructuring of Eskom is intended to:

- achieve separation of the transmission group, which operates the national grid, from the distribution and generation groups, to ensure independence of the transmission group in procuring from the lowest-cost generation capacity;
- provide greater transparency of the performance of the various Eskom groups and of the economic flow between them;
- enable Eskom's distribution interest to be incorporated into a restructured distribution sector;
- enable the possible future separation of power stations into a number of companies to facilitate competition; and

- formalise the government's role as owner, and enable the payment of dividends and company tax.

Eskom[60] has an annual business plan, and uses this to formulate a high-level 5-year electrification business plan. The first stage entails drawing up a least-cost network expansion plan to meet the national residential targets over time. The plan is then adjusted according to the available resources, external influences and cost reduction targets.

Eskom's electrification programme[60] is moving into the rural areas that are remote from the electricity grid. A substantial portion of Eskom's plans is for the former self-governing and independent states where, in many areas, there is no electrical infrastructure. Costly bulk infrastructures in the form of high-voltage lines and substations are needed to bring the electricity grid to the communities in these areas. The housing densities are lower than those in urban areas, and therefore a more extensive network is required, which makes electricity supply more expensive in rural areas.

Eskom initiated the national electrification programme in the early 1990's, raised expectations for grid electrification, and as a result reduced the demand for non-grid electrification technologies.

In 1995 Eskom established a new department, Non-Grid Electrification, which electrified 1 200 schools with photovoltaic systems during 1995 and 1996 in various provinces. This initiative paved the way for renewable options in South Africa.

4.4.3 Rural Development

Multiple fuel use is a widespread occurrence in low-income households in South Africa. The types and combinations of fuels usually vary greatly between and within areas. These variations are influenced by a number of factors, including levels of household income, the availability and cost of fuels, access to electricity and the length of time in residence.

The rural population in South Africa consists of commercial farmers on 60 000 farms, the workers on the farms and their families, and the inhabitants of the former homelands (2.3 million households)[61].

Rural communities make use of wood for cooking and heating. Paraffin is the second choice for cooking. Once they have money, they will consider electricity, energy and gas. Many rural people are poor, and because there are limited economic activities going on, money is not readily available. The move away from wood depends on access to wood resources; the cost of paraffin, coal and gas appliances; disposable income; attitudes and preferences.

Rural development should be seen as long-term, nationally integrated processes (education, health services, regular income) to redress imbalances in income-earning opportunities, and to rebuild the quality of life in rural areas. Therefore, the supply of basic services (water, sanitation, electricity and other forms of energy) and protection of the resource base is central issues.

Electrification has a positive impact on the quality of people's lives and can stimulate development. However, electricity cannot be seen in isolation and must be linked to integrated development strategies. To implement a rural electrification programme successfully, basic economic, education and other preconditions should be present. The shift from lower- to higher-grade fuels is part of the broader social process, which involves development, and the modernisation process.

Communication with rural communities needs rapid change. Instead of dictating the way information is to be conveyed from the top down, professionals are learning to listen to the needs and desires of the target audience themselves, and building the programme from there. This focus on the "customer" involves thorough research and constant re-evaluation of rural electrification involving every aspect of the programme. Research and evaluation together form the very cornerstone of the social marketing process[62], and part of the marketing strategy should be a partnership with the community. Policy change is necessary and the politics need to be supported by community organisations in order to gain access to the target market.

4.5 CONCLUSIONS

Rural electrification has been promoted since 1950 as a major force for the development of rural areas in the Third World. The expectations, particularly in the 1960's and 1970's, included rapid economic growth and improvement in the quality of rural life, increasing use of electricity for productive activities, modernisation, and other social changes. Such hopes were not surprising, given that rural electrification has played a significant part in the developed nations. Rural electrification is seen as a key to development, and planning for such a programme must consider all the available options, including new and renewable technologies. Some energy policies include matters such as rural productivity, decentralised generation of electricity, and postponement of rural electrification programmes in countries with extremely low levels of Gross National Product[63,27]

Rural electrification is generally thought of as grid electrification, and this is indeed the most common and most sought after means of supply. However where load densities are low, diesel generators, renewable energy (solar photovoltaic, micro-hydro, wind, biomass-fired generators) and hybrid systems are often more cost effective.

In Europe, many national and European Union photovoltaic programmes are demonstrating the feasibility of photovoltaic electrification. An electrification programme for scattered communities in rural areas of the world could be the means of bringing about social, educational, economic and ecological revitalisation of the community. The objective should be to provide electrification that is adequate to their needs in the same degree as they would receive if they migrated to the cities. Providing a reliable source of electrification for communities without electricity connects them with the rest of the world through radio, television and telecommunication; offers water pumping, lighting, studies at night, etc.

Appropriate research into and development of renewable energy technologies in developing countries is important for building capacity to absorb renewable technologies. This research and development should:

- promote goal-orientated research and development work, with the emphasis on technologies that hold promise of greater commercialisation;
- emphasise product/process technology development that leads to commercialisation; and
- be in partnership with industry, both domestic and foreign.

New organisational methods have to be developed and tested to avoid mistakes or shortcomings that have caused the failure of some projects. Community involvement is of paramount importance to the success of stand-alone photovoltaic programmes. Involvement of users in the organisational structures encourages the drive behind the project, the introduction of a sense of ownership, and involvement in maintenance

With apartheid overthrown, South Africa experienced fundamental shifts resulting in significant changes in the energy policy. This may be seen in the Draft White Paper discussed in this chapter. The election of a new government necessitated a review of the existing policy.

The energy sector is an integral part of the whole economy, and energy planning requires analysis of the links between the energy sector and the national economy. Local economy can be developed, if energy provision and supporting services are made available to rural areas. South Africa has, so far, developed and implemented energy activities without a solid base in energy policy and macro-economic planning. This has resulted in the situation where energy planning has taken place on a sectoral basis without much regard for socio-economic development objectives or inter-energy considerations.

South Africa is in need of an integrated energy policy framework, based on new social and economic imperatives relating to reconstruction and development in South Africa.

There appears to be no single or simple answer to the energy dilemma of developing countries; it is likely that a mixture of mutually supporting technical, institutional and developmental approaches will be needed. From a technical point of view, energy experts regard photovoltaic technology as being the most promising renewable energy technology for applications in the rural areas of developing countries. Photovoltaic conversion can be achieved by simple devices that involve no moving parts, no additional sources of energy, and little maintenance.

There is a need to investigate renewable technologies for medium scale rural installations in South Africa, with reference to the international experience. The question of life cycle cost analysis is to be addressed in terms of medium-scale rural installations. The complexity of the South African situation is to be considered i.e. distances from grid, vast areas, density of communities, etc.

5 APPROPRIATE RENEWABLE ENERGY OPTIONS FOR MEDIUM-SCALE RURAL INSTALLATIONS IN SOUTH AFRICA

5.1 INTRODUCTION

When the economics of renewable electricity supply options are evaluated, there is often an implicit assumption that they have to compete with the cost of grid-supplied electricity in urban areas, namely about 21c/kWh (1997) in South Africa. The actual cost of grid-connected electricity escalates sharply for remote, small energy users. If rational, economically sound decisions are to be taken, available information on renewable supply options such as photovoltaic and diesel generators must be compared with the actual cost of extending the grid to remote users[64].

Renewable energy has four common characteristics, which may have both positive and negative attributes. Firstly, most renewable energy technologies are modular, so their minimum cost-effective size is relatively small. Secondly, renewable generation facilities are expensive to build, though not to operate. Thirdly, some renewable projects produce power intermittently - only when the sun shines, the rainfalls, or the wind blows. And, fourthly, renewable power projects must be sited where good-quality resources are found.

To realise the economic advantages of switching to modular capacity, utilities and regulators must develop the analytical capability needed to estimate the effects of dispersed generation projects on the cost of transmission and distribution systems and reliability, and online losses. In calculations of avoided cost, for example, potential savings from remote non-grid renewable applications must be compared with the cost of line extensions and service drop-off. All utilities should be required to compare the cost of new connections that require grid extensions with that of independent renewables. Eskom has concentrated on grid electricity (core business).

However, adding renewable energy sources to a mix of power-generation sources dominated by coal or oil could smooth out utility cash flow. In contrast to those associated with oil and gas, the operating expenses associated with renewables are relatively fixed.

5.2 SUITABLE TECHNOLOGIES FOR MEDIUM-SCALE RURAL INSTALLATIONS

5.2.1 Grid Electricity

Grid electricity needs to be taken into account, although it is not a renewable option. Renewable options should be compared with the cost of grid extension supply, since grid electricity has several advantages over other energy-supplied systems. Lower cost grid extension technologies have become available to Southern African users, significantly reducing the cost of remote connections. These lower costs may be applied only in specific conditions, typically within certain distances and demand-related limits, but are often suitable for many smaller applications, such as rural households, schools and clinics[65].

5.2.2 Petrol and Diesel Gensets

There are currently about 10 000 non-electrified farms[66] in South Africa. Many use 3–5 kVA 220/230V AC single-phase gensets that supply domestic appliances, excluding stoves and hot water geysers.

In all there may be about 10 000 diesel gensets in use in South Africa[67]

Typical diesel system configurations include the following:

- A single stand-alone set as the sole supply of electricity to the load(s)
- Two sets: one running and the other as stand-by in case of breakdown
- Twin duty/standby sets supplying the load(s) alternately over time
- Two or more synchronised sets capable of running together at times of peak load
- Gensets-plus: incorporating battery storage to optimise genset run-times and supplying the load(s) over a longer period
- Genset with mechanical power take-off (PTO): a genset combined with shaft- or belt- driven loads.

Non-grid households have used small petrol gensets increasingly. These 250-5 000 W packaged units are often bought to run television sets and video recorders. These generators have a limited lifespan owing to the high maintenance requirements and extended duty cycles[67].

5.2.3 Photovoltaic

Small photovoltaic systems for basic household electricity are popular. Most of these systems have been sold privately, and although the number of sales remains uncertain, a survey conducted in 1992 estimated that a total of 60 000 home lighting systems had been installed in South Africa.

There is a demand for these small household systems in South Africa, and rapid expansion is forecast, particularly in Zimbabwe and South Africa. In a Southern African Development Community (SADC)[68] report it is estimated that very small photovoltaic lantern systems could be affordable to households with a low-income level of about US$150/month, while multilight photovoltaic household systems could be affordable to households with an income of over US$500/month.

The main community facilities where photovoltaic systems are widely used are rural schools and clinics. More than 300 secondary schools in

Bophuthatswana (previously called Bophuthatswana, now part of South Africa) had been supplied with photovoltaic systems to power educational television sets and video recorders by 1992. In Botswana, 45 schools are reported to have photovoltaic supply and 32 in Zimbabwe. Over 200 rural clinics had been equipped with photovoltaic systems in Southern African Development Community (SADC) countries by 1992, the main requirement being reliable energy for vaccine refrigerators. In South Africa, some 150 clinics have photovoltaic systems for lighting and refrigeration, and by 1998, there were 1 245 schools that had photovoltaic systems for lighting, television, video and overhead projector use.

Photovoltaic water pumping is estimated to account for some 0.5% of water pumps in SADC countries, while in South Africa an unpublished survey has estimated that 2 500 photovoltaic pumps had been installed by 1992[72].

Photovoltaic systems are widely used for remote telecommunication systems. In 1992 approximately 600 installed systems were reported for telecommunications and railways in SADC countries. This sector has come close to saturation, and although it has dominated photovoltaic applications in the past, it is likely that other development applications will take the lead increasingly. Towards the end of 1997, Telkom awarded a R30 million contract for photovoltaic telecommunication in the rural areas of South Africa.

5.2.4 Wind

Wind turbines for generating electricity have limited potential. Wind systems require high windspeeds, but over most inland parts of South Africa the wind resource is insufficient to make wind-electric generation an attractive option. In the coastal regions, where average speeds are considerably higher, wind-chargers are an option.

There has been a mechanical wind pump market since the 19TH century, with local manufacture only since the Second World War. Lately the market is viewed as decreasing, owing to the spread of the electricity grid in rural areas and increasing competition from photovoltaic pumping systems. The estimated sales for 1994 of some 1 200 units are less than 20% of the 1985 figure. Stassen[69] estimated that there were 309 000 installed wind turbines in South Africa, and some 278 000 units still operational.

5.2.5 Hybrid System

Hybrid systems consist of the combination of two or more energy generating technologies to provide an energy service to the end user. Hybrid systems in this study are defined as those that relate to the production of electricity and do not include a mix of electrical combined with thermal or motive power. The most common examples of these hybrids are combinations of diesel generators, photovoltaic systems, or wind turbines. The most common hybrid systems in South Africa are diesel/photovoltaic combinations.

A large number of hybrid systems are in use for domestic or small business energy provision in low-income and rural settlements. These systems include combinations of grid electricity, diesel or petrol generators, and photovoltaic systems. Few of these systems are fitted with control mechanisms, or even operated as hybrid systems.

The market[71] includes thousands of small generators in operation across the country, which could be linked to photovoltaic systems with a controller and battery storage capacity as a retrofit option. The obstacles to market development are:

- lack of technical know-how and skills to design and operate a hybrid system;
- lack of off-the-shelf systems;
- high capital cost of most systems; and
- lack of awareness of the potential offered by hybrid systems.

5.3 LIFE-CYCLE COST ANALYSIS OF APPROPRIATE TECHNOLOGIES FOR MEDIUM-SCALE RURAL ELECTRIFICATION IN SOUTH AFRICA - QUALITATIVE DISCUSSION

5.3.1 Grid Electrification

The cost of Grid extension is R40 000.00 per kilometre[1] The main constraint to supplying grid electricity may be the capacity of the local utility to connect schools, as well as their connection schedule over the next few years. Connection of schools to the grid is clearly preferable where it is available and financially viable, as this energy source can be used for every school energy need.

The cost of grid extension should be treated differently from that of other supply systems. The reason is that the capital cost of an extension line is borne by the local utility (Eskom in South Africa), not the user. The user is required to repay the fixed monthly rate in addition to the usual service (fixed rate) and energy (cents per kWh) charges. Comparable life-cycle costs may be calculated by totalling the current value of monthly payments (extension plus service and energy charges) over the project life. These costs vary depending on the extension distance[65].

5.3.2 Diesel Generators

This is an expensive option for small applications, but for energy consumption over 3 kWh/day the cost of energy from diesel generators becomes competitive with renewable options. The load profile and capacity factor will be major determinants of whether this supply source is more economical than other options. Applications where diesel generators[65] may be cost effective include rural farmsteads, rural communities where generation is centralised, and schools or other community facilities with substantial electricity needs. Without adequate maintenance, however, the cost of energy becomes prohibitive owing to inefficient operation and frequent breakdowns. Fuel transportation and storage costs need to be addressed. Diesel generators offer more flexibility in that they can be run when the electricity is required, and in this respect their use can be tailored to actual energy demand. Disadvantages include operation and maintenance requirements, and surprisingly-high energy costs, at low capacity factors.

5.3.3 Photovoltaic Energy

Photovoltaic electricity is suitable for good quality lighting and can provide power for small demand appliances such as radios, television sets and overhead projectors. Telecommunication could also be supplied. It could offer a very reliable power supply too, and is clearly a suitable option for schools, although it is expensive and not cost-effective for heating loads such as water heating and cooking. This indicates that photovoltaic is a better option for rural schools, since it supplies the limited electrification needed for educational purposes. However, it requires a maintenance infrastructure to be established, and users to be given basic training in correct use of the systems.

There are no strong economies of scale with photovoltaic systems. Most other supply options tend to be too expensive where daily energy demands are small. Photovoltaic systems are therefore able to provide the cheapest power for small, remote applications. This suggests that the main customers are isolated low-income households, small businesses and community facilities. The other major factor that favours photovoltaic applications is a requirement for low-maintenance, extremely reliable non-grid electricity (eg for remote telecommunication repeater stations). Since photovoltaic systems have a relatively fixed energy supply capacity throughout the year (in most Southern African locations), they are unlikely to be cost effective if there are great seasonal variations in load energy demand[66].

5.3.4 Diesel Generator Plus Batteries

Where the load profile results in a poor capacity factor for the stand-alone diesel genset (and therefore high energy cost), the addition of battery storage to the system could bring the cost of energy down by up to 40%. Nevertheless, for small demand applications this configuration is unlikely to be able to provide energy at a reasonable price, as is the case with stand-alone gensets. At 1992 South African prices, costs were typically high for daily demands below about 2 or 3 kWh. For higher demand applications, however, the cost of energy could be very competitive. Typical situations where diesel gensets may be economically feasible are much the same as those for a stand-alone set, but they would have an advantage over stand-alone sets.

The cost of diesel/hybrid generation is not expected to increase by more than 10% before 2010 because the technology is mature[70].

5.3.5 Hybrid

A hybrid system creates the potential to increase efficiency, or provide additional energy services, at minimal increase in expense. Combining a diesel generator and a photovoltaic array, for example, enables the use of applications demonstrating both low and high current, and the service of a highly variable load. Since it is inefficient to run a diesel generator at loads far below its rated capacity, and a photovoltaic system cannot provide the high levels of electrical current required for welding, a combination of the two could serve both purposes at far reduced life-cycle costs. Hybrid systems require a higher level of technical complexity - in terms of system design, operation and maintenance - than non-hybrid systems[71].

5.3.6 Wind

South Africa has the capacity to supply 40% of a wind energy project, from labour and infrastructure to towers and cabling. The only significant imports are the hi-tech turbines and blades[72].

Eskom is embarking on a project called SA Bulk Renewable Energy Generation – Wind (SABRA-GENSET, Wind). This project will establish the groundwork for a large-scale implementation project for wind energy.

The price for a wind turbine installation is R10 000 - R80 000 per kW[72] capacity for 12kW. Wind energy installations are site-specific and need wind speeds in excess of 6m/s[2], before economic viability can be considered as the output of a wind turbine is a function of the cube of the wind speed.

5.4 LIFE-CYCLE COST ANALYSIS OF APPROPRIATE TECHNOLOGIES FOR MEDIUM-SCALE RURAL ELECTRIFICATION IN SOUTH AFRICA - QUANTITIVE ANALYSIS

Economic viability is necessary for any project to be successful. It is important to do a cost analysis to determine the cost of service per day and the level of service provided by grid electrification, diesel generator, photovoltaic energy and wind. Diesel generators are not renewable options, but owing to the possibility of using diesel generators in rural areas, it is included in the cost analysis.

In the RAPS Manual the costing method[66]used enables different systems to be compared on an equal financial basis, and involves the following process:

- User's electricity needs are met – daily load demand and reliability of supply required.
- Period over which the systems are to be costed (project life).

- Establish all costs incurred by the systems over the period. This includes initial costs, operation and maintenance costs, and component or system replacement costs that may arise over the project life. Costs incurred other than the initial cost is converted to equivalent present value using real discount rate. The total current value of all costs for a particular system is called the life-cycle cost.

The cost comparisons used in this study have been normalised to accommodate grid, diesel, photovoltaic, photovoltaic/diesel, hybrid and wind, by calculating the cost of providing three levels of service. Calculations were based on the following:

- A large service (30 kWh/d) consisting of lighting in 10 classrooms and 2 offices for 8 hours/day, television and video for 4 hours/day, overhead projection for 2 hours/day, computer use for 4 hours/day and photocopying for 2 hours/day.
- A medium service (15 kWh/d) consisting of lighting in 10 classrooms and 2 offices for 4 hours/day, television and video for 3 hours/day, computer use for 4 hours/day, photocopying for 1 hour/day and overhead projection for 1 hour/day.
- A small service (3 kWh/d) consisting of lighting in 3 classrooms and 2 offices for 4 hours/day, television and video for 2 hours/day, overhead projection for 1 hour/day.

The levels of service have been calculated in kWh/d in Table 10.

Table 10 Daily Energy Consumption for Large, Medium and Small Service Options

Daily energy consumption for large, medium and small service (kWh/d)						
Service description	**Lighting**	**TV/video**	**OHP**	**Computer**	**Photocopier**	**Total**
Large service efficient equipment	13	0.8	0.7	0.4	0.6	15.5
Large service conventional equipment	26	0.7	0.7	0.4	2	30
Medium service efficient equipment	0.7	0.5	0.3	0.4	0.3	0.8
Medium service conventional equipment	13	0.5	0.3	0.4	1	15
Small service efficient equipment	0.2	0.3	0.3	0	0	0.3

The cost comparison has been done in this way because it is difficult to compare renewable energies with grid supply. Grid electricity can give more service than some of the renewable energies. The other reason for taking three levels of service is because it compares levels of service provided, not kilowatt-hours supplied.

Parameters used in costing calculations:
- Discount rate = 6% P.A.
- Transmission line cost = R 40 000/km
- Electricity energy cost = R 0.29/kWh
- Diesel Genset cost = R 2 000/kW
- Genset room & fuel tanks = R 3 500
- Diesel fuel = R 2.50/L
- Fuel consumption = R 0.8L/kWh
- Wind turbines cost on particular sized units
- PV system cost on array size
- Storage battery replacement every four years

Life cycle costing period:
- Grid – 20 years
- Diesel Genset – 15 years
- Wind turbine – 15 years
- PV system – 20 years

Service interval:
- Grid – NA
- Diesel Genset – 500 hours
- Wind turbine – 1 year
- PV system – 1 year

Service cost (Maintenance):
- Grid – nil
- Diesel Genset – R 1 200
- Wind turbine – R 600 to R 1 916 (based on specific unit)
- PV system – R 500

There is no internationally accepted way to compare the costs of providing an electrical service to a customer, which provides a fair evaluation of the full range of technologies being considered. Most utility calculations simply use cost per kWh as a basis of comparison. This is a very biased factor, as it tends to favour the maximisation of consumption by the customer, as the infrastructure cost is divided by a larger denomination (kWh) thus yielding a lower cost per kWh figure. An attempt is made in this study to give the various technologies an unbiased evaluation by looking at the life-cycle costs of providing a given level of service, and then reducing this life-cycle cost to a daily "service provision cost".

The exact levels of service provision were a best estimate open to debate. However systems were costed to provide:
- All the educational electricity requirements for an average sized school (10 classrooms)

- A reduced electricity supply for the same sized school (less operating hours per day)
- A limited electrification of only three classrooms and catering for lighting, TV and video only.

This best supply was arrived at in consultation with the Department of Education and the Department of Minerals and Energy who believed that this was the most important items of supply required and that this was the correct level to be provided.

The cost comparisons[73] used in this study have been normalised by calculating the cost of providing three levels of service for:

- grid supply efficient equipment
- grid supply conventional equipment
- diesel supply efficient equipment
- diesel supply conventional equipment
- photovoltaic system efficient equipment
- photovoltaic diesel hybrid efficient equipment
- photovoltaic diesel hybrid conventional equipment
- wind efficient equipment
- wind conventional equipment.

The items where the efficiency is very important are lighting and the photocopier. The lighting used in the efficient equipment installation are 20-watt fluorescent lamps, which can be distributed to provide adequate lighting using eight lights per classroom. Light-fittings (40 watts) for conventional equipment installations are used, which in normal practice provide a level of lighting in excess of the minimum level required. Since the two fittings take different sized tubes, there is no possibility of using the wrong lamps without actually replacing the light-fittings in question.

The photocopier (300 W) is used in the efficient equipment installations, whereas a 1 kW unit is used in the conventional installations. Since these types of units can easily be interchanged, it would be advisable to hard-wire the photocopier into the efficient system. Then too, it is important that no additional high-consumption devices, such as heaters and kettles, be used in the low-energy systems. This can best be ensured by training and educating all the people who will be responsible for operation of the system, and by posting clear notices at all socket outlets.

The cost calculation method proposed in the RAPS Manual[66] was used (data was updated to current R-values and minor manipulation was done to accommodate levels of cost comparison).

In this study the different options were compared according to level of service provided and the cost of service per day. Table 11 illustrates the cost comparison of different options per day for the service provided. The cost of grid supplied electricity is included for purposes of comparison.

By making a comparison on cost for service[3] provided (rand/day), rather than cost per kWh, the bias against renewable energy conservation technologies is removed.

Supply levels for large school service (Figure 3) and medium school service (Figure 4) were calculated for both conventional and efficient equipment. The difference was that the conventional systems used normal fluorescent lighting and a “cheap”1kWh photocopier while the efficient systems used high efficiency fluorescent lights and a low power yet expensive 300W photocopier. The capital and maintenance costs of all installed equipment were built into the life-cycle costs of each of the systems. However the costs for the user equipment were not included in the calculations for cost of service supply.

School service supply level, small (Figure 5) was only calculated using efficient equipment as it was felt that to provide a limited service of essential equipment only and then to use inefficient equipment did not make sense. On the systems implemented, all replacement equipment was locally available to the Department of Education.

The following assumptions have been used in the calculations of the cost of supply:

- Grid and photovoltaic taken over a 20-year lifespan
- Diesel and photovoltaic/diesel hybrids taken over a 15-year lifespan
- Efficient equipment includes efficient fluorescent lamps and a low-power photocopier, where applicable
- The wind turbine power output is very site-specific

Comments
Grid is more dependent on distance than on the size of the system installed.
Photovoltaic systems are very size dependent.

Table 11 Cost Comparison of Different Options

Level of Service Provided	Large (30/16 kWh/day)					Medium (15/8 kWh/day)					Small (3 kWh/day)				
Distance from Supply Point	1km	5km	10km	15km	20km	1km	5km	10km	15km	20km	1km	5km	10km	15km	20km
Cost of Service per Day (R)															
Grid supply, efficient equipment	R40	R109	R196	R284	R371	R38	R107	R195	R282	R369	R29	R99	R186	R273	R360
Grid supply, conventional equipment	R42	R111	R196	R281	R366	R39	R109	R196	R283	R371					
Diesel supply, efficient equipment	R67	R68	R70	R71	R73	R54	R54	R55	R56	R57	R36	R36	R37	R37	R37
Diesel supply, conventional equipment	R92	R94	R97	R100	R103	R65	R67	R68	R69	R71					
PV, efficient equipment	R94	R94	R94	R94	R94	R52	R52	R52	R52	R52	R23	R23	R23	R23	R23
PV/Diesel, conventional equipment	R132	R134	R136	R138	R140	R81	R81	R82	R83	R84					
Wind, efficient equipment	R98	R98	R98	R98	R98	R76	R76	R76	R76	R76	R40	R40	R40	R40	R40
Wind, conventional equipment	R180	R180	R180	R180	R180	R93	R93	R93	R93	R93					
PV/Diesel, efficient equipment											R28	R28	R28	R28	R28

It is clear from Table 11 that the grid supply costs are virtually independent of the size of the service provided, but are almost entirely dependent on distance to point of connection. On the other hand, the wind turbine and photovoltaic costs are independent of distance to point of supply, but very dependent on size of service. The diesel and photovoltaic/diesel systems are slightly dependent on distance to point of supply and dependent on the size of service. Since there is a need to travel to provide a supply of diesel fuel, or to have the diesel delivered, the distance involved affects the cost.

In, Figure 3, Figure 4 and Figure 5 the options are illustrated, as per level of service, to show which options are the best according to the distance from the grid. From Figure 3 it may be seen that grid supply is the lowest cost service up to a distance of 3km, after which diesel supply proves to be the lowest cost option.

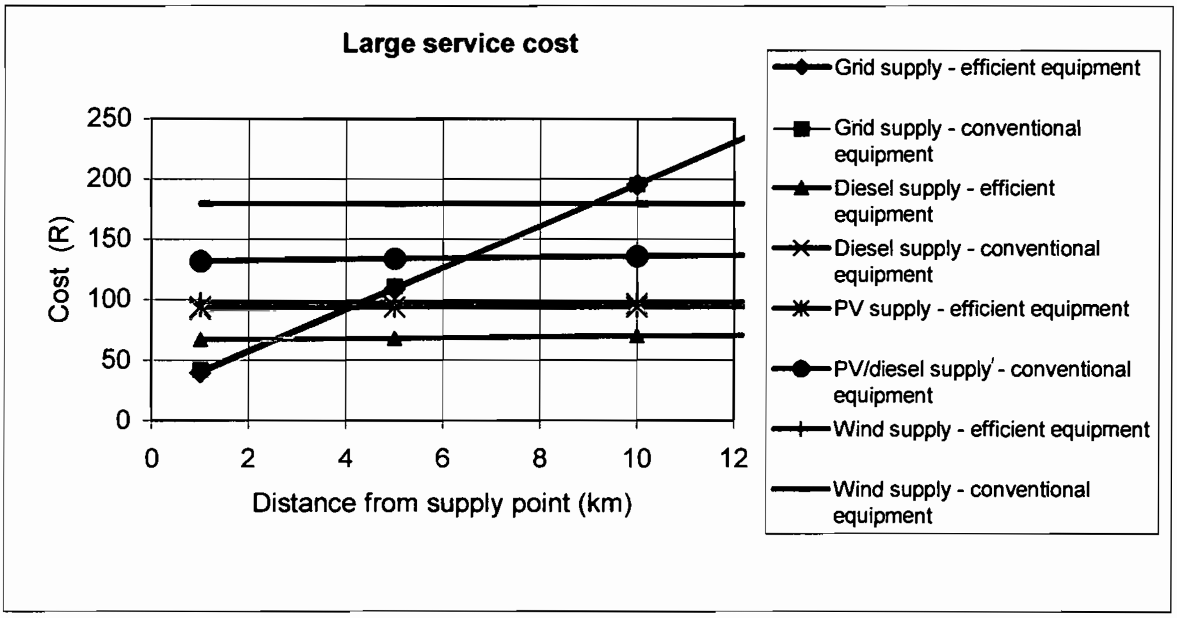

Figure 3 Large School Service

In Figure 4 a medium service grid supply is the lowest cost service up to a distance of 2km, after which diesel and photovoltaic options are close competitors, with diesel showing a slightly lower cost for the calculation parameters used here. Diesel as an option would be determined by the availability of funds to purchase the diesel fuel to run the system.

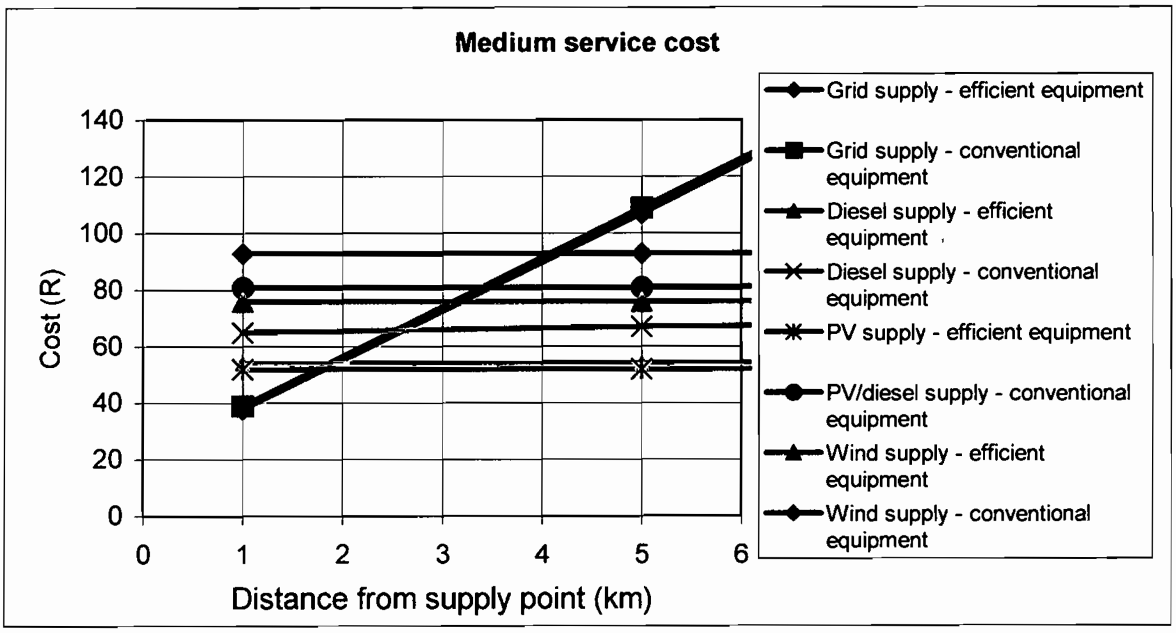

Figure 4 Medium School Service

For a small service, it may be seen in Figure 5 that photovoltaic is the lowest cost option for any distance greater than one kilometre. From the figures used in the calculation spreadsheets, the next best option is seen as photovoltaic/diesel hybrid.

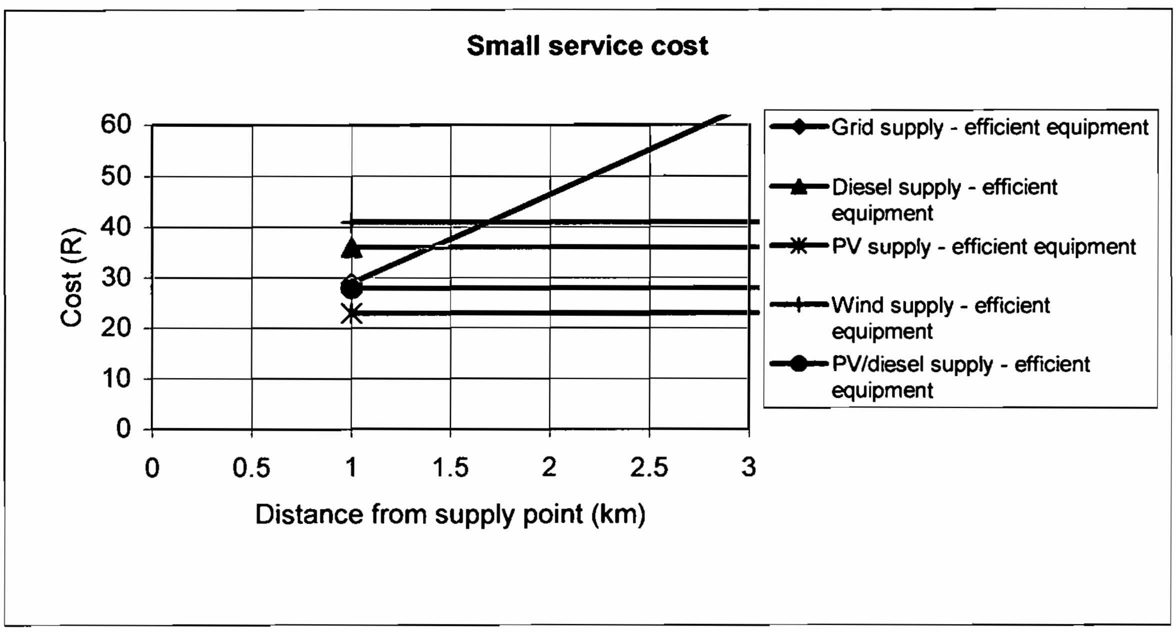

Figure 5 Small School Service

The project evaluated was a donor driven project with specific educational benefits expected. While the schools are not all utilising the systems' full capacity, the need is to increase this usage through education and training rather than to reduce the system size. If the systems that are provided do not have the potential to achieve the desired educational benefits then no donor would be prepared to become part of such a programme.

Diesel engines are extremely commonly used in South Africa for providing electricity in areas where grid supply is not available. The major usage's are by the agricultural sector and for water supply.

While the programme did not allow for a field evaluation of different technological options, the Department of Education due to poor experience specifically excluded diesel engines because of:

- unavailability of a regular fuel supply
- theft of fuel when available
- relatively high maintenance requirement.

5.5 CONCLUSIONS

The quantitative analysis in this chapter indicates that grid electricity is the best option for electrification of a school with a large service, 1km from the grid. Moving 5km or more from the grid, the best option would be diesel, followed by photovoltaics, and lastly wind.

Grid electricity would also be the best option for supplying a medium service 1km from the grid. For such a service 5km or more from the grid, photovoltaic is the best option, then diesel. For a small service, photovoltaic is the best at any distance, but diesel could be an option at 1km from the grid.

From the analysis in this chapter it is shown that photovoltaic is the recommended energy supply option for low levels of service. Medium-scale rural installations in South Africa, using low levels of service, could therefore be electrified cost effectively using photovoltaic systems.

Photovoltaic systems are currently a mature and available technology to meet the demand for rural electrification. The significant benefits in terms of staff satisfaction and school operational effectiveness are among the main reasons for this choice, and these benefits are considered to outweigh clearly the extra initial cost when compared with diesel.

Chapter 6 presents phase 1, which deals with the pre-electrification stage.

6 PHASE 1 - PRE-ELECTRIFICATION PROCESS

6.1 OBJECTIVES – PHASE 1

This research phase involved the compilation and review of relevant background data on the design, structuring and implementation of the non-grid schools electrification programme, as well as mobilisation of the communities to be an integral part of the decision-making process. The background determined the basis of phase 2 – assessment of the utilisation and impact of school systems, and teaching staff perspectives.

6.2 METHODOLOGY - PHASE 1

The focus of this phase was on the non-grid electrification of 890 schools in the Eastern Cape Province, South Africa, installed by Eskom Non-Grid Electrification in the period 1995/6.

Background data gathering was done and detailed discussions were held, with:

- Department of Minerals and Energy
- Eskom Grid Electrification
- Eskom Non-Grid Electrification
- Energy Development and Research Centre (EDRC)
- Energy and Development Group (E&DG)
- Department of Education, Eastern Cape
- Photovoltaic suppliers

Interviews[74] were conducted with key stakeholders to solicit views on the non-grid electrification of schools in rural areas with particular reference to the following:

- Rationale and history of the programme
- Processes of identification and selection of schools
- Institutional role-players
- Principles of programme ownership and community involvement
- Co-ordination mechanisms among the various stakeholders, especially service providers and implementation agents
- Financial and technical support
- Quality and capacity of facilities and services

6.3 RESULTS – SUMMARY OF PHASE 1

The findings of this phase of the study were generated through background data gathering and review, as well as detailed discussions with key stakeholders to solicit their views on the non-grid electrification of schools in remote areas in South Africa in general and with particular reference to:

- rationale and history of the programme;
- processes of identification and selection of schools;
- institutional role-players;
- principles of programme ownership and community involvement;
- co-ordination mechanisms among the various stakeholders, especially service providers and implementation agents;
- financial and technical support; and
- quality and capacity of facilities and services.

Eskom's Non-Grid Electrification Programme was conceptualised to satisfy all the requirements stipulated by the RDP White Paper[75]. The programme relied solely on the use of photovoltaic systems. A limited number of school classrooms were electrified in remote rural areas, based on the original decisions. This decision is supported by the cost analysis shown in Table 11. Where a small service cost was applicable, as was the case with the schools programme, the photovoltaic option was the most cost-effective as pointed out in Figure 5

The programme gave, in principle, full attention to community and especially end-user (school) involvement in the planning and implementation processes.

The Department of Minerals and Energy had, within its budgetary constraints provided NGE with the necessary financial resources to finance all the project components - photovoltaic systems and spare parts, installation and maintenance services.

The Department of Education had accepted the programme and taken full responsibility for creating support systems and facilities to enhance the utilisation and maintenance of the systems in all the schools.

All the stakeholders supported the programme, but saw a need to co-ordinate various activities in order to foster the advantages of synergy.

In chapter 7 the assessment of the utilisation and impact of school systems, and teaching staff perspectives, are described.

7 PHASE 2 – ASSESSMENT OF THE UTILISATION AND IMPACT OF SCHOOL SYSTEMS, AND TEACHING STAFF PERSPECTIVES

7.1 OBJECTIVES – PHASE 2

This phase involved an assessment of the status of the already-installed school systems and the teaching staff's perspectives on the systems. Community involvement is vital to the non-grid electrification of schools, and this phase was aimed at determining the effectiveness of Eskom's communication with communities. Does the community understand the technology; do they take ownership of the project?

7.2 METHODOLOGY – PHASE 2

The focus of this phase was on a representative sample of 48 schools out of a total of 890 schools. The list of schools, showing their location in the Eastern Cape, was provided by Eskom[76] and confirmed by the regional Department of Education in Bisho. The selection of schools to be surveyed was done in close collaboration with Eskom and the Permanent Secretariat of the Department of Education.

The Department of Education classifies schools according to regional circuits:
Butterworth with installations only in Ngqamakwe
Umtata with installations only in Engcobo
Queenstown East with installations in Cala, Cofimvaba, Ezibeleni and Lady Frere
Kokstad with installations at Bizana, Lusikisiki, Matatiele, Mount Fletcher, Mount Frere and Tabankulu

7.2.1 *Sample Stratification*

In order to generate the relevant statistical data required, the following sample stratification principles were chosen to guarantee representation of the sample population and, by the same token, to ensure validation of the study findings and reliable conclusions:

- Categorisation of all the schools under: junior primary, senior primary, junior secondary and senior secondary.
- The Department of Education clustered the schools according to regions - namely Butterworth, Queenstown, Umtata and Kokstad - and the sampling of the 48 schools was to reflect the regional classification.
- It was also noted that the distribution of schools with NGE installations showed great disparities in terms of numbers, geographical location and distance into the hinterland. The sample stratification took these characteristics into account.

Two workshops to familiarise the communities were organised, one in Queenstown and the other in Umtata. The plan was to organise only one workshop, ideally in Umtata, which is located centrally to the schools sampled for the survey. However, this original plan was changed as a result of observed concerns during the planning phase. Two workshops were therefore held to accommodate the articulated concerns and needs of the communities.

The workshop participants were educational officers, principals/headmasters, leaders of civic organisations and other stakeholders from the communities. The purpose of the workshops was to explain further the Eskom Non-Grid Schools Electrification Programme and the objectives of the planned survey. The ultimate goal was to win local support for the interviewers who were sent to different areas to administer the questionnaires.

7.2.2 Design of Survey Instrument

Against the background of the information and insights obtained from the interviews with key stakeholders, a well-structured survey instrument was developed. Eskom's views and comments were incorporated to finalise the survey instrument to be used with the principles, teachers, pupils, and village residents.

Two *questionnaires* (Appendix B and C) were developed:

The *first questionnaire* (APPENDIX B) focuses on the school background – school principal/teacher. In this section the researcher sought to determine the insight of the principal and teachers. It is important to know how many classrooms, teachers and students there are. This was to determine how many students would benefit from electrification of the school. Community involvement is vital and can be determined by the replies from teachers to questions such as: Is the system still working? How many times do you use the system per day? Does the community use the system and for what? Testing the teachers' knowledge of the system also determines whether the teachers understand the technology.

Student's view's were determined by asking whether the electrification helped with their studies and in what way, and asking them to comment on other areas in which electrification could help.

The *second questionnaire* (APPENDIX C) focused on the teacher's and staff perspectives as well as community members. This was to determine the awareness and ownership of the systems, usage, operation and maintenance, impact and comparison with grid.

The following *sample stratification* principles were chosen to guarantee representation of the sample population and, by the same token, to ensure validation of the study findings and reliable conclusions:

- Categorisation of all the schools under: junior primary, senior primary, junior secondary and senior secondary.
- The Department of Education clustered the schools according to regions - namely Butterworth, Queenstown, Umtata and Kokstad - and the sampling of the 48 schools was to reflect the regional classification.
- It was also noted that the distribution of schools with NGE installations showed great disparities in terms of numbers, geographical location and distance into the hinterland. The sample stratification took these characteristics into account.

7.2.3 Recruitment and Training of Interviewers

Given the distances travelled during the field survey, owing to the widely dispersed locations of the sampled schools, interviewers were recruited not only from the four defined regional localities but also, more importantly, from among those who know the areas well for purposes of logistics. Another crucial consideration in the recruitment and selection process was to have people with a basic understanding of interviewing techniques. All these considerations were to enhance timely and efficient administration and completion of the questionnaires.

Four interviewers were selected and trained, and they were allocated as follows:

- Two interviewers to cover the Kokstad region, which extends over the widespread, remote areas of Lusikisiki, Bizana, Mount Fletcher and Matatiele
- Two interviewers to cover schools in the Butterworth, Umtata and Queenstown regions, which extend over remote areas of Nqgamakwe and Engcobo.

The training of interviewers covered the following:

- Interview protocol
- Interview techniques and procedures
- Content and objectives of the survey instrument
- Logistics

7.3 RESULTS – PHASE 2

Determining the effectiveness of the Eskom process led to Phase 3, which was an in-depth study analysis of the impact of school electrification.

7.3.1 Profile of Surveyed Schools

To assess the profile of a typical school the average numbers of students, classrooms and teachers were determined as illustrated in Table 12

Basic data have been generated relating to the number of students, teachers and classrooms of each school. The average school has 11 classrooms, 445 students per school, 40 students per classroom, 14 teachers per school and 31 students per teacher per school as illustrated in Table 12.

Table 12 Profile of Surveyed Schools

	Average
Classrooms/school	11
Students/school	445
Students/classrooms	40
Teachers/school	14
Students/teacher	31

The profile of the schools shows that approximately 7 298 000 students will have the benefit of electrification in the 16 400 schools, extrapolating the data to the other provinces of South Africa. The average student-teacher ratio is 31:1. The number of teachers that will benefit from electrification is 229 600 in 16 400 schools.

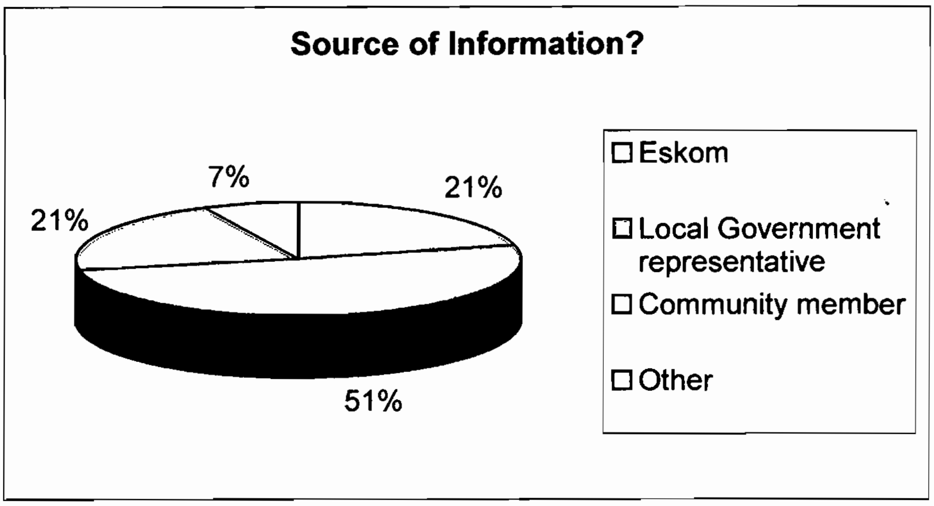

Figure 6 Source of Information

The study demonstrated that almost all the schools were 16 km or more from the grid, and 53% of the schools were 30km and more from the grid (Figure 19). This emphasises the remoteness of the schools.

7.3.2 Communication, Identification and Selection Criteria.

In order to determine the communication efficiency of Eskom during the project it was necessary to determine the level of understanding from a community perspective. The information was needed to establish the possible effect of pre-knowledge of solar energy on the actual application by schools since the inception of the schools programme. Figure 6, Figure 7, Figure 8,

Figure 9, Figure 10, Figure 11, gives an indication of the communication, identification and selection criteria for the schools electrification programme.

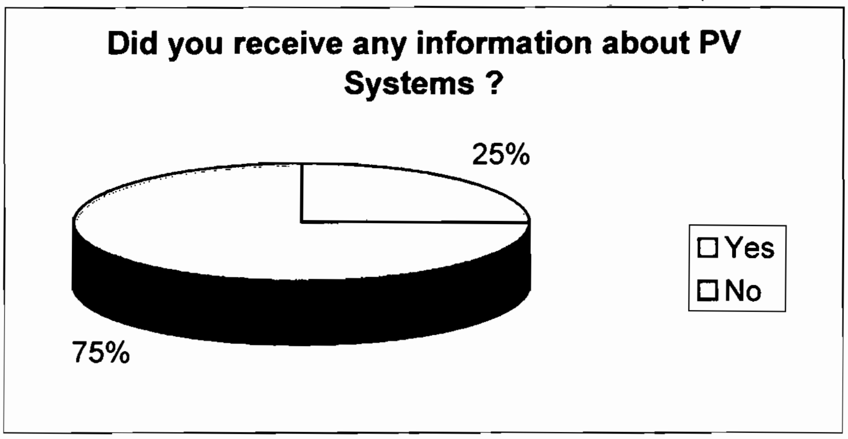

Figure 7 Information Received about PV

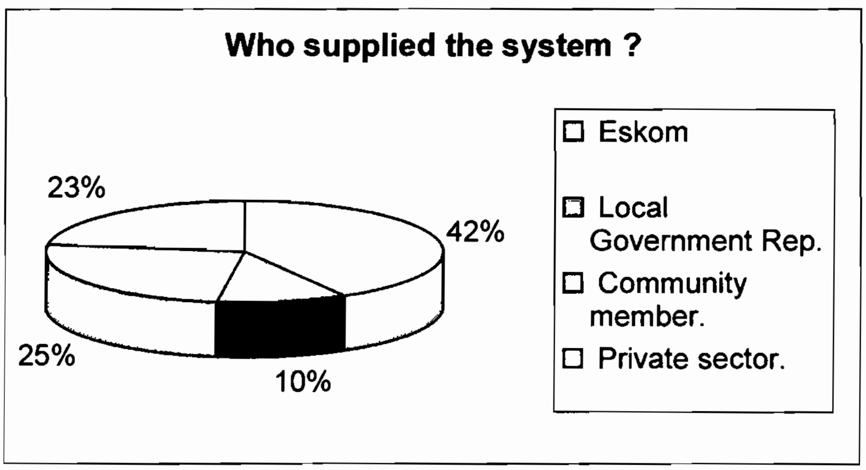

Figure 8 System Supplier

It was necessary to determine the source of information as in Figure 8.

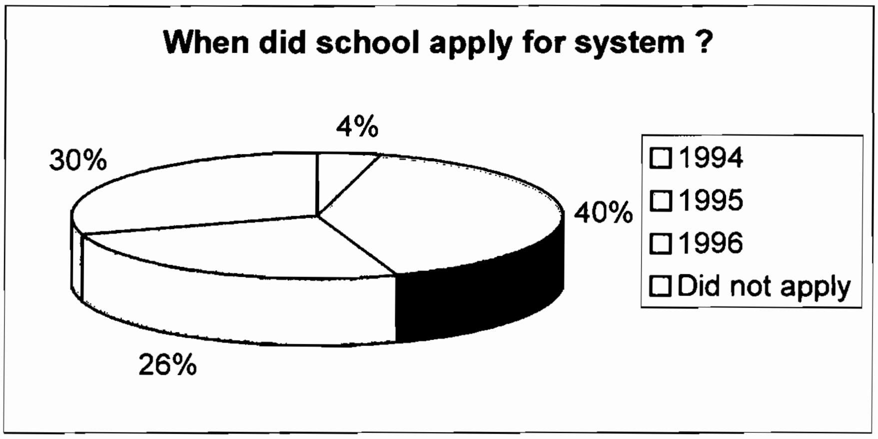

Figure 9 Application Date

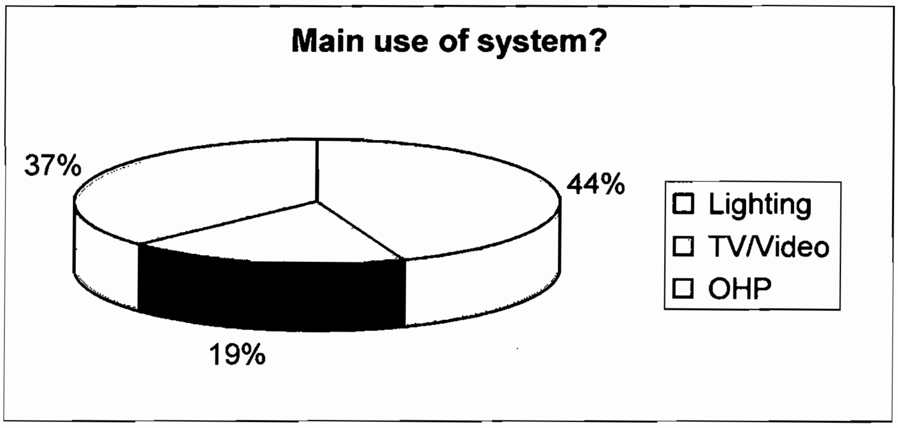

Figure 10 System Usage

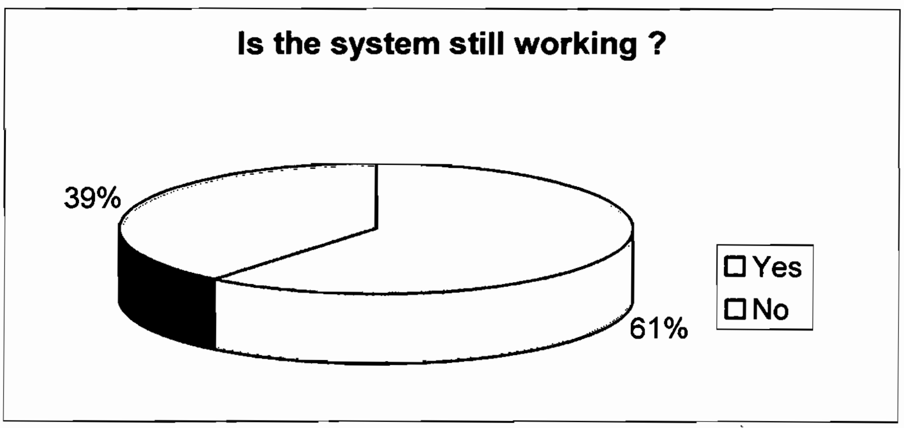

Figure 11 Operational Condition of the System

The communication process was not effective. In Figure 7 it is illustrated that 75% of the respondents did not receive any information about PV systems. Yet in Figure 6 the source of information is given as 51% from different sources. The indications are that this question was not properly understood.

In Figure 9 there is a 30% indication that the schools did not apply for the system. This is contradictory to the application process. Every application form had to be signed by the principal or the chairman of the Parent Teacher Association before any installation would be considered. This is an indication that the wrong people were approached to sign the application forms, or the decision-makers felt they had not been recognised in the process. This indicates a lack of understanding of community structures by Eskom. There is coherence between the application dates and installation dates; the School Electrification Programme started in 1995.

When asked who supplied the systems (Figure 8), the respondents referred to Eskom (42%). This indicates a communication problem in that the programme is funded by the RDP, and the RDP is therefore not acknowledged in the programme. When marketing the schools electrification programme it was expected that the school should know the installed cost of the system, but 96% of the respondents did not know what the system cost (Figure 20).

The operational condition of the systems indicated that 61% of the installations are still working.

The satisfaction index for the systems is 38% (Figure 22). The suggested improvements are found in Figure 24 and listed in order of priority:

- Provide system with higher power 40%
- Provide more lights 19%
- Ensure regular maintenance 19%
- Improve system capacity to allow ironing 12%
- Ensure stability of system 8%

Respondents are aware that the system is for lighting, television, video and overhead projector usage (Figure 10), for a specified period of the day. The respondent opinion in Figure 21 is that the system could be used for cooking (31%), water pumping (23%) and heaters (43%). This indicates a communication problem in that the communities did not understand the advantages and disadvantages of PV.

7.3.3 Usage and System Utilisation

Individuals often try to use the systems for purposes for which they were not designed. To determine this, the question in Figure 12 asked was for how long the system was used per day.

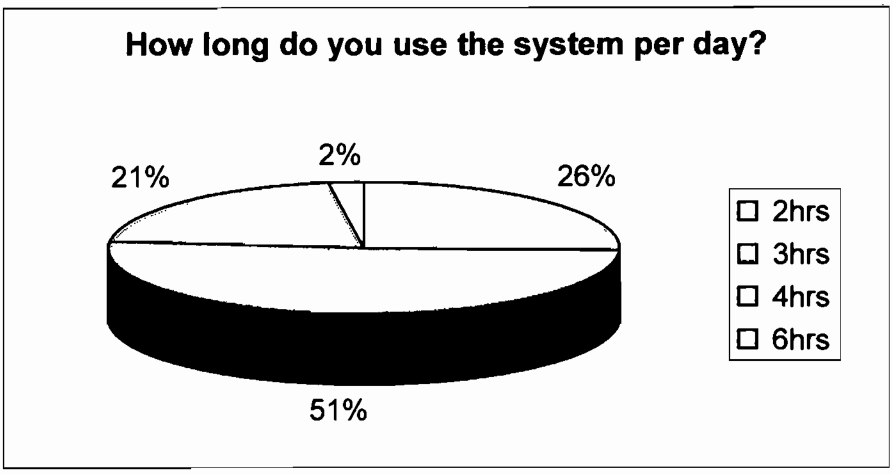

Figure 12 System Use per Day

All the systems were designed to enable the schools to have lighting in three classrooms, to run a television set and video recorder, as well as to use an overhead projector, as teaching aids. According to Figure 10, the main use of the systems is lighting (44%), television and video (19%) and overhead projector (37%). All the load components that the design anticipated are used. Figure 12 indicates that the average daily period of use corresponds to the design (3h/d).

7.3.4 System Operation and Maintenance

The following questions pertain to systems operation and maintenance. The questions in Figure 13 and Figure 14 were to determine the incorporation of maintenance to achieve sustainability of the programme.

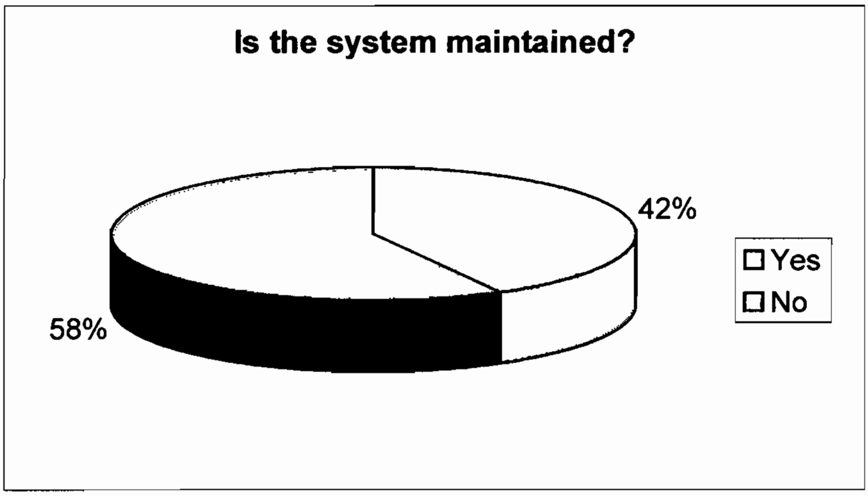

Figure 13 System Maintenance

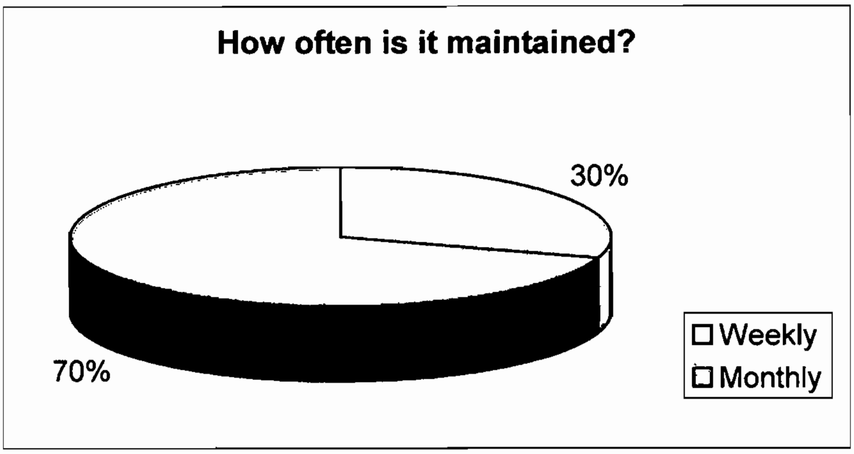

Figure 14 Maintenance Frequency

The question in Figure 13 was to determine ownership of the systems by the schools/communities. Figure 15 indicates that in the case of failure to whom they go for technical advice.

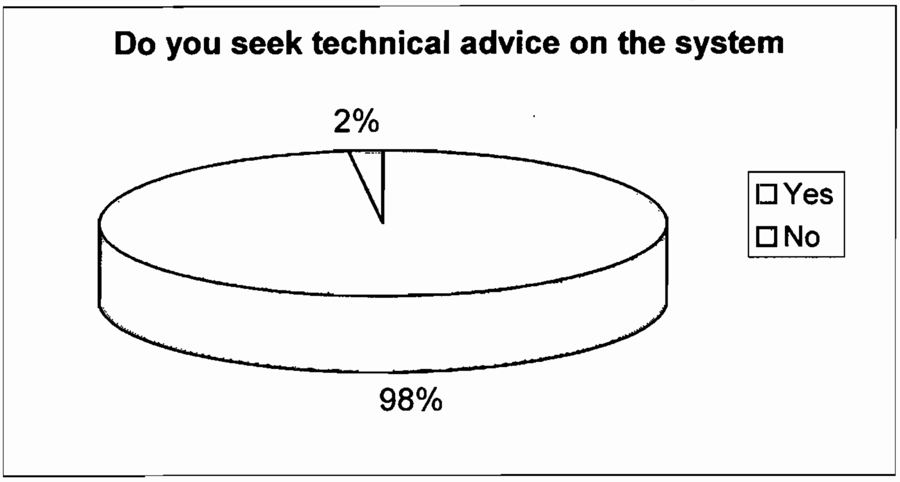

Figure 15 Technical Advice

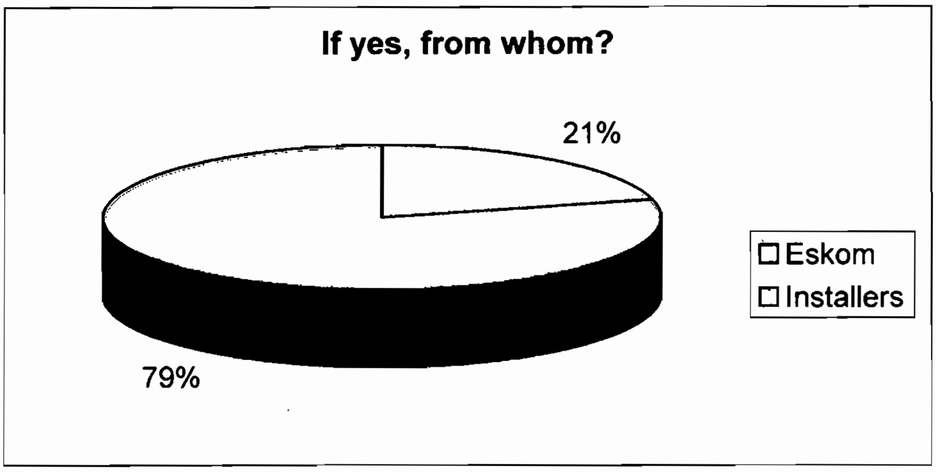

Figure 16 Suppliers of Technical Advice

In Figure 17 the question was to determine the involvement of the staff in the system.

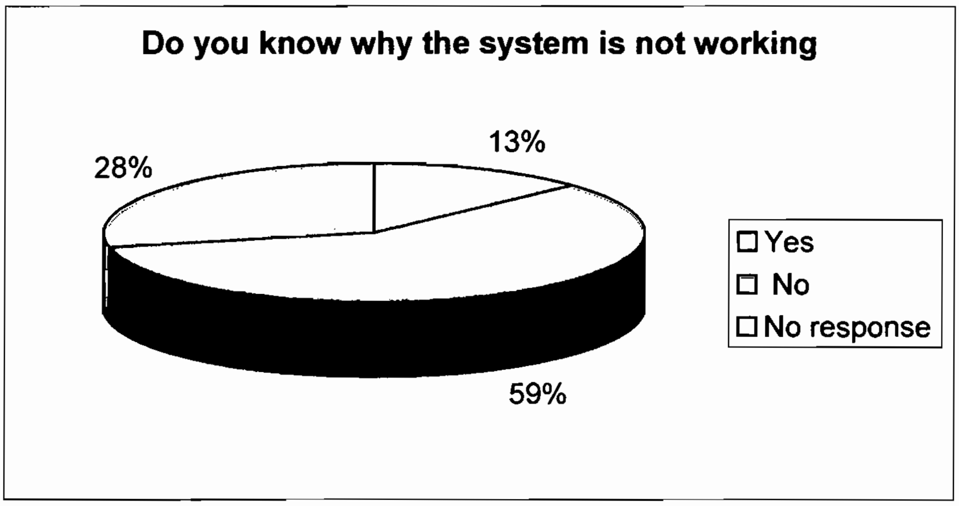

Figure 17 System Breakage

Figure 18 pertains to the staff's satisfaction regarding the response from the information provider.

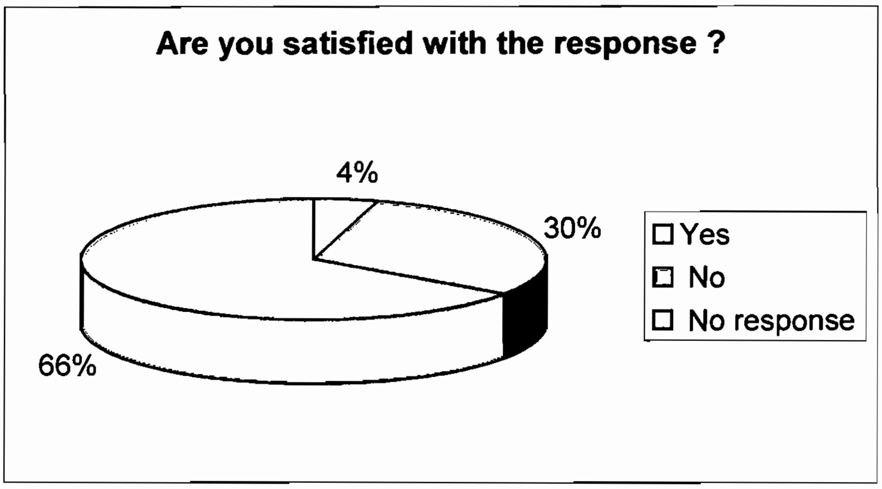

Figure 18 Satisfied Responses

A critical link in any programme is the incorporation of an effective maintenance schedule to achieve sustainability. Only 42% maintain the system regularly (Figure 13). Figure 14 indicates that the maintenance (where applicable) was done as prescribed (monthly). 79% of the respondents indicated that technical advice was sought (Figure 15), mainly from the installers (Figure 16). The latter indicated that the school staff had a better communication link with the installers than with Eskom. Obviously the reasons for failure were not understood (Figure 18), or explained properly to the school. Figure 18 is ambiguous: at best the conclusion is that the community is dissatisfied with the response of information providers.

7.3.5 Post Installation Impact

The distance criterion for the installation of a PV system is 3km away from the grid. In Figure 19 the question solicited information to establish the relevant distances in kilometres.

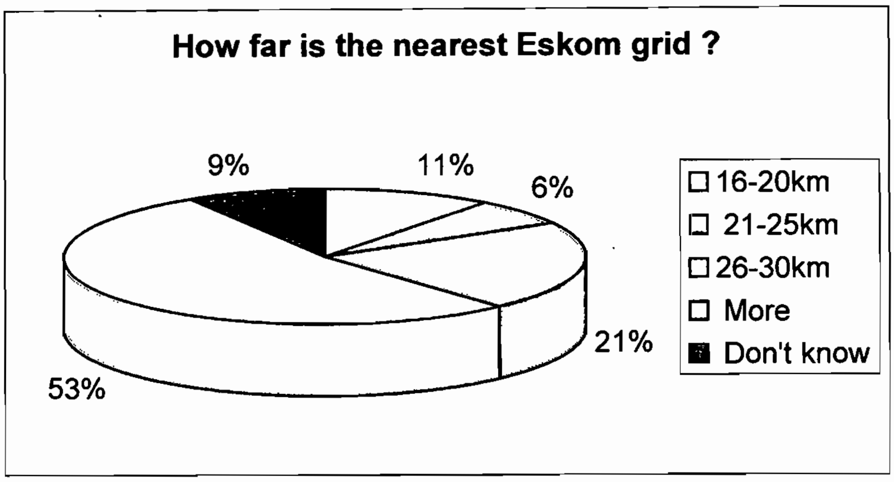

Figure 19 Distance from Grid

In Figure 20 the effectiveness of Eskom's communication process was determined.

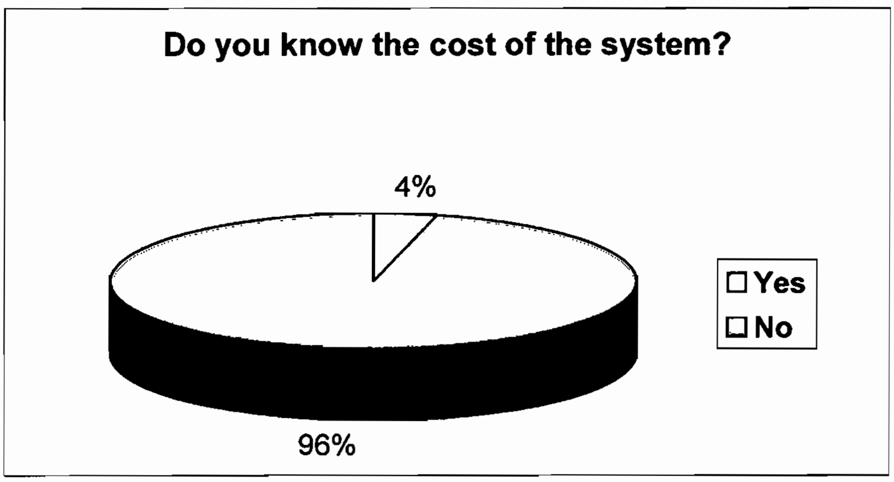

Figure 20 Cost of System

In Figure 21 and Figure 22 the respondents' satisfaction with the system was determined. The communities understanding of the technology was determined by assessing what other applications it could be used for.

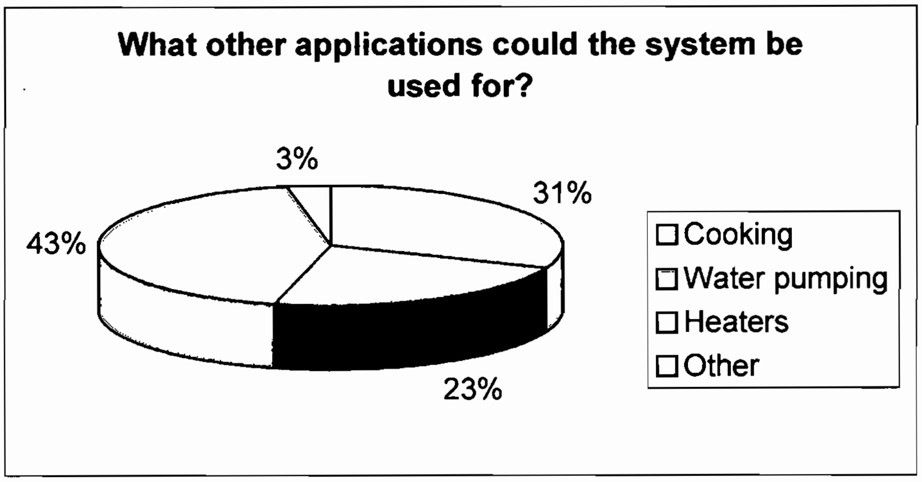

Figure 21 System Applications According to Teaching Staff

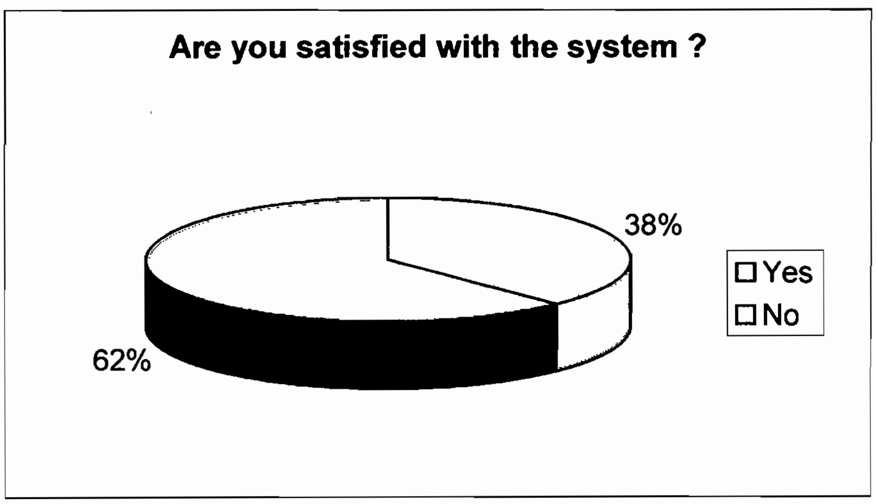

Figure 22 Satisfaction with System

Improvements, according to the community, were determined by an open question as in Figure 24

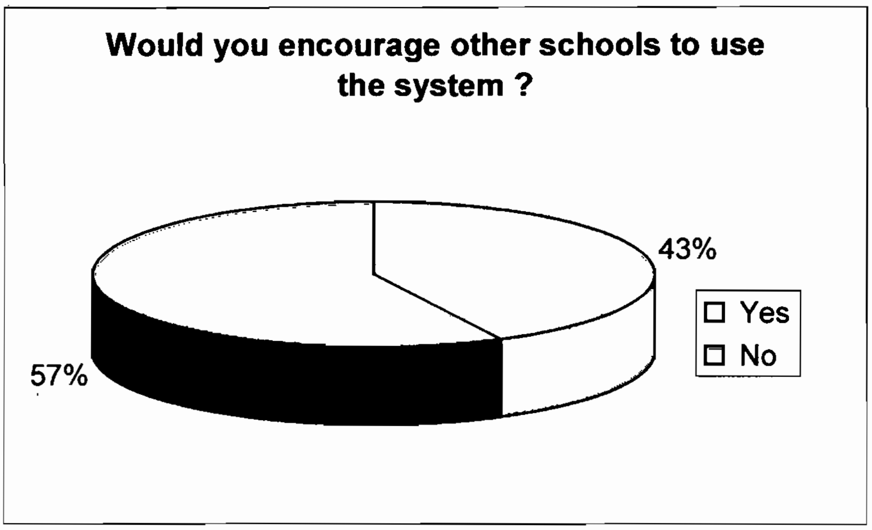

Figure 23 Respondents' Views on Encouraging Use of Systems

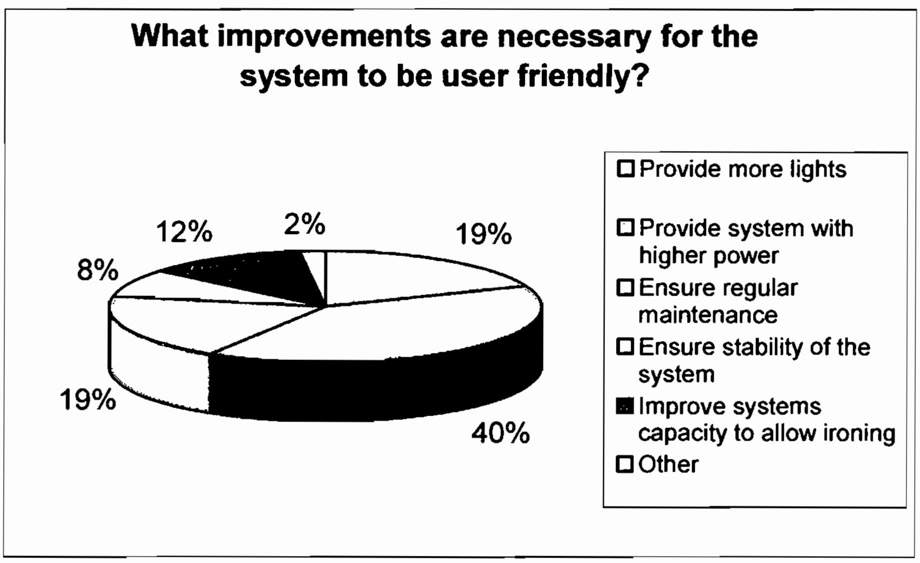

Figure 24 Users' Perspectives

The respondents' perception of the system was determined in Figure 23 by the question "would you encourage other schools to use the systems? The assumption is that the systems should contribute to education, and this was determined by the student views.

Figure 25 indicates a positive contribution to education. 94% of the respondents indicated that the system helped with studying. This was achieved by 55% more study time and 38% use of educational aids.

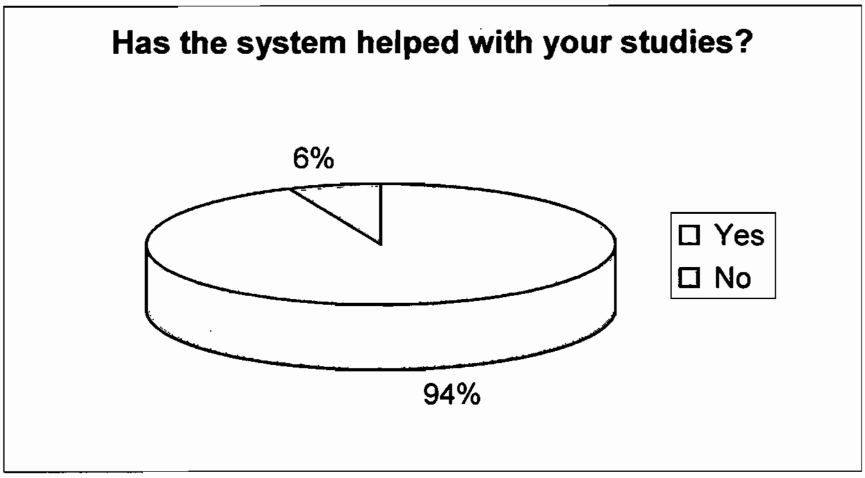

Figure 25 System's Contribution to Studies

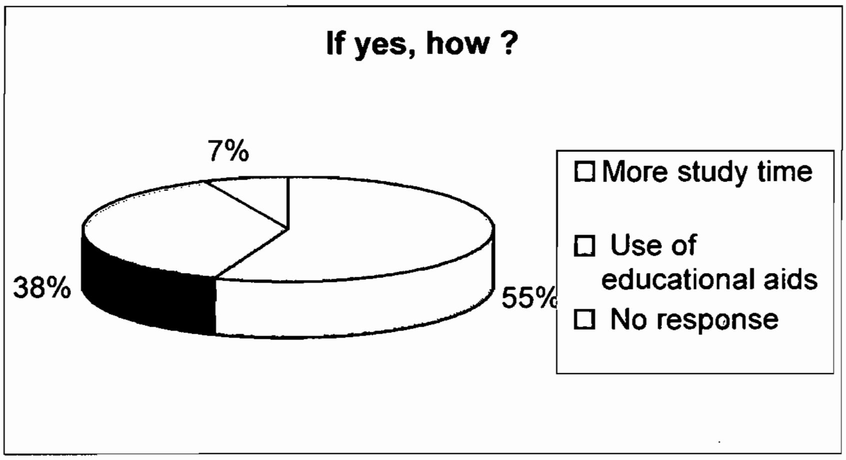

Figure 26 Areas of Improvement because of System

In Figure 27 the perception of the students was determined on why they would not encourage other schools to use PV in the schools. This was done using an open question.

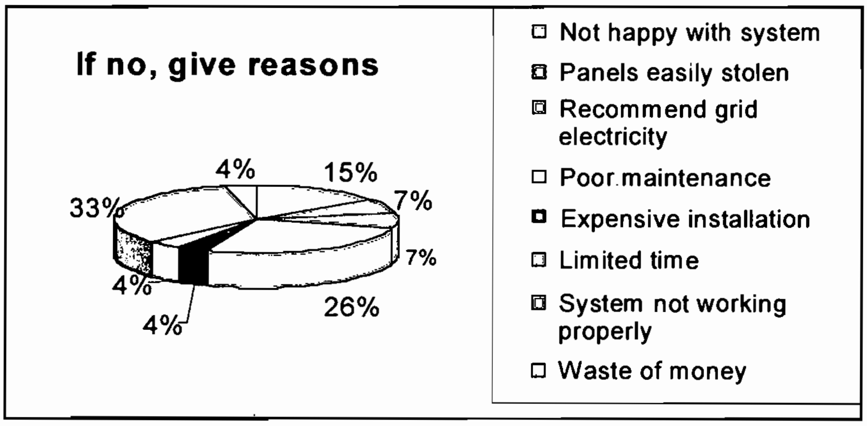

Figure 27 Respondents' Views on Why Other Schools should not be Encouraged to Use the System

The results indicated in Figure 22, Figure 23 and Figure 26 are simultaneously significant and important for the future of the programme. Figure 23 indicates significant dissatisfaction (62%) with the system. Consequently from Figure 25 a significant portion (57%) of the respondents would not encourage other schools to use the system.

7.4 CONCLUSIONS

Through interviews in Phase 2 the following were concluded from a teaching staff perspective in 48 schools:

- Profile of surveyed schools
- Communication, identification and selection criteria
- Usage and system utilisation
- System operation and maintenance
- Post installation impact.

In Chapter 8 an in-depth analysis regarding the impact of school electrification as experienced by teaching staff, pupils, parents and local leaders will be explored

8 PHASE 3 - IN-DEPTH STUDY ANALYSIS OF THE IMPACT OF SCHOOL ELECTRIFICATION

8.1 OBJECTIVES – PHASE 3

Phase 3 was an in-depth analysis of the impact of school electrification. This phase concentrated on 15 schools, taken from the 48 schools in Phase 2. The objective was to determine the use of the system and to determine the needs of the community.

8.2 METHODOLOGY – Phase 3

From the 48 schools electrified in phase 2, 15 were selected. The target group included teaching staff, pupils, parents, village residents, and local leadership structures. A questionnaire[3] was developed, and the interviewers were trained in how to conduct the survey.

The questionnaire examined the use of the school system after hours as seen by the teachers, the students and the community. Community needs were determined through the questionnaire.

8.3 RESULTS – Phase 3

The results are shown in the form of pie charts.

The use as seen by the teachers and the community leads to Phase 4 – Technical Evaluation.

8.3.1 Awareness and Ownership

Figure 28 and Figure 29 determined the effectiveness of Eskom's communication.

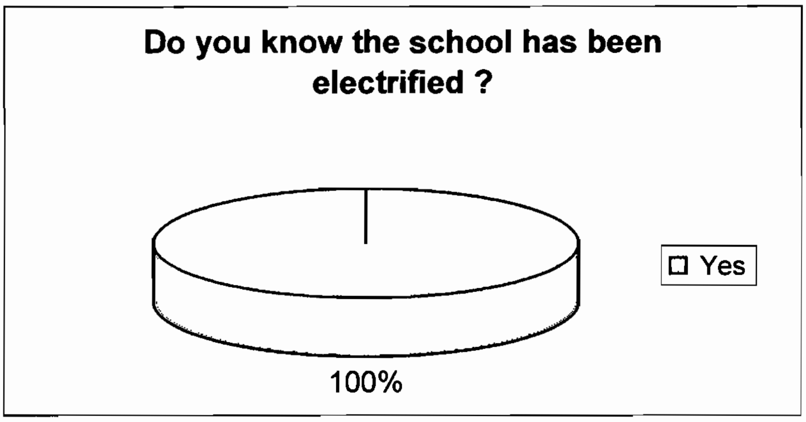

Figure 28 Awareness of Electrification of School

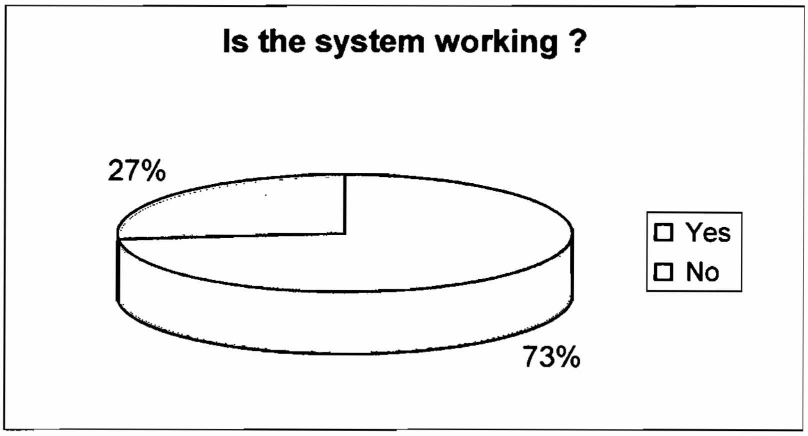

Figure 29 System in Operation

It is clear that the communities knew (100%) the schools had been electrified, as illustrated in Figure 28.

When evaluating whether the systems were still working, only 73% of the respondents (Figure 29) said yes. During Phase 2, 61% of respondents indicated that the systems were in working order. This aspect is discussed in Chapter 10.

This phase was a more in-depth analysis and the source of information was as previously, Eskom (35%), School Committee (35%), Parent Teacher Association (18%) and students (12%). This illustrates that Eskom was a significant source of information to the community.

8.3.2 Use of System

In Figure 30, Figure 31, Figure 32, Figure 33 the use of the system was determined from the community perspective, as well as from the school perspective. The duration of use was determined per week and per day; this data was compared with the design process in chapter 9.

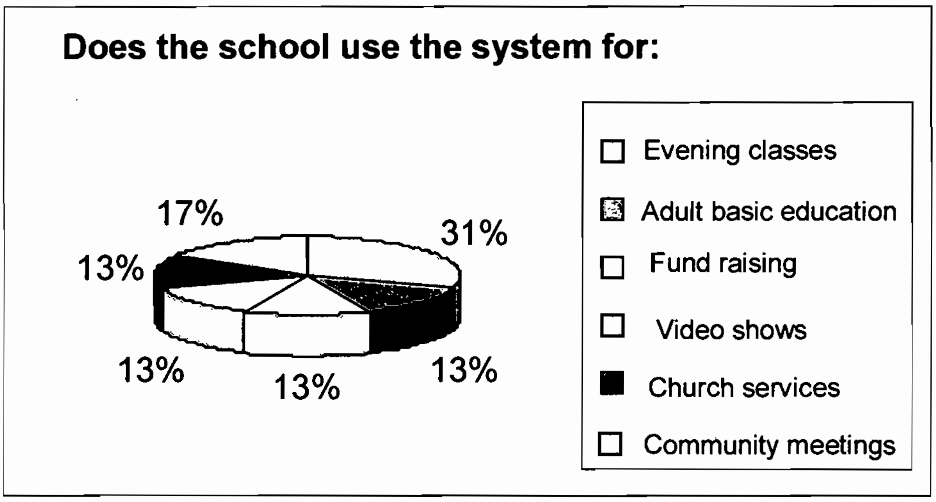

Figure 30 Use of System by School

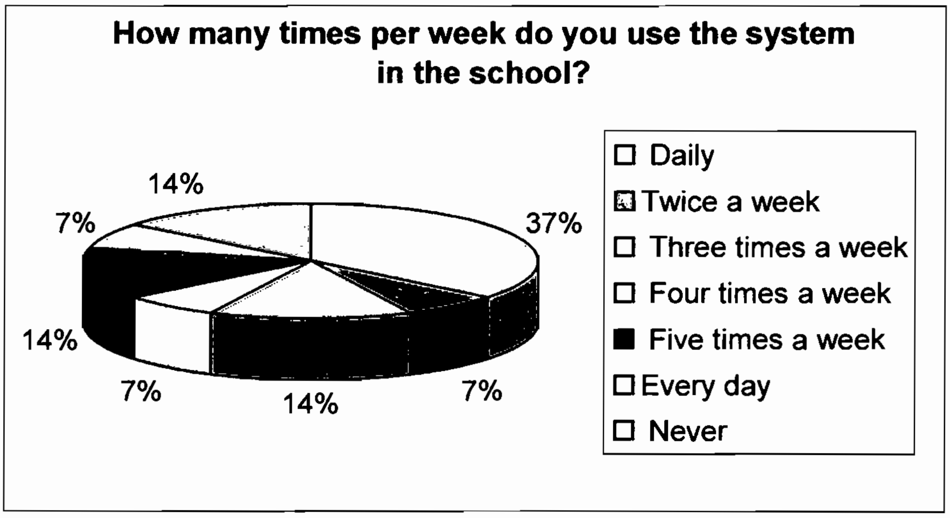

Figure 31 Use of System by School per Week

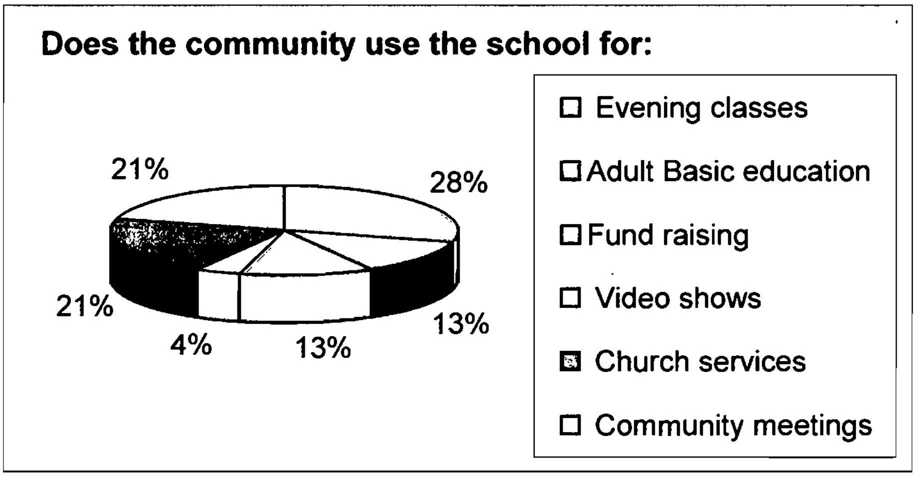

Figure 32 Use of School by Community

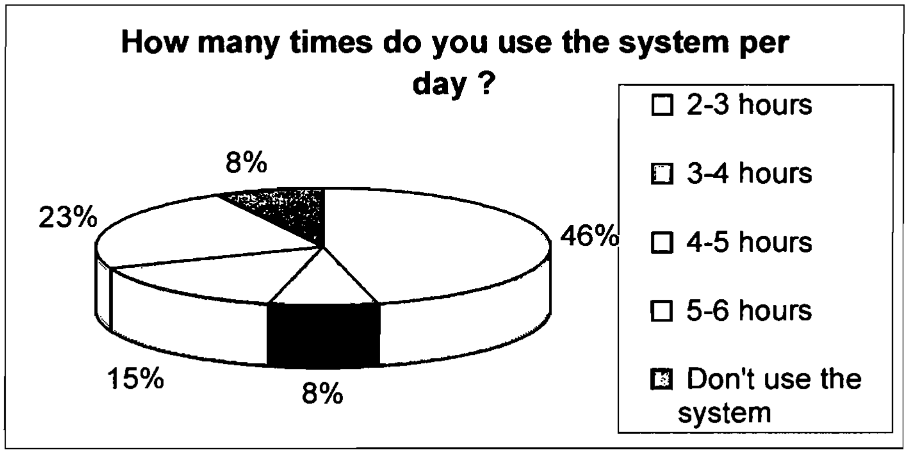

Figure 33 Use of System per Day

The school and the community agree that the system is used for the same activities as illustrated in Figure 30 and Figure 33.

The majority of schools use the systems daily (37%) (See Figure 31). The average use of systems is 2-3 hours per day (Figure 33), which is within the designed available time. This is a confirmation of the findings in chapter 9, where the school systems are used for 3 hours (54%) per day. However, the concern is the 23% use of the systems for 5-6 hours, as the systems were not designed for this period. Comparison will be made in chapter 10.

8.3.3 Operation and Maintenance

In Figure 34 the process of fault reporting by the school was determined, and to whom.

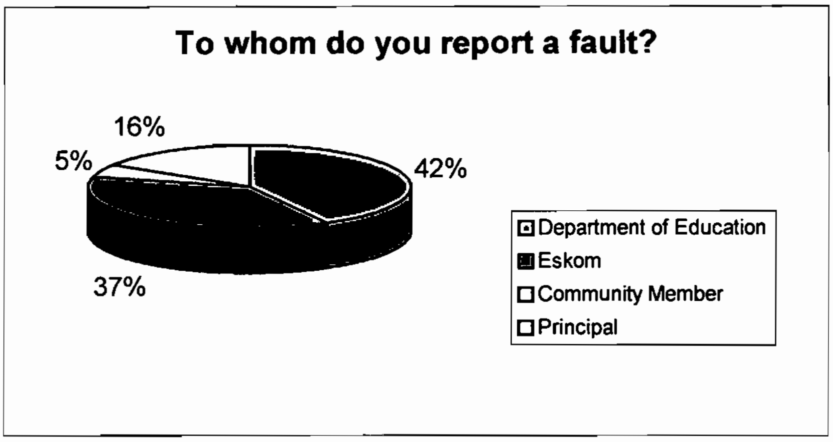

Figure 34 Fault Reporting

Faults are reported to the Department of Education (42%) and Eskom (37%). Maintenance of the systems has been unsatisfactory. The situation was exacerbated by the lack of technical knowledge and skills to motivate the staff. This is an indication that for a programme to be sustainable there is a need to improve the training in maintenance so that there is no confusion about who is responsible for maintenance.

The Department of Education is the system owner after handover and therefore should negotiate maintenance with an appropriate unit. Maintenance should be negotiated with the Department of Education, a private contractor or the Department of Public Works.

8.3.4 Impact

In Figure 35 and Figure 36 the teaching staff determined the impact of the systems on the education process.

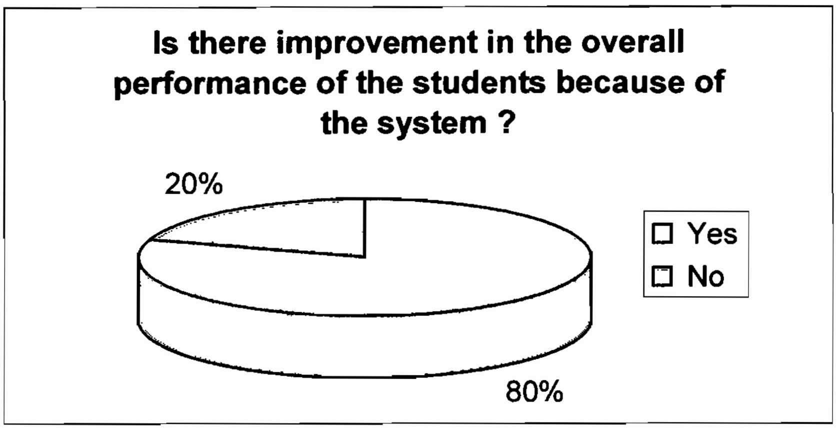

Figure 35 Improvement in Student Performance

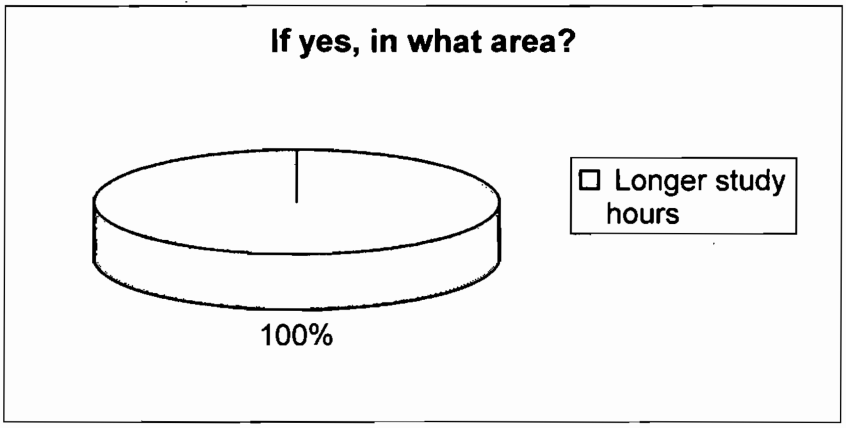

Figure 36 Area of Improvement

An average of 80% demonstrated that the system had impacted positively on pupils' performance. This was based on more study hours (Figure 35) and audio-visual aids. The impact of the system on helping the teacher with the education process was also positive (Figure 36).

8.3.5 Comparison with Grid

To evaluate the distance from the grid the respondents had to confirm the distance from the grid per school.

In Figure 37 and Figure 38 respondents were asked if they would recommend NGE to other schools.

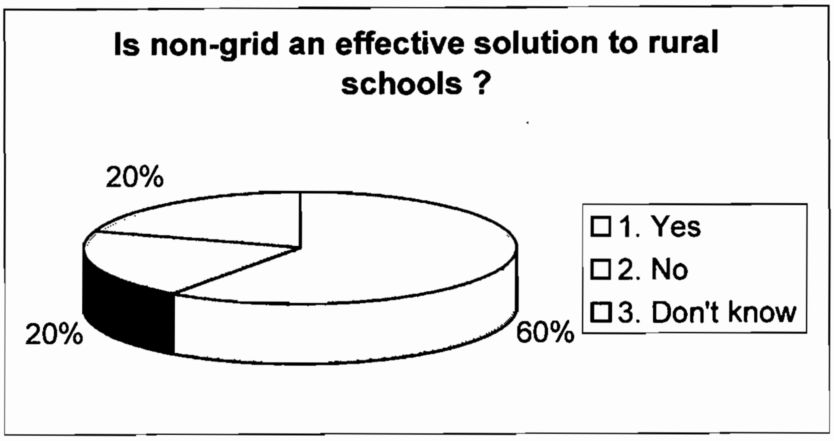

Figure 37 Non-Grid as Effective Solution for Rural Schools

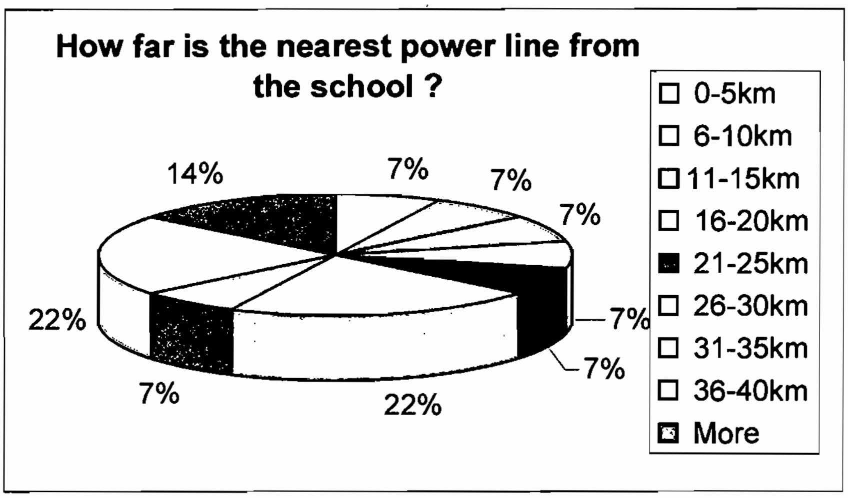

Figure 38 Nearest Eskom Grid from School

All the schools electrified fall within the 3km criterion for electrifying the school (Figure 38). Respondents indicated that 60% saw PV as an effective solution for rural schools (Figure 37). A high percentage (65%) would recommend NGE to other schools (Figure 38), whereas in phase 2 only 43% of the respondents would have recommended NGE. This phenomenon could be explained by the schools' longer-term exposure and understanding of the benefits.

8.4 CONCLUSIONS

The analysis obtained was from the following:

- Awareness and ownership
- Use of system

- Operation and maintenance
- Impact
- Comparison with grid

In Chapter 9 a technical evaluation is discussed so that the data obtained from the previous three phases could be verified.

9 PHASE 4 - TECHNICAL EVALUATION

9.1 INTRODUCTION

Of the 890 schools electrified with photovoltaic systems by Eskom Non-Grid Electrification in the Eastern Cape of South Africa, 15 schools were equipped with data logging equipment.

The reason for limiting the sample to 15 schools was cost. The cost for each system amounts to R10 000.

Specifications were clearly defined for this study to ensure the best possible results. Each site was analysed in detail in order to study the user profile and the photovoltaic system operation. On completing the data gathering process, a site report was produced summarising the essential information.

9.2 OBJECTIVES – PHASE 4

A technical evaluation was needed so that the data obtained from the previous three phases could be verified. The objectives of this phase were as follows:

- To evaluate the potential sun radiation the site receives over the period
- To establish whether the sizing of the installation is correct as far as the photovoltaic array and the battery autonomy (battery autonomy is an indication of how many days service can be provided without interruption during periods of no solar insulation) are concerned
- To establish whether the actual consumption corresponds to the consumption forecast in the sizing, and to evaluate the quality of the sizing procedure used to date
- To obtain more accurate user profiles
- To define the faults and determine the causes of possible failure or malfunction
- To evaluate the reliability of the installations

9.3 METHODOLOGY – PHASE 4

9.3.1 Data Logger Specifications

The data logging system performed the following functions:

- Monitoring and regulation of systems in real time mode, including the permanent display of sampled data
- Capturing of 13 different data values per day for one year
- Display of possible faults in the installation

When linked to a modem, the data logger ensures remote control in real time of the photovoltaic installation from a personal computer (PC), either locally or from a remote location.

Measured Data

The data logger measured four parameters that were representative of the photovoltaic system operation:

- UB: Battery voltage (V)
- IC: Charge current (A)
- IU: Load current (A)
- TB: Battery temperature (in degrees C)

From the measured currents, the data logger calculated the following parameters:

- AHP: Potential charge available from the array without regulation
- AHC: Energy actually supplied by the solar panels
- AHU: Energy used by the end-user

The data logger recorded the potential energy that could have been supplied by the solar panels in the absence of a charge regulator. This daily charge represented the real potential of the site where the panels were installed. It is possible to calculate the total energy that could have been supplied by the photovoltaic generator in one year. This energy also represented the potential amount of solar radiation on site at the array level.

The recording and calculation of the different charges allowed validation of the system sizing.

Minimum and Maximum Values of the Measured Data

In addition, the data logger recorded various minimum and maximum values:

- UB-, UB+: Minimum and maximum voltages of the battery
- IC+, IU+: Maximum charge and load currents
- TB-, TB+: Minimum and maximum temperatures of the battery

9.3.2 Data Processing

The data gathering performed by the data logger allowed conclusions to be drawn regarding the sizing of the installation and its use.

Considering the recorded data, it is useful to have a number of graphs to evaluate the efficiency of the installation. These graphs allow comparison of the different installations in order to obtain a general view of the sample considered.

The graphs illustrate the solar radiation, array performance (Ah production potential), consumption data, system sizing, user estimate versus user profile, and system utilisation.

9.4 RESULTS - PHASE -4

9.4.1 Introduction

The results of the technical study are presented in three sections:

- Summary of the site conditions.
- Graphical summary of the system performance at each site.
- Summary of the average overall performance of all the schools based on performance ratios.

9.4.2 Summary of the Site Conditions

Of 15 schools chosen initially, only six were analysed based on the data gathering done over a nine-month period. The data of the remaining eight schools could not be analysed by the data logging system for reasons given in Table 13. The chosen sites are situated in the regions of Queenstown, Umtata, Kokstad and Butterworth in the Eastern Cape. Their geographical distribution is shown in Table 13 below.

Table 13 Schools for Technical Evaluation

No	Area	Name of school	Data received	Problems
1	Matatiele	Lerato	Received	
2	Bizana	Nkundla	Received	Obtain information from Tenesa
3	Mt Frere	Qumra	Received	Obtain from Tenesa
4	Lady Frere	Seplan	Received	Lights not working
5	Cofimvaba	Mazimvubu	Received	Obtain from Tenesa
6	Engcobo	Zamiwonga	Received	
7	Matatiele	Nyaniso		Cable broken underground
8	Engcobo	Rasmeni		Batteries stolen. Data logger problem
9	Nqgamakwe	Zakhele		Battery connections loose and state of charge of batteries too low for the system to operate. Top-level circuit breakers were switched off and the users had discharged the low-level circuit breakers while the panels could not charge the batteries. Data logger problem
10	Ezibeleni	Bolotwa		1Battery exploded. Data logger problem
11	Lusikisiki	Vulindlela		Vandalism, wiring and lights damaged
12	Lady Frere	Stoney Croft		Batteries totally discharged on installation of data logger first time Lights not working. Problems with data logger
13	Ezibeleni	Xumabokwe		Downloaded. Data logger problems
14	Engcobo	Mboleni		Battery too low (4.8 V)
15	Engcobo	Mgudu		Theft. No panels

9.4.3 Graphical Summary of the System Performance at each Site

The results obtained from the logging systems at each site[77] were consolidated per school to show the installed system performance at each site. Included in the output is a comparison of original design data with measured data. Information obtained from the comparison will aid in the improvement of future design methodologies.

The measured data do not include watt-hour measurements. This would have meant a more complex and costly data logging system. Charge flow (amps) is recorded and used in all calculations.

The consolidated results are presented in six graphs. These graphs are discussed briefly.

- **Solar Radiation**

The *assumed solar radiation data* used for design purposes was an average for one year. This was done to reduce the complexity of design. This design practice was compared with the best available monthly meteorological data for each site. In all cases, the *Durban solar radiation* data were used. Variations may be expected but the overall comparison should indicate agreement between predicted and measured data over the total period.

The solar radiation data for all the schools produced the same results as the same meteorological data was used in each case. The results indicate a fair comparison between the assumed radiation used during the design process and the radiation that could be expected.

- **Array Performance (Ah production potential)**

It is important to compare the array performance (*measured AHP*) with the expected or design performance (*anticipated AHP*). The actual solar radiation is not measured directly. Instead, the potential charge production of the array is recorded as if no regulation takes place. This is compared with the calculated array performance based on the available meteorological data and the array peak power design.

An exact comparison between predicted and measured values is not expected, but overall (yearly averages) should be the same.

- **User Estimate (load profile)**

It is important to determine the load demand (*measured AHU*) and to compare it to the assumed load demand (*anticipated AHU*) at the time of design. This is done on a monthly average. The comparison provides valuable information for future design efforts. The results obtained in phase 2 and 3 have been taken into consideration when evaluating this information in chapter 11.

- **Consumption Data**

The charge consumed (measured AHU) is compared with the battery charge acceptance (AHC). This indicates the difference between charge used and excess battery charge. The comparison is an indication of the efficiency of the battery and whether the charge control setting is correct for the particular battery.

- **System Sizing**

To determine whether the original design makes sufficient provision for the expected user load profiles (*anticipated AHU*) it is compared with the actual array performance (*measured AHP*).

In all cases the available charge would not have been sufficient to provide for the anticipated load demand. As the overall array performances were acceptable, it must be assumed that the design process was not correct.

- **Utilisation**

The actual consumption (*measured AHU*) is expressed as a percentage of the design data (*anticipated AHU*) as well as a percentage of the battery capacity (*Cn*).

The lower than expected load demand is clearly indicated. Considering the battery sizing and comparing it with the actual consumption, the results indicate that for the anticipated consumption, the battery sizing is correct. An average discharge of twenty percent would have been experienced, which is acceptable.

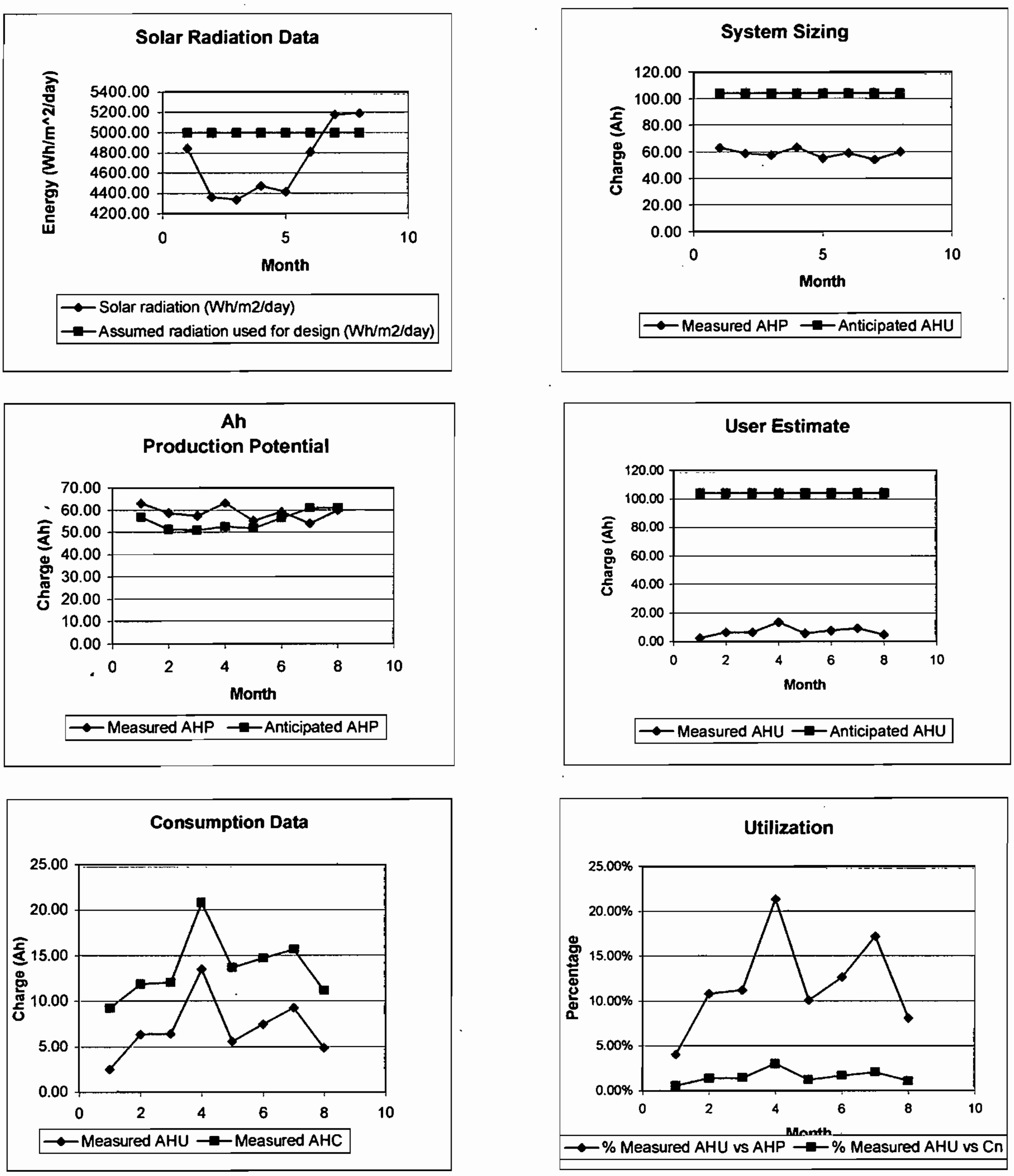

Figure 39 Zamiwonga results

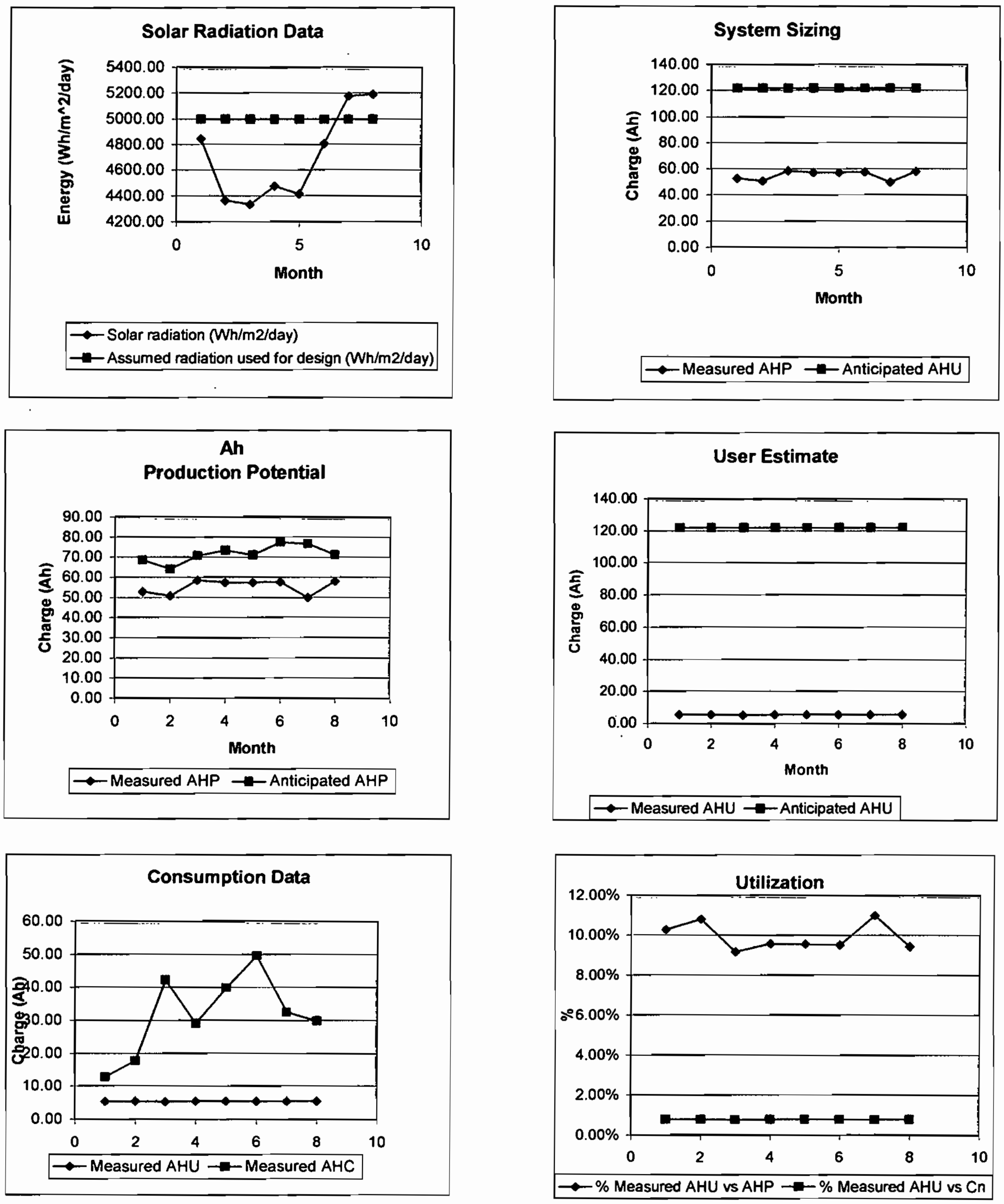

Figure 40 Seplan Results

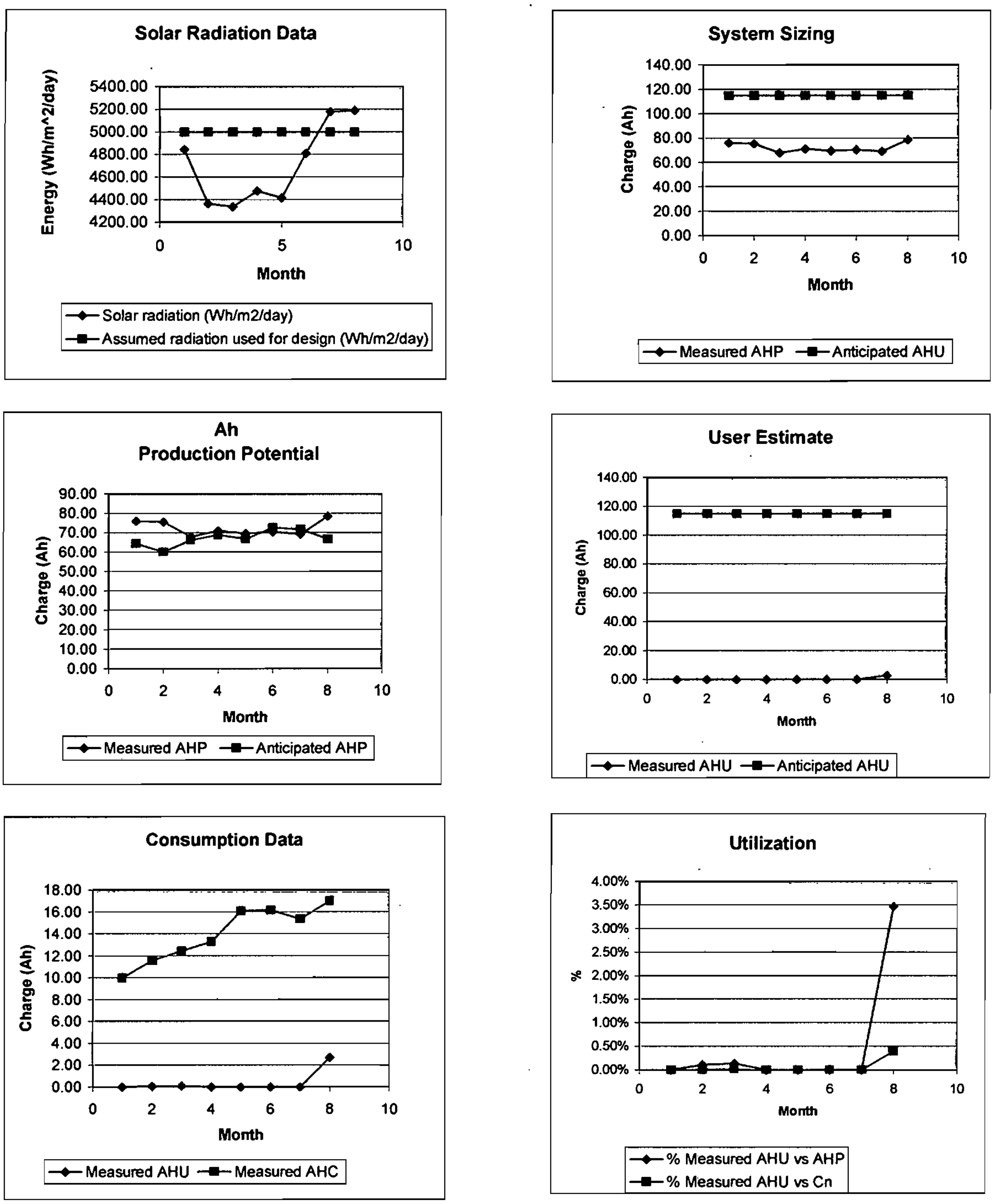

Figure 41 Nkundla results

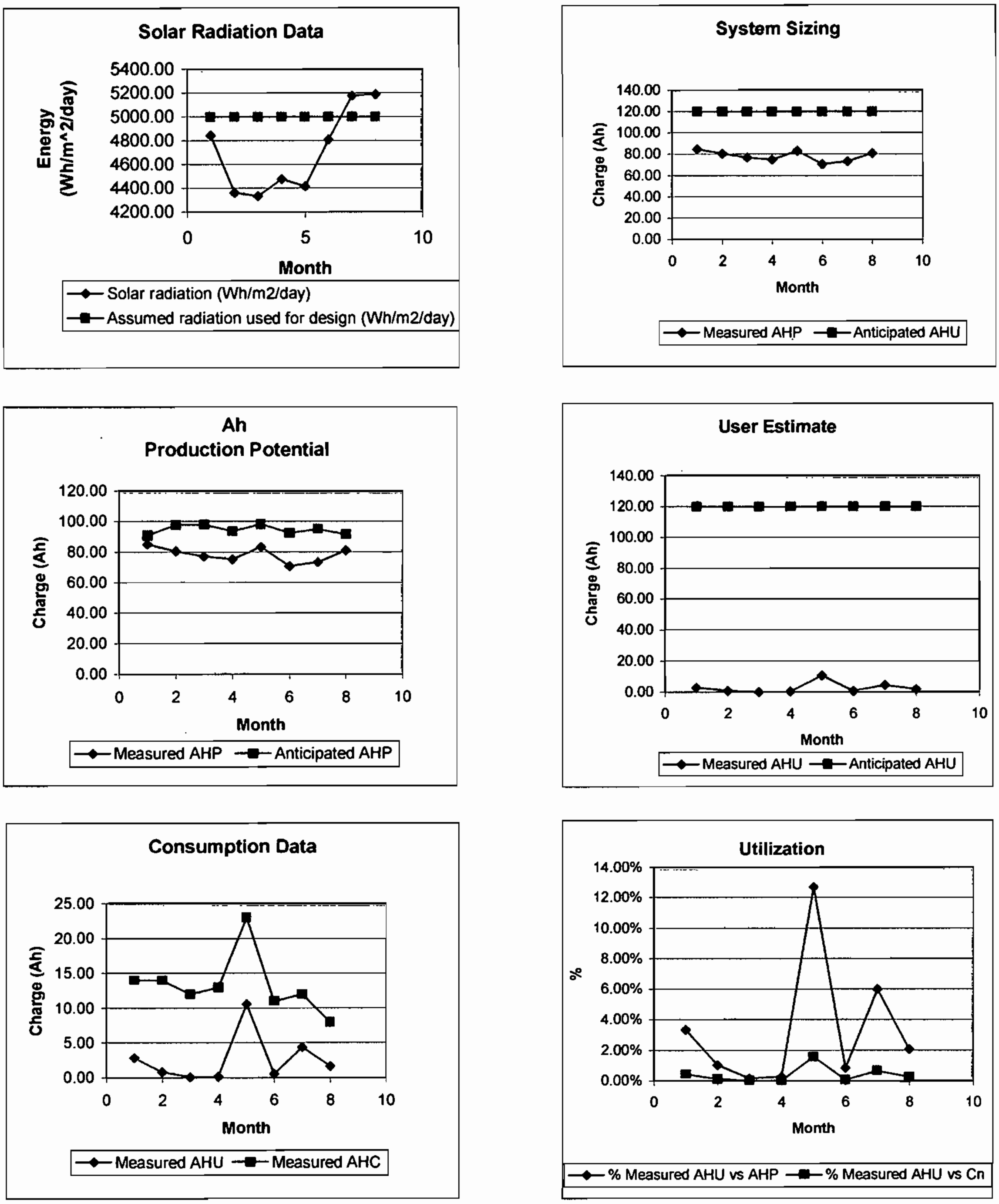

Figure 42 Mazimvubu results

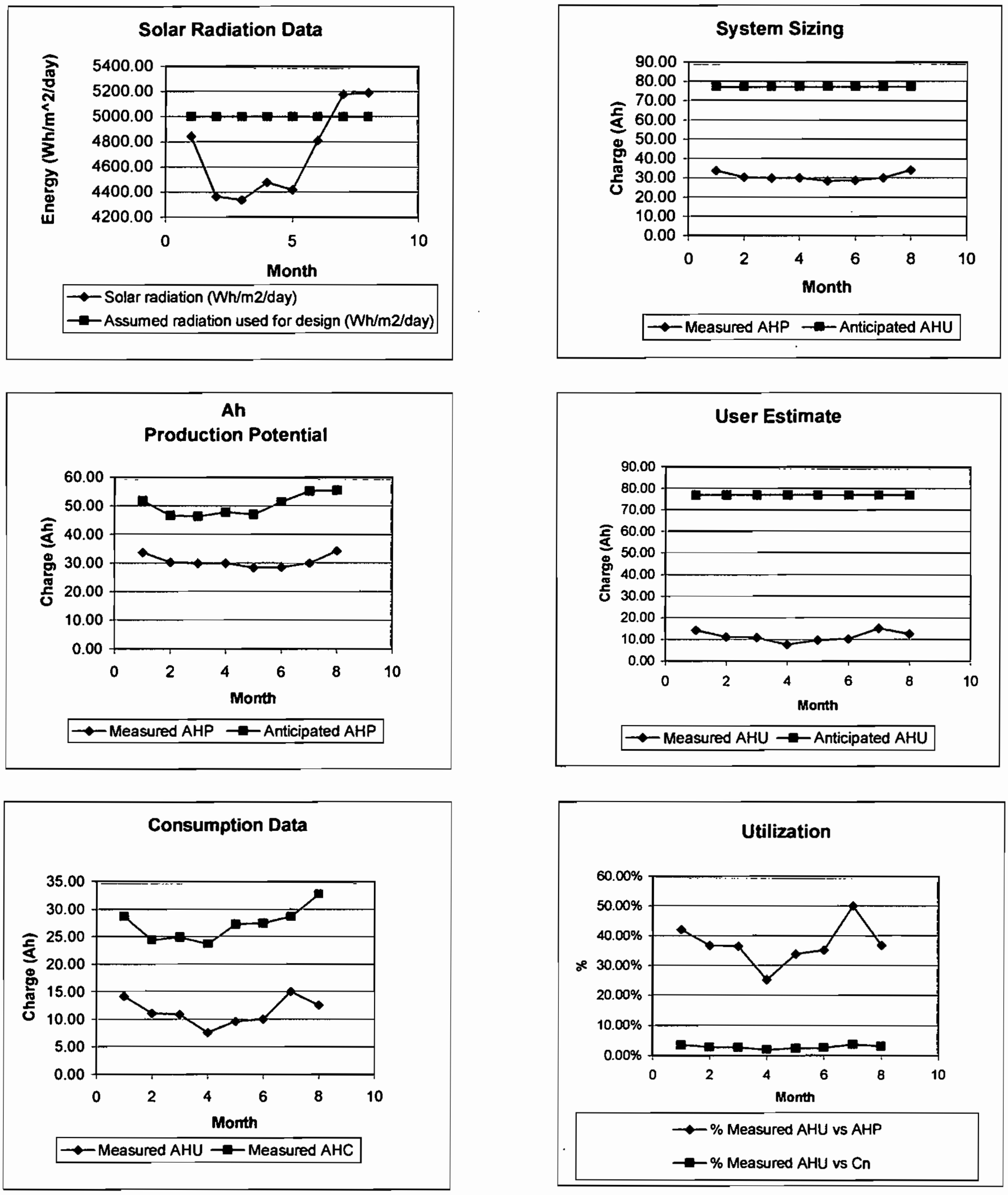

Figure 43 Lerato results

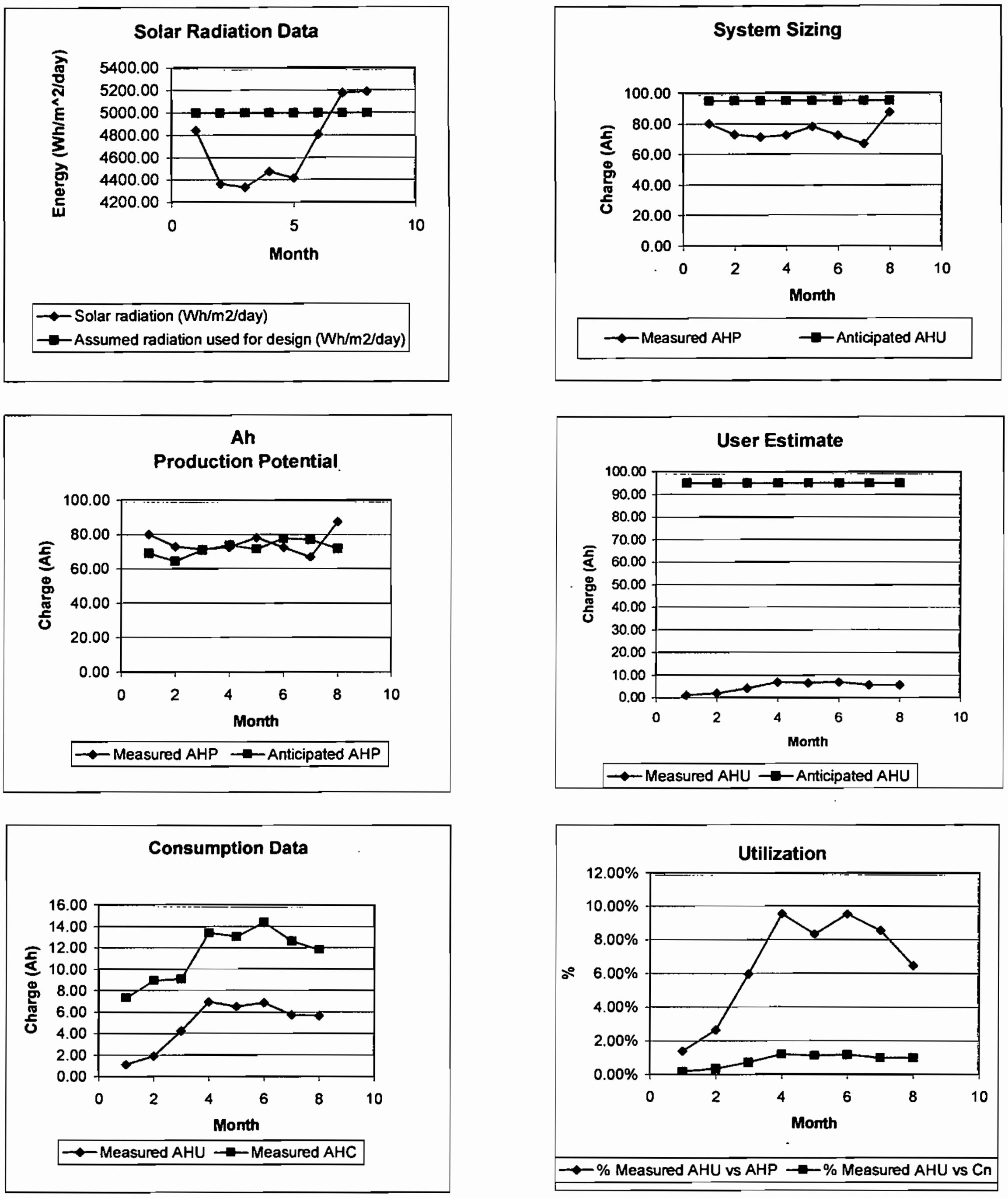

Figure 44 Qumra results

9.4.4 Summary of the Schools Data

In order to interpret the results collectively it is necessary to consolidate the information and determine average performance indexes. These indexes are expressed as ratios or percentages, thereby normalising all data.

In addition, the results are compared with ideal values to determine the deviation from the norm. Table 14 shows the consolidated data.

Table 14 Schools Data Summary

Name	% Variation actual AHP vs anticipated AHP	% Variation measured AHP vs anticipated AHU	% Measured AHU vs anticipated AHU	% Measured AHU vs AHP	% Measured AHU vs Cn	% Measured AHU vs Measured AHC	Overcharge as a % of Cn	% Maximum array current vs theoretical array maximum
Lerato	61	39	14	37	3	41	4	88
Qumra	104	79	5	6	1	40	1	121
Mazimvubu	82	65	2	3	1	17	2	101
Nkundla	108	62	0	1	0	2	2	110
Seplan	77	45	4	10	1	20	4	72
Zamiwongo	107	56	6	11	2	49	2	131
Average	90	58	5	11	1	28	3	104
Ideal	**100**	**120**	**100**	**80**	**20**	**85**	**2**	**100**

To interpret the data the graph shown in Figure 45 was produced. All schools parameters, as well as the average for all parameters, and the norm are indicated.

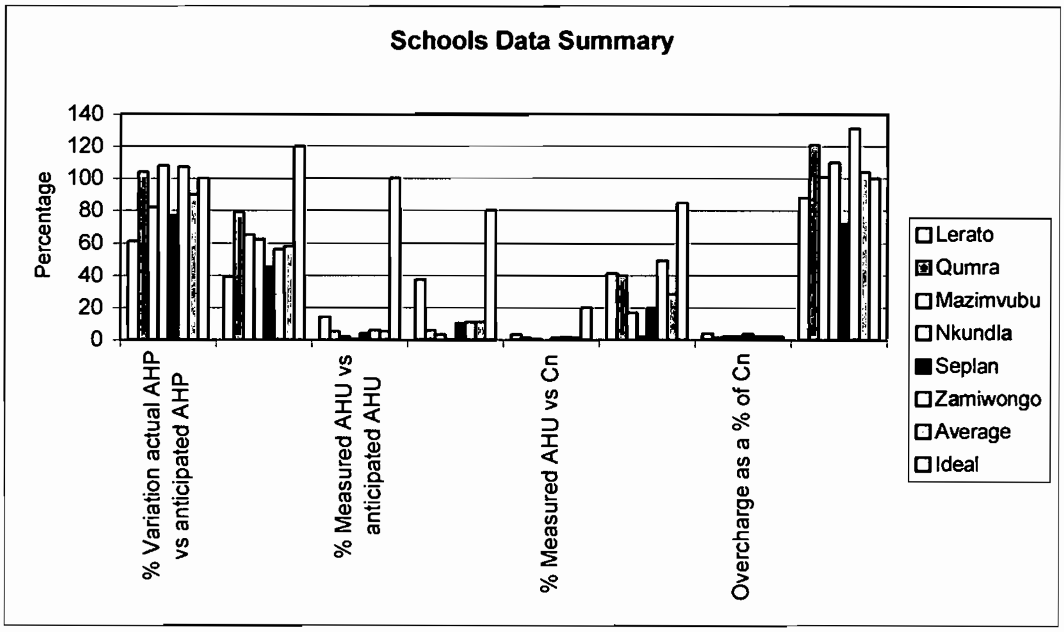

Figure 45 Summary Graph of the Schools Information

- **Percentage Variation Actual AHP vs Anticipated AHP**

The ideal situation should be 100%. For all schools monitored the average is 90.2%. This indicates that the photovoltaic arrays produce on average 10% less charge than expected. Considering the solar radiation data used for design purposes, which is on average approximately 10% higher than the meteorological data indicates, such performance can be expected. Furthermore, the average maximum array current versus the theoretical array maximum current is in good agreement (refer below), indicating that the 10% lower production is not attributable to the actual array performance but rather design considerations.

- **Percentage Variation Measured AHP vs Anticipated AHU**

The potential array energy produced is significantly less than the anticipated consumption (58.2%). As pointed out, the average array performance is within specification, indicating error in the array design and sizing procedure to accommodate the anticipated load demand.

- **Percentage Measured AHU vs Anticipated AHU**

The average consumption is only 5.6% of the anticipated consumption. This result indicates that the systems are under-utilised. The degree of under-utilisation is high enough to warrant serious consideration regarding anticipated consumption needs and communication. This result could be attributed to various aspects including lack of understanding, lack of equipment, inappropriate assumption of needs etc.

- **Percentage Measured AHU vs AHP**

If the actual consumption is compared to the available actual array potential a figure of 11.5% is obtained, indicating that the sizing of the array, even if it is incorrect, exceeds the load demand by a factor of ten. It could also be stated that the current demand could be met with only 10% of the current array size. This result should be viewed with caution. There are cases (Lerato school) where the consumption is 37% of the array potential, indicating a greater average need not expressed currently, owing to aspect such as those mentioned in the previous paragraph.

- **Percentage Measured AHU vs Cn**

The result of the low consumption figures can be seen also in the charge consumed versus the battery capacity (Cn). Only 1.1% of the nominal battery capacity is utilised. If the design assumptions are taken into consideration, the sizing of the batteries is in accordance with good practice. The actual consumption is 5.6% of the design consumption, meaning that twenty times more energy should be available. Increasing the demand by twenty would place the battery discharge at 20%, being an acceptable figure.

- **Percentage Measured AHU vs Measured AHC**

The charge used should be about 85% of the charge delivered to the battery, considering battery charge efficiency. The research result indicates an average figure of 28.6%. This value is very low. The reliability of this result is influenced by the fact that in two cases (Seplan and Nkundla) indications are that the charge regulator malfunctioned.

- **Overcharge as a Percentage of Cn**

If the excess charge as a percentage of the battery capacity is considered, approximately 2% is expected to maintain battery equalisation and prevent stratification. The study has revealed that the average for the school where data was logged is 2.3%. This is in agreement with expectation. Again the result must be viewed with caution as some schools indicated a significant deviation from the mean.

- **Percentage Maximum Array Current vs Theoretical Array Maximum**

The average maximum array current is in agreement with the theoretical maximum array current (104.4%). This result indicates that array performance is, on average, in accordance with the supplier specifications. The installations were undersized if one considers the needs calculated when sizing was made. More solar panels would have been necessary to provide for the needs expressed when the sizing was made. The actual utilisation is approximately 10 times less than the design value.

It is clear that the photovoltaic arrays operate as per the designs. The assumed solar insolation data proved to be acceptable. Serious consideration should however be given to the design methodology in determining the array size, which is completely inaccurate according to the results

The over sizing of the systems lead to recurrent boost charging in several cases related to the functioning of the type of regulator used. Regulator malfunctioning and/or inappropriate regulator functioning is possibly the cause. This will result in premature ageing of the batteries and therefore shortening of the battery lifespan.

9.5 CONCLUSIONS

Only six schools data could be analysed. Due to theft, vandalism, low batteries and systems that are not operational because of the fact that the systems are not used by the end-users.

The conclusions of the different phases are discussed in Chapter 10.

10 CONCLUSIONS OF THE STUDY

10.1 INTRODUCTION

Certain themes emerged consistently throughout the activities in the study. The conclusions of the different phases are discussed in this chapter.

10.2 PHASE 1 PRE-ELECTRIFICATION PHASE

The schools electrification programme was to some extent initiated by the RDP and implemented by Eskom and Department of Minerals and Energy as a conventional “top-down” development strategy. The Department of Minerals and Energy and Eskom decided on the justification of providing photovoltaic solar energy systems to rural schools as a priority. The schools and communities, as end-users, had no option of either accepting or not accepting the technology. The end-users’ choice was further constrained by the predetermined capacity and thus the utilisation option, which were set by the technical specifications of the systems.

The electricity provider, and the equipment and accessories manufacturing and distribution industries primarily drove the NGE programme. There was therefore little or no local capacity building through effective technology transfer.

The limited capacity of the NGE system implies that communities are equally constrained to initiate meaningful income generating activities through Small, Medium and Micro Enterprises (SMMEs), which require a critical source of energy. Potential SMME economic activities are carpentry, sewing and knitting, small-scale irrigation farming schemes, food processing, etc.

There is a lack of structured and functional co-ordination among all the stakeholders to promote synergy and, by the same token, achieve smooth and efficient running of the programme at all levels (community, provincial and national).

The Department of Education is a key role-player in this programme because the programme demands full participation of the professional cadre in the education system (directors, regional and district officers, headmasters/principals, teachers and school management committees). These professionals do not, however, have the crucial technical skills, or indeed the time, to contribute to sustainable functioning of the systems.

However, past training evaluation of the maintenance process, Figure 13, indicates maintenance problems, possibly due to a lack of financial and business support, enabling the local people to function as entrepreneurs in the rural environment. This indicates the necessity for revision of the Eskom training programme.

The issues of ownership and maintenance of installed systems need to be addressed urgently.

The non-grid schools electrification programme does not take into account the developmental level and needs of communities. Hence there is no calculated link between the programme and the economic activities taking place in the communities. There is an acute lack of data on the socio-economic space in which schools are situated, and a lack of information on the real needs and priorities of schools and communities.

The process of identifying and selecting schools for the programme has evolved on an ad hoc basis with no clearly defined general selection framework. The potential for schools as a framework has to be checked carefully against Eskom's Five Year Electrification Plan to ensure that only schools outside the expansion plan are evaluated for non-grid electrification.

It was observed that the implementation process of the programme has often resulted in tenders not being awarded to the technically lowest bidders, owing to the capacity constraints of such bidders, who are mostly black small-contractors. The consequence is that the big contractors with financial muscle win tenders.

Eskom NGE has been successful in promoting technical capacity building through the Faculty of Engineering at the Port Elizabeth Technikon. The faculty has developed special modules for training photovoltaic installation technicians and commissioning officers. NGE has also developed appropriate documents for the different stages of the non-grid electrification process, such as:

- a well-structured and simplified application form
- photovoltaic design specifications
- standard technical specifications for the installation of photovoltaic systems for schools
- certificate of evaluation by an accredited person
- take-over of non-grid school electrification system
- user operating and maintenance manual for rural school solar electric plant

10.2.1 Summary of Conclusions – Phase 1

The following items were concluded in Phase 1:

- RDP, Eskom and DME followed a "top-down" approach
- Community had no choice in accepting new technology
- Predetermined system specifications by Eskom and DME
- Lack of local capacity building
- No meaningful income generating activities in communities
- Lack of synergy between stakeholders
- Lack of sustainability because of DOE minimal involvement
- Lack of training and development of entrepreneurial skills in communities

- Ownership of systems a problem
- Maintenance process
- Needs of community not taken into account
- Lack of needs and priorities of schools
- Selection process of schools to be electrified not clear
- No criteria for selection of schools to be electrified
- Black Economic empowerment not enhanced

From the above conclusions it is clear that:

- Apart from the decision makers, Eskom and DME, various other parties were involved such as communities, Department of Education, suppliers, contractors and Port Elizabeth Technikon, leading to,
- No synergy.

These conclusions need to be integrated into the consolidated and robust process for the application of photovoltaic solar energy to medium-scale installations.

10.3 PHASES 2 AND 3

10.3.1 Profile of Surveyed Schools

The electrification of 890 schools contributed to the educational benefit of 396 050 students as shown in Table 12. This is a significant number of students that could improve their studies. The number of teachers who would have been using audio-visual equipment is 12 460 in the rural areas of South Africa. The teacher-student ratio, Table 12 is not that high considering a ratio of 31:1. Referring to the literature, teachers do not stay in rural areas owing to the lack of electricity. This situation must be monitored.

10.3.2 Communication, Identification and Selection Criteria

Photovoltaic systems involve a new technology and rural people do not willingly or readily accept unknown technologies. In South Africa the rural communities regard renewable energy as second-class energy and therefore do not accept renewable energy per se. The process of introducing the new technology to communities should be well planned and well presented.

The success of implementation and popularisation of a new technology for rural populations (the photovoltaic technology) is invariably related to meeting three basic conditions: commercial availability, ability to obtain replacement parts, and the services of local technical personnel with the ability to install and maintain the new technology-based systems[78].

Eskom's communication process needs to be adjusted considering that 75% of respondents indicated that they did not receive any information about photovoltaics. The process of dealing with the right people in the community needs attention. Local government should have been more involved in the communication process. It is a community project and communities should feel part of the electrification process in full, which means participation from the start of the programme.

Although 75% of the respondents did not receive any information on PV during phase 2, 100% of the respondents knew that the schools had been electrified with PV during phase 3.

In order for the community to participate they should know what will be installed, by whom, when and what the cost of the installation is. In this way appreciation for a project can be achieved. This is clearly illustrated in Figure 20: 96% of the respondents did not know what the system cost.

In paragraph 8.3.2 it is indicated that 30% of the respondents did not apply for the systems. This is a cause for concern in that each school should apply up front before the electrification can begin. This illustrates the lack of application procedure by Eskom and by the Department of Education. The researcher has checked the application forms signed by the schools, each of which bears the signature of the principal and the school stamp.

Before a system is designed, the needs of the school and the community should be taken into account. The needs will determine the size of the system. However, the systems have been designed without taking the needs of the school and the community into account.

Other community needs should also be considered when planning is done for a community, such as water, sanitation, roads and clinics. If Eskom and the IDT had worked together in the areas, more clinics would have been electrified. Clinics are probably more important at this stage than electrifying schools, considering the use of the schools as illustrated in this study. In order for development to take place in rural areas, role-players should strive to plan their efforts together.

The Department of Education has accepted the schools electrification programme as can be seen through the different phases. The concern is that the decision has not been filtered properly down to the schools, which is seen clearly from the knowledge of the electrification programme that the communities have revealed.

The Department of Education is unable to provide for the basic needs of the schools. The low level of maintenance in the schools does not contribute to the planned audio-visual equipment improvements associated with electricity. Most of the schools do not have any television sets, video recorders or overhead projectors, which hampers the use of the system. Supplying basic equipment with the PV system would immediately give the school a means of using the system and appreciating its advantages. Most of the schools do not participate in Adult Basic Education, as shown in Figure 30 and Figure 32, and this should be a policy decision by the Department of Education so that the communities can benefit from the electrification of schools. The improvements at schools associated with electrification are virtually all linked to the supply of audio-visual equipment (Figure 25 and Figure 35).

10.3.3 Usage of System

During phase 2 (Figure 11), 61% of the schools were in a working condition; in phase 3 (Figure 29), 73% indicated that the systems were still working. During phase 4, only 26% of the schools were using the system. Phase 4 measured usage via a data logger, and although only six of the 15 schools were measured, it is still an indication that the systems are poorly used.

Most of the schools are using the systems daily, on an average 2-3 hours, which is within the designed available time. The results indicate that 23% of the schools are using the system for 5-6 hours.

Expectations for the use of the systems are that they want to use them for more than just lighting, television and video recording. This is clearly illustrated in Figure 21. The advantages and disadvantages should be clearly spelled out during community meetings.

Although the results show a positive perceived contribution to education, more study hours, there is a tendency not only for educational purposes but also for community interaction. This is an indication that the respondents do not understand the systems, and they should therefore be helped and shown how to make use of the systems optimally, not only for educational proposes but also for community interaction. The reasons for not recommending the systems may be seen in Figure 27. This does not contribute to the success of the programme. Since the communities do not know enough, or take the initiative, someone would have to work with them to show them how to be entrepreneurial with the systems.

10.3.4 System Operation and Maintenance

The greatest weakness of photovoltaic programmes to date has been the serious underestimation of the need for adequate repair and maintenance of the systems. Although the repair and maintenance needs of photovoltaic installations are much lower than those of diesel engines, for example, they still have to be met, or the photovoltaic unit will inevitably go out of service. Problems are found among privately installed systems in homes, schools and clinics.

Providing training courses for electricians would not meet the need. Emphasis should be placed on establishing sustainable repair and maintenance services and skills at community level. These include technical and managerial skills.

During phase 2 only 42% of the systems were being maintained regularly. For the programme to be sustainable an effective maintenance programme should be incorporated. The respondents indicated that they requested

Eskom to do maintenance therefore the training given to the schools should emphasise the fact that the Department of Education is responsible for maintenance of the system. The Department of Education should have a maintenance plan for the systems, because if they are not maintained, the PV market in South Africa will not be sustainable.

The fact that maintenance has not been implemented according to a desired programme, raises a concern. Owing to the importance of electrifying rural schools with PV, problems should be monitored and evaluated so that they can be resolved before the viability of the systems is affected.

For renewable energy programmes to become more effective in developing countries, firm priorities must be set. Technologies that are mature and reliable must be promoted with vigour. For some, the implementation aspects need to be evaluated for rural electrification. For others, specific R&D efforts on particular features of a system need to be promoted.

10.3.5 Post Installation Impact

Opinions voiced by the teachers show (Figure 25 and Figure 35) the systems have contributed to an improvement in student performance, which was due mainly to extended study hours (Figure 26). Although this is a perception, the importance of this aspect warrants in-depth factual research. Since electrification of the schools, the following activities have been arranged in the communities: evening classes (31%), Adult Basic Education (13%), fund-raising (13%), video shows (13%), church services (13%) and community meetings (17%).

10.3.6 Needs of Community

The literature review[38] has highlighted an acute lack of detailed socio-economic data, and of information on the real needs and priorities of schools and communities. It is widely recognised that the most successful products and services are that most closely linked to customer needs, preferences and values.

The literature[38] also demonstrates the urgent need to involve a coherent and integrated energy strategy that promotes the various energy sources. The historically disadvantaged rural population could be in danger of being marginalised once again, if their energy requirements are not addressed holistically.

10.3.7 Summary of Conclusions Phase 2 and 3

The following items were concluded in Phases 2 and 3:

- Educational benefit to 396 000 students
- Improved studies

- Teachers do not stay in rural areas where there is not electricity.
- Lack of process to introduce new technology to rural people
- Community interaction a problem
- Local government not involved in process
- No community buy-in
- Who is the systems owner?
- No application to support the installation of systems
- Schools and community needs were not determined - sizing
- Participation with other role-players not considered
- Department of Education accepted the programme, although information has not filtered down to community levels
- No audio-visual equipment was provided to schools from Department of Education
- No Adult Basic education took place as was originally discussed and planned in original proposal
- School not used as a community centre
- Usage of systems a concern
- Advantages and disadvantage not clear to school staff
- Use of systems as far as communities are concerned to be exploited
- Entrepreneurial skills are lacking
- Maintenance programme lacking
- No training of technician from Department of Education or community electricians
- Roles and responsibility for maintenance not clear
- Maintenance programme not in place
- Monitoring of systems lacking
- Photovoltaic standards and Best Practises lacking
- Longer study hours at schools
- Lack of detailed socio-economic data
- No coherent and integrated energy strategy

From the above it is clear that:

- No community interaction prior to electrification leads to lack of understanding and knowledge of communities' needs. Full use of systems not possible – i.e. no community use of school facility, Adult Basic Education, etc
- Individual schools and community needs were not determined and addressed simultaneously, which created isolation of the schools
- Department of Education were not fully involved, no audio-visual equipment were provided to schools, maintenance lacking and no post installation evaluation was done on the systems at the schools

10.4 PHASE 4 - TECHNICAL CONCLUSION

The technical monitoring highlighted the overall behaviour of the end-users, which depends on their geographical location and on their consumption habits. The project has enhanced general knowledge and expertise in the field of photovoltaic autonomous systems, particularly as far as utilisation of gathering data is concerned.

10.4.1 Solar Radiation

In order to simplify the design a single radiation figure was used ($5kWh/m^2/d$). The decision was checked against the available meteorological data, and the same weather station (Durban) data were used for all the schools. The assumed solar insolation data proved to be acceptable. For each month the deviation from the assumed constant value of $5kWh/m^2/d$ was not more than 13%.

10.4.2 Array Performance

The photovoltaic array in most cases operated according to the design specifications. If an average performance index is selected (Actual AHP vs Anticipated AHP - Table 14) to represent all the schools, a figure of 90% is obtained, whereas the ideal would be 100%.

10.4.3 User Estimate (Load Profile)

In all cases, the measured load demand was extremely low compared with the anticipated load demand. No trend could be determined from the results. Although an increase in load demand is to be expected in time, it is doubtful whether the anticipated demand would be reached within a reasonable time. Communication with the communities is essential to understanding the reason for the situation.

10.4.4 Consumption Data

The results indicate a reasonable agreement between the charge consumed and the charge accepted by the batteries. In two cases (Seplan – Figure 40 and Nkundla – Figure 41) regulator malfunction is suspected, which would lead to severe overcharging of the batteries. During the logging period no action was taken to intervene, indicating a lack of maintenance.

10.4.5 System Sizing

The results show that from a technical point of view the installations had not produced the expected daily energy delivery. Consideration should be given to a review of the design model and methodology. However, paradoxical as it may seem, after analysing the consumption habits of the end-users it appears that the systems are in fact oversized.

10.4.6 Utilisation

The actual utilisation is approximately 10 times less than the design value. Although provision should be made for an increase in future consumption, it is doubtful whether the consumption will grow to such an extent as to warrant the extreme oversizing.

Oversizing of the systems led to recurrent boost charging in several cases, related to the functioning of the type of regulator used. Regulator malfunctioning and/or inappropriate regulator functioning could be the cause. This would result in premature ageing of the batteries and consequently shortening of the battery life.

10.4.7 Summary of Conclusions Phase 4

The following items were concluded in Phase 4:

- Gained knowledge and expertise in the field of photovoltaic systems
- Single radiation figure was used
- Average Performance index used – 90% obtained – 100% would be ideal
- Measured load demand low compared to the anticipated load demand
- Lack of maintenance
- Installations did not produced the expected daily energy delivery
- Systems oversized
- Utilisation approximately 10 times less than the design value
- Oversizing of the systems led to recurrent boost charging

From the conclusions for Phase 4 it is clear that:

- No maintenance plan is in place
- Systems are oversized
- Utilisation is a problem

10.5 CONCLUSION

The conclusions of phases 1, 2, 3 and 4 have been discussed in this chapter. The recommended process for the electrification of photovoltaic solar energy to medium-scale installations in South Africa will be discussed in chapter 11.

11 PROPOSED PROCESS FOR THE APPLICATION OF PHOTOVOLTAIC SOLAR ENERGY TO MEDIUM-SCALE INSTALLATIONS

11.1 INTRODUCTION

The discussion of the Non-Grid Electrification Schools Programme in the Eastern Cape formed the basis for this study. It has shown that many problems experienced all over the world are similar in nature. The success of the non-grid schools electrification programme must be based on both a solid social and technical foundation. This chapter discusses at recommendations that should be implemented with regard to the application of photovoltaic solar energy to medium-scale installations in South Africa. The recommendations are applicable for South Africa, but lessons learned from this study can be applied world-wide.

The structure of this chapter is as follows:

- Summarising the key success factors for such a programme
- framework for a new consolidated and robust process
- discussing the consolidated and robust process.

11.1.1 Summarising the Problem

The key success factors for such a project were identified in chapter 1 and are summarised here with an indication of the degree to which they have been achieved.

Key Success Factor	**Level achieved**			
	Fully	**Partially**	**Weakly**	**Not at all**
Department of Education				
Systems usage 3-4 hours daily for lighting, television, and video recording			✓	
More study hours available for pupils after hours			✓	
Improved student performance			✓	
Well maintained systems, and there will be a schedule available for the maintenance of each school.				✓
Maintenance programme in place for the first level of maintenance as well second level of maintenance				✓
Prioritisation and statistical analysis of schools making electrification planning possible				✓
Local Government will be involved in the process			✓	
Accepting full responsibility for the ownership of the systems		✓		
School applied for the non-grid electrification before installation	✓			
Audio visual equipment available at the schools			✓	
User education provided by the installer	✓			
Awareness at all schools regarding non-grid electrification		✓		
Education Management Information System in order to realise the impact of electrification and other commodities in the schools				✓

Key Success Factor	Level achieved			
	Fully	Partially	Weakly	Not at all
National Electricity Regulator				
The development of an integrated rural development plan				✓
Implementation of new technology. The introduction of new technology will be in accordance with the electrification programme				✓
Communities				
Technical and entrepreneurial skills development			✓	
Extramural activities such as adult basic education, fundraising etc. available at schools			✓	
Small, Micro and Medium Enterprises development				✓
Participation with Government, Department of Education, Eskom and other roll players for the electrification of schools		✓		
Energy Committees making informed decision regarding the areas to be electrified				✓
The suggested needs of the school in order to design the appropriate system for the school				✓
The use of the school as a community centre			✓	
Improved community interaction with the school and ongoing fundraising initiatives.				✓
Government				
Integrated energy strategy that promotes various energy sources				✓
Stimulate economic development			✓	
Gained knowledge regarding photovoltaic systems in the field, broad database	✓			
Integrated electrification planning			✓	
Energy Database available showing the areas for grid and non-grid				✓
Observed synergy between all stakeholders. Government should be responsible for the overall planning of electrification of areas, and the participation of various stakeholders in the electrification process			✓	
Clear policy regarding non-grid electrification areas In South Africa. Communities should know that they will only receive grid within the next five years. This should allow communities to make an informed energy choice				✓
Local black economic empowerment should be enhanced. The fact that the systems are easy to install should allow for Black Economic Empowerment to be developed within rural areas. This will ensure job creation.			✓	
Training of local entrepreneurs to enhance job creation within the community. Meaningful income should be generated within communities because of the systems that are designed according to the needs of the community. This will allow for Small, Micro and Medium Enterprises size companies to be formed. Again this will show that Government is looking after growing business throughout South Africa			✓	

Key Success Factor	Level achieved			
	Fully	Partially	Weakly	Not at all
Service Provider/Utility				
Participation with other stakeholder should be visible such as roads, water, telecommunication				✓
Monitoring of systems should be able to determine the status of the programme at all times				✓
Best practises should be readily available		✓		
Standards regarding the implementation available		✓		
Gained knowledge regarding photovoltaic systems in the field, broad database			✓	
Performance index should be 100%				✓
Measure load demand will be high				✓
Installations to produce the expected daily energy delivery				✓
Correct sizing of systems			✓	
Utilisation high				✓
Internet design support				✓
Data collected during the pre-electrification process should be used for the design			✓	
Tendering process should consider Black Economic Empowerment		✓		
Post installation impact study			✓	
Clear policy regarding non-grid electrification known to all departments in Eskom. Role clarity between the various line groups should be in place				✓
Cost effective systems		✓		
High levels of community participation			✓	
Feedback to Government regarding the programme and the success achieved			✓	

While the table shows the complete record, each stage of the process had particular lacks.

- At all stages entrepreneurial skills in communities were not addressed. No job creation was promoted within the existing process. Any process hoping to achieve sustained development should make provision for job creation.
- Community participation and needs. Eskom had interaction with the communities but it is clear that communities did not understand the process and the needs of the communities as well as the school needs were not addressed. The use of the school after hours was not discussed and elaborated.
- Pre-electrification process. The needs of the school and community were not fully investigated and understood during the pre-electrification, evaluation and selection process. If the needs are identified properly within the context of the social life in the community, the systems can be designed to suit the school and community needs.
- Systems design. Systems were oversized because needs were nor taken into consideration. Sizing should be in accordance with the needs of the school as well as the prioritisation of the Department of Education. In the commercial process the training and appointment of local entrepreneurs should be promoted.
- Installation and Training. The training of the installers should have been addressed before contract award. Sustainable development can only be enhanced with the integration of the community economic fibre in a well-organised commercial process that follows the design phase. Installation

by the contractors has been according to a standard set by Eskom. These standards should be addressed in the training programme of all contractors. Ownership is a problem and this needs to be included in the policy of government.

- Maintenance. From the conclusions, specifically Phase 4, it is clear that no functional maintenance programme was in place. Apart from the systems that are not used, theft and vandalism is a problem for the Department of Education. If a maintenance programme is in place the community and school will see that the Department of Education is serious about school electrification.
- Post Installation Monitoring. No post installation monitoring was in place. This could have prevented the low utilisation of the systems at an early stage, making corrective action possible, which would have prevented damage to batteries and possibly reduced theft. From the study it is clear that the low or no usage by the school run down the batteries.

The process followed involved only the Department of Minerals and Energy, Eskom and the Department of Education as illustrated in Figure 46.

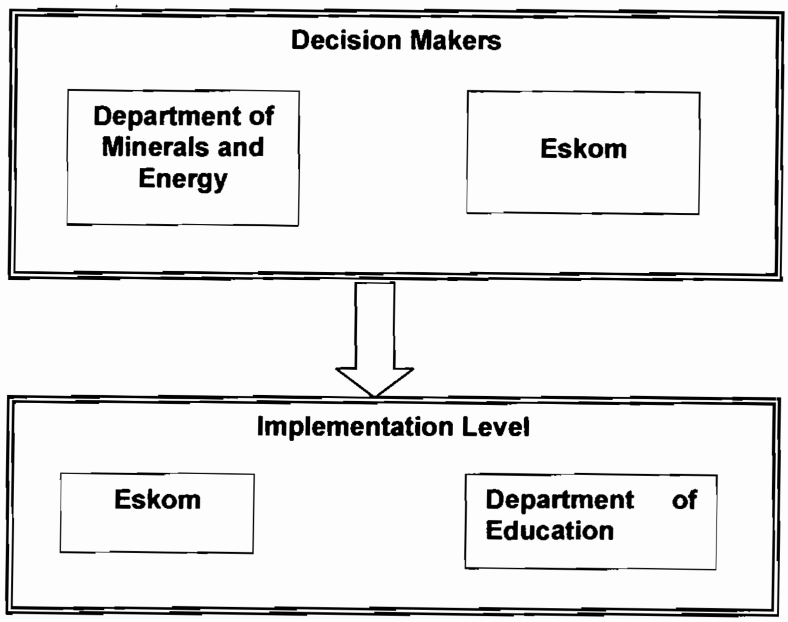

Figure 46 Existing Non-Grid Electrification Programme

11.2 THE NEED FOR A CONSOLIDATED AND ROBUST PROCESS

While these are specific problems, it is argued here that they were inevitable consequences of the way in which the initiative was structured (Figure 1). This structure resulted in a situation whereby the non-grid electrification programme was tackled as a series of projects, rather than an integrated process: it occurred outside of an integrated, consolidated framework. Any lasting improvements require a totally different framework.

This raises the question of what the nature and form of a framework to guide a robust process should be. The following sections attempt, on the basis of the conclusions discussed in chapter 10, to develop such a framework. It is contended that the framework outlined could be applied to the application of photovoltaic solar energy (or any other renewable form) to any medium-scale installations.

The overarching anatomy of the framework is shown in Figure 47

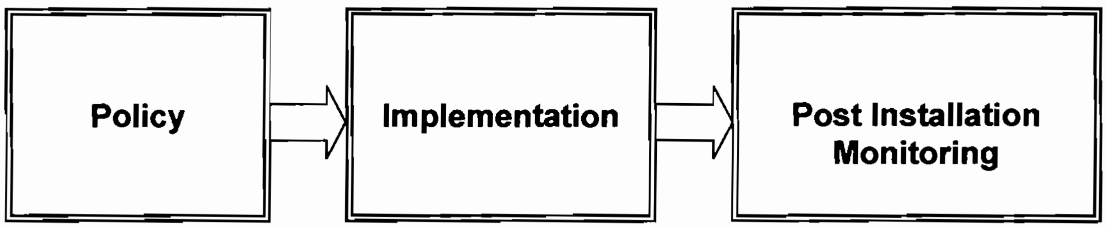

Figure 47 Anatomy of the Framework

11.2.1 Some Central Starting Points

This framework (under DME custodianship or other identified Government body) starts with the formation of a national and provincial policy, which will demarcate the National Electricity Regulator's responsibilities. The policy will have to look at the objectives and responsibilities of each role-player in the electrification of medium-scale installations for rural areas in South Africa. The NER will have to comply with the policy of national government. A national policy will ensure synergy between all role-players. Job creation should be clearly spelt out in the policy as far as rural development is concerned.

Community participation for such a programme is clearly vital for the sustainability of such a programme. The community will safeguard systems that belong to the community.

The research results indicate that a pre-electrification phase is required in the process. The pre-electrification evaluation and selection criteria by the Department of Education will look at the needs of the school and community needs. In order for the Department of Education to plan electrification in collaboration with DME and NER according to the established policy it is necessary to have a database of all schools in the respective province. The school needs have to be considered, as well as the community needs. The lack of a clear policy led to the electrification of schools in isolation, alienating community support. Determining the needs will determine the design specifications necessary to suit the schools and communities needs. Such an integrated approach will also prevent theft and non-maintenance of systems.

Having obtained the correct design and knowing the needs of the school and community, local entrepreneurs can be appointed through the commercial process. Training of local entrepreneurs creates jobs within the community and will ensure sustainability of the programme.

Maintenance is critical to such a programme. Without a maintenance programme the sustainability will not be achieved. All role-players should be aware of what is expected and by whom. Training of entrepreneurs, and staff from the Department of Education needs to be implemented so that the maintenance of the systems can be looked after.

Installation needs to be according to Best Practises and set standards.

Post installation monitoring is necessary to ensure the sustainability of all systems at schools. The objective should not only be electrification but also to promote other areas of infrastructure development such as roads, water, sanitation, communication and education in South Africa.

11.2.2 Fleshing out the Framework

The elements of the framework are summarised in Figure 48and are discussed below under the broad heads of policy, implementation and post installation monitoring.

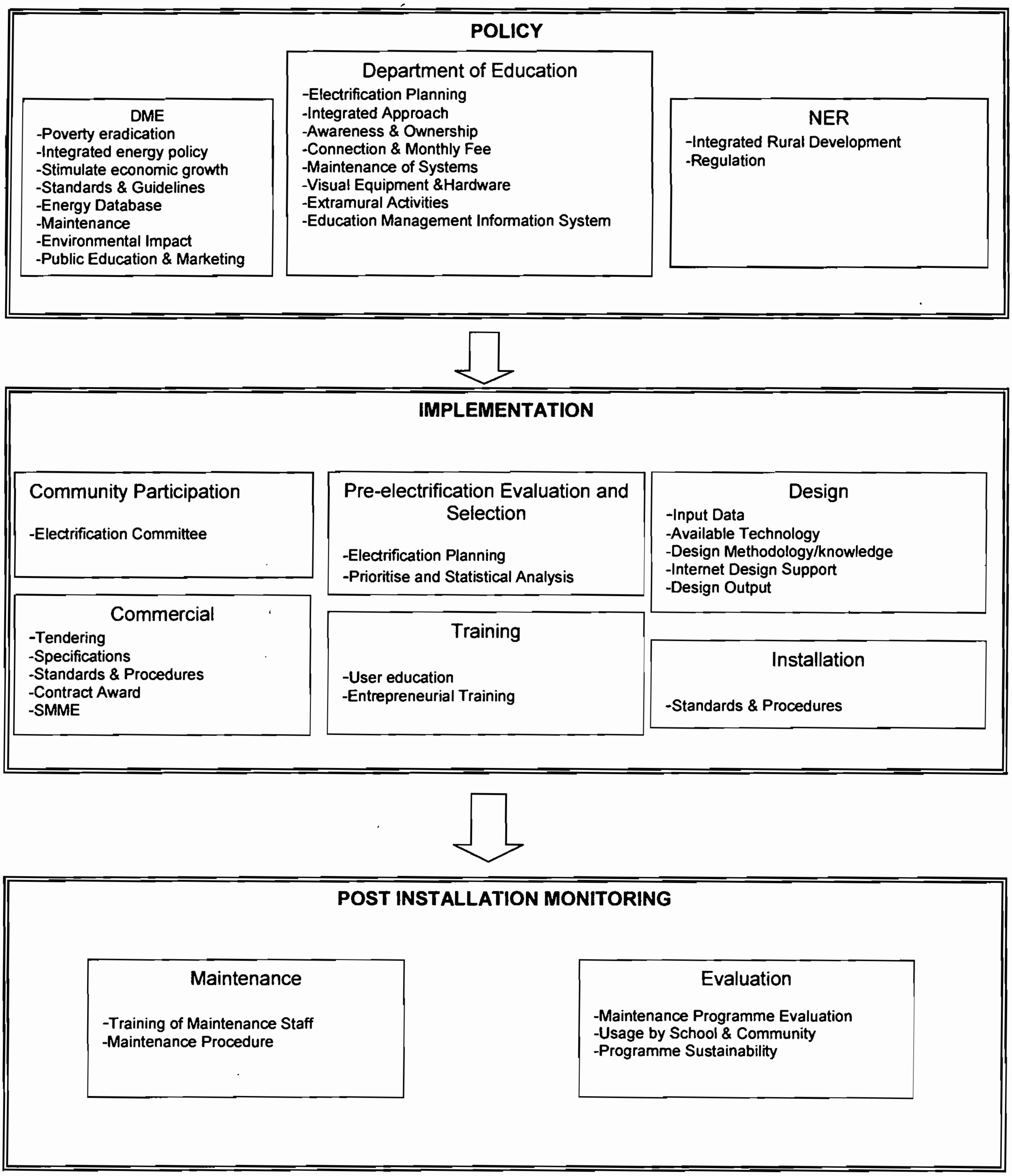

Figure 48 Consolidated and Robust Process

* **Policy**

South Africa needs an integrated energy policy based on new social and economic imperatives relating to reconstruction and development in South Africa. All the role-players should form a group to discuss co-operation around relevant government policy. The policy should be developed within a framework[27] that is:

* holistic – within the context of the national economy: the energy needs should be determined, and meeting them should achieve growth and development targets
* realistic – based on the capacity of the government, that is managerially skilled manpower, and financial and physical resources available; and
* Participatory – with attention being paid to design, implementation, support, training of technicians, monitoring of programmes and projects, and educational material to support community education to ensure maximum popular involvement and distribution of benefits. Unemployment needs to be minimised.

Department of Minerals and Energy

The policy should be linked with the Energy White Paper[79] prepared by DME. The following aspects mentioned in the White Paper should be included in the policy:

* *Integrated energy policy*. Renewable electrification should be treated in the same way as grid electrification. Integration of grid and non-grid electrification should be planned according to a single National Electrification Programme. This integration will form an integral part of the restructuring of the electricity distribution industry. The policy should increase access to affordable energy services. Specific attention should be paid to disadvantaged households, small business, and community services. The end-user should know the energy choices and be able to make the choices themselves. In this manner household energy services are improved, including electrification. A way to determine cost-reflective tariffs should be established. Rural villages should be electrified by providing institutional power supplies to schools, and clinics. Co-ordination with the Department of Water Affairs, Telecommunication, etc should be established. In order to have a sustainable renewable programme in South Africa the government should encourage and support renewable sources of energy. This should not only apply to PV but also to new initiatives.
* *Stimulate Economic Development*. Stimulating economic development in rural areas should be encouraged by fair competition within energy markets. The policy should make provision for government to provide focused support for both small and large-scale applications. The support of local Renewable Energy industry with specific focus on job creation and capacity building is necessary. Funding for the electrification of villages should be through the utility. This should be regulated by the NER. Through the Non-Grid schools electrification programme, black economic empowerment is facilitated. This way the previously disadvantaged people of South Africa are assisted in gaining entry to the energy sector.

- *Standards and Guidelines*. Provide for the development of appropriate standards and guidelines and codes of practice for the correct use of Renewable Energy Technologies. Appropriate training courses should be developed.
- *Energy Database*. Renewable Energy and related information should be integrated into the envisaged energy database co-ordinated by the DME. This information should be gathered in a Geographical Information System (GIS) The government should establish appropriate renewable energy information, statistical and database systems. This database will assist in the dissemination of the renewable energy statistics.
- *Maintenance*. Communities should be trained to encourage maintenance of renewable energy technologies.
- *Environmental Impact*. An environmental programme should be in place that will harness effective environmental project selection, design and implementation.
- Public Education and Marketing. Public education is necessary in order to promote these programmes. Renewables are foreign to targeted end-users and some of the technologies are still in the assessment phase.

The policy needs to give guidance to all of the major agencies involved in the initiative.

Department of Education

The Department of Education needs to build into its policy electrification of schools and the following areas of responsibility should be addressed:

- *Electrification Planning*. The Department of Education is to prioritise schools according to real needs. The Department of Education is a key role-player in this programme because the programme demands full participation of the professional cadre in the education system. The Department of Education should accept the programme and take full responsibility for creating support and facilities to enhance the utilisation and maintenance of the systems in all schools.
- *Integrated approach*. It was found in Phase 1 that there is a lack of structured and functional co-ordination among stakeholders to promote synergy and, by the same token, achieve smooth and efficient running of the programme at all levels. An integrated approach is to be created by the Department of Education so that more facilities are incorporated into a community once development begins. The integrated approach is to work with the Department of Water Affairs, Telkom, IDT etc.
- *Awareness and ownership of systems*. The Department of Education should develop a campaign to raise awareness in the education profession and communities. This will increase a feeling of ownership once systems are installed.
- *Connection and Monthly fee*. As with grid connected systems some form of connection fee should be payable. The monthly fee per student should make provision for the maintenance of the systems. The community should participate so that commitment from school and community is ensured.

- *Maintenance of systems.* Before a school is electrified, a maintenance contract should be in place to ensure that the system is in working order at all times. This will contribute to the sustainability of the programme.
- *Visual equipment/hardware.* The Department of Education is to ensure that visual equipment is in the budget and schools are to be provided with television sets, video machines, and overhead projectors. The Department of Education should decide about satellite dishes to be supplied to senior secondary schools so that distance learning can be accommodated at the school. This will ensure that there is greater value added to the education process.
- *Extramural activities.* The extramural activities of the school will determine how much the electrification will be used, and school and community should be encouraged to use the school for these activities. The Department of Education needs to provide permission to use school facilities.
- *Education Management Information System.* In the second Education White Paper[80] on the organisation, governance and funding of schools, the need is expressed for an Education Management Information System (EMIS) to link all schools to the provincial education departments, and the provinces to the national department. Such an EMIS would supply the information, including an index of needs, on which decisions for the allocation of resources could be based. The index is also required as a planning tool for departments of education. Linking these information needs with an Education Geographic Information System would support and enhance educational planning and decision-making. It would also supply providers of basic services to the schools with the geographic positions of schools, while maps of spatial patterns of indicators could serve as a tool for monitoring on the implementation of the programme. Aggregated education data is important for national level planning and budgeting purposes.

National Electricity Regulator

The NER receives its mandate from the Electricity Act 41 of 1987 as amended in 1994 and 1995. Any undertaker of electricity distribution should obtain a distribution license from the NER if the distribution of electricity is in excess of 5 GWh/annum. The NER[81] sees the following:

- *Integrated Rural Development.* In an effort to develop an appropriate sustainable non-grid electrification programme plan, attention should be paid to an integrated rural development policy, which targets rural areas with the aim of lifting incomes above subsistence levels. The NER should advise the policy makers to give some attention to formulate income polices in order to create self-sustainability.
- *Regulation.* The objectives should be:
- *Implementation of new technology.* The introduction of new technology requires a massive educational effort. New technology should be introduced with care. Adapt the technology to human needs and not humans to the needs of technology. The values of the community should be taken into account when new technology is introduced, and the project should be driven by demand from the community. This way the community

gains confidence in the new technology and sustainable development is ensured. In order to achieve the maximum benefit at the minimum cost, not only to fulfil their needs today, but those of their children and of the future generations the community should be made aware of the need to manage the resources wisely. The implementation of school electrification should be fast enough to ensure motivation and political/institutional interest, but slow enough to have leeway for corrections without deviating from the project. This kind of balance should help the installer and the community to adapt to the new technology. People-driven development has its origin in the concern that the people who are the beneficiaries of a project should have control over it. People-driven projects thus aim to build capacity in the process of implementing the project, rather than just delivering a product. These types of projects can be slow, as their starting point is determined by the existing capacity of the intended beneficiaries. The community determines what project to implement, and through the process of implementing the project capacity is increased, thereby changing the parameters of what can be achieved in the next project. Once the community knows what the programme entails, and what the value of the new technology is, the community will take ownership of the project, reducing theft and vandalism. Communities need to be educated on the ways that this new energy source can be utilised and improve their way of life, standard of living and income.

- *Rural development.* Rural electrification should be aimed at achieving rural development. Rural development is to alleviate labour intensive practices for domestic needs, boosting the income of rural dwellers and improved way of life by means of energised and properly serviced public facilities.
- *Innovation.* Regulations should encourage innovative approaches to achieving government objectives and rural transformation.
- *Monitoring and Evaluation.* Criteria to monitor and evaluate development impacts should be developed.

- **Implementation**

There are a number of issues, which need to be addressed at the installation stage. This are discussed under the broad heads of phases in the process.

Preparing the Ground

It is necessary to establish an electrification committee from the outset. The implementation body should discuss the programme with the Provincial Government and win support for the programme. The Transitional Local Government (TLC) should be informed and their approval obtained. The TLC in the area should advise all the stakeholders of the programme, and chiefs in the villages made aware of and lend their support to the programme. The most important factor in the success of this programme is support from the provincial government, TLC's and chiefs from the area. The community structures should be followed according to the culture of the area. An electrification committee within the communities in collaboration with Provincial, Local Government, implementation body, suppliers and community role-players needs to be established. These identified villages and their needs should be evaluated according to pre-electrification criteria developed by the Department of Education, the implementation body and provincial and local authorities. Women should be included in the electrification committee to address inequalities and to empower one of the most oppressed sectors of society. Women have accepted strategic responsibility for the welfare of the rural household, so empowering women inevitably leads to improve education, nutrition and health care opportunities for the children. Hence there are enormous social benefits to improving the situation for rural women.

Pre-electrification Evaluation and Selection

The following issues are important in the pre-electrification evaluation and selection of schools:

- *Electrification Planning.* The Department of Education through its policy should have an electrification plan. This plan should be contained in the process. Eskom will have to support the Department of Education in this.
- *Prioritisation and Statistical Analysis.* The Department of Education should prioritise schools according to real needs. Provincial, regional and area forums should be established. These identified villages and their needs should be evaluated according to pre-electrification criteria developed by the Department of Education, Eskom, and provincial and local authorities. Some form of statistical evaluation should be developed to incorporate the above criteria, which could serve as a prioritisation tool:
- Distance from grid. There should be a predetermined distance (for instance 5 km from grid will qualify for non-grid electricity)
- Condition of a school. The school building should be from brick, secure windows, and safety fence.
- Type of school. Senior secondary schools should be electrified before considering senior primary or junior primary schools. The use of platooning (double shifts) plays an important part in determining the criteria
- Support from the community for the school. Community participation should be clearly shown by interaction through needs analysis and involvement in raising funds for the school.
- Security at the school. The school should have a safety fence, doors that lock and burglar bars.
- Teachers staying in the village. Where teachers stay in the village the success of the electrification will be greater. Through this teachers will be recruited for the Department of Education.
- Maintenance contract and maintenance team; training of maintenance team. The training of the school staff and contractors should be determined up front. Maintenance contract to be in place with the Department of Education.
- Existing GEAR projects in the community. Look at other GEAR projects to improve the successfulness of the programme.
- Development in the community. Other community development should enhance the programme and should be taken into consideration.
- SMME's in the area for installation. In order to create jobs within the community, SMME's in the area should be noted and trained.

- Needs to be incorporated into other projects such as Telkom, Department of Water Affairs. Other needs and co-operation should be taken into account and co-operation with other departments, institutions should be considered.
- Extra mural activities.
- Best energy option. According to the policy the best option for the specific area should be considered.
- Database to determine energy source for the area. An energy database is needed and according to the predetermined source the choice should be made.
- Classrooms per school. The school needs to determine the needs and electrification should be handled accordingly.
- Students per school. Again the needs of the schools and total number of students needs to be considered.
- Teachers per school. Teacher's houses should be electrified in order to keep the teachers in the communities.
- Principal to complete application form. All application forms needs to be signed by the principal so that he/she has a contract with the Department of Education to maintain the system.
- School's stamp. The school stamp needs to be on the application form so that the school name can be identified and can be used as prove that the school applied for the system.
- GIS address. Each school should have a GIS address in order to comply with the energy database as per the DME policy.
- Area lighting. In order for the school to be used at night area lighting should be part of the installation at each school.

Design

- *Input data.* Information collected during the pre-electrification process should be used to provide input data for the design phase of the proposed process. School needs and school priority according to Department of Education as well as allocation of other equipment to the school (audio-visual, satellite, etc.) should be used to determine system size (number of lights and inverter power), installation criteria and energy made available (amount of PV modules, hours of use).
- *Available technology.* The available products and technology should be selected according to Eskom procedures based on set standards and directives.
- *Design methodology/knowledge.* The process should include a design algorithm for PV systems applicable to the schools situation.
- *Internet Design Support System.* Considering the conclusions, a school electrification decision support system should be developed and hosted on the Internet and/or intranet of the Department of Education and or Eskom for easy and continual access. This decision support software design tools system will save on the cost of manpower. The design can be carried out at the regional office because it is available through electronic media.

- *Design Output.* The design output should be contained in a standard format prescribed by the process such that all parties involved have access to relevant information applicable to the commercial process.

Tendering

The proposed process should make provision for a stipulated commercial process. The commercial process should consider the following:

- *Tendering.* Project particulars should be described in detail in the tender document
- *Specifications.* All specifications should be with the tender so that contractor knows what is expected during installations.
- *Standards and procedures for installation.* These standards and procedures should form part of the tender and contract.
- *Contract award.* Contract award should be in terms of the DME and Department of Education's policy.
- *SMME.* Tenders have to be evaluated according to quality of workmanship, Black Economic Empowerment, and previous records of installers.

Training

The process should consider the following:

- *User education.* The school staff should be trained in maintenance, and a dedicated person allocated to the maintenance of the system. Eskom or the installer needs to train the person and evaluate the maintenance from time to time, the principal should have a contact person for any faults that may occur. A help line should be available at schools.
- *Entrepreneurial Training.* Training programmes should be in place to develop local SMME's.

Implementation

The proposed process should contain the following document/s:

- *Standards and Procedures.* The requirements for the installation of PV systems needs to be according to the Installation Procedures, Code of Practise and Ancillary Equipment for Photovoltaic Systems.

- **Post Installation Monitoring**

Two issues are central in this phase.

Maintenance

The process should make provision for a maintenance programme. Photovoltaic systems are known to be low maintenance systems, but in order to maintain optimum, reliable and safe performance, to monitor the system, prevent breakdowns, and to detect possible problems it is important that a regular systematic maintenance programme be executed.

In the maintenance programme the following needs to be addressed:

- *Training of maintenance staff.* The contractor should train staff on PV system maintenance. Maintenance on the systems should be done six-monthly. In cases where the Department of Education is not committed to maintenance, schools should not be electrified. This programme is there to enhance education, but the PV market in South Africa should also be sustainable. Co-operation of all the stakeholders will add value to the programme.
- *Maintenance Procedure.* A maintenance procedure should be put in place. This programme should be followed to ensure optimum use of the systems.

Evaluation

The impact of technology on education and electrification should be monitored continually. The following needs to be monitored:

- *Maintenance Programme.* The maintenance programme should be evaluated against the set procedure
- *Usage by School and Community.* The limited capacity of the PV system implies that communities are equally constrained to initiate meaningful income generating activities through SMME's, which require a critical source of energy. SMME economic activities such as carpentry, sewing and knitting, small-scale irrigation farming schemes, food processing, etc. could be enhanced by finding a mechanism by which such services could gain access to the school system as it is currently not fully utilised by the schools. Provision should be made in the proposed process to address such issues if and when they arise.
- *Programme Sustainability.* The sustainability of the programme should be evaluated during post installation monitoring and provision made for corrective action, should it become necessary.

A checklist is attached in APPENDIX D.

11.3 FUTURE RESEARCH

The framework has attempted to be comprehensive. However, there are areas in which considerable further work is required. These include:

- Industrial growth and regional development – Different studies claim that because of electrification, industrial growth and regional development takes place. This should be a measured interim of the schools programme.
- Education – Studies claim that electrification enhances education; this is an opportunity to evaluate the outcome.
- Adult basic education – The Department of Education wants to enhance Adult Basic Education, but some of the teaching staff are against the programme because of uncertainty regarding remuneration for extra work. Role clarity should be achieved.
- The relationship between rural electrification, income and education in South Africa is an area that needs clarification.

- Costing method for renewables in South Africa – this study suggests the development of an expert system; this should be taken up and developed further. Expansion on the decision-making tool should include other energy options design, costs etc.
- Hardware failure – This is a problem that needs urgent attention if the PV fraternity in South Africa want to have a sustainable PV programme in South Africa.
- Use of educational aids – evaluate the teacher's knowledge and ability on the use of TV, video and overhead projector, etc.
- Evaluate the availability of training aid consumables, such as overhead transparencies, pens and suitable video material.

11.4 CONCLUSIONS AND IMPACT OF THE PROPOSE CONSOLIDATED AND ROBUST PROCESS

The recommendations proposed as a result of the current study culminate in a proposed consolidated and robust process for the electrification of medium-scale installations (Figure 48).

As shown in this study the potential human development impact could be tremendous. 80% of all the respondents indicated an improvement in education results through longer study hours. This finding warrants all the necessary effort to make a success of such a programme.

If all role-players (DME, NER, Relevant Government Departments, community, etc) implement the proposed consolidated and robust process, it would lead to an enhanced rural community electrification drive.

The study shows that the existing programme (Figure 47) is inadequate and not executed properly considering the key success factors mentioned under 11.1. The existing programme although exhibiting a top down approach contained significant pre-electrification activity. However, these activities where ad hoc due to the lack of an *integrated national policy*. The proposed consolidated and robust process, different from the existing programme, suggests the drafting of a clear policy before any implementation is to be executed in future. This policy and hence process is not to be confused with the DME Energy White Paper but should rather be viewed as one of many logistical energy implementation processes.

The participation of the Department of Education and Public Works (according to the findings) was not sufficient to ensure sustainability. The results demonstrate this in the areas of maintenance, community involvement, vandalism and theft. This situation may be attributed to the fact that photovoltaic systems are decentralised sources of power generation and as such become the property of the owner and not the service provider (electricity) as is normally the case. The research showed that communities and Education staff do not perceive the systems as Department of Education property. This resulted in a lack of post installation responsibility and *ownership.* A clear policy will alleviate such problems in future.

The study showed that the level of utilisation of the systems was far below the *design* sizing. It can be argued that utilisation levels will increase in time but as the study was done approximately one year after electrification, the expectation would be that utilisation has stabilised. This being the case one of two conclusions can be drawn. Either the design was inappropriate (over designed) or community needs were not identified properly. In either of the cases better pre-electrification evaluation and selection will lead to more realistic input data that will result in a more appropriate design.

The study showed that *maintenance* and post installation attention was seriously lacking. In the schools where a completed technical evaluation could be undertaken lights were found inoperative, batteries were stolen, battery connections were loose, vandalism was experienced and batteries were found in a discharged state. If adequate maintenance was done problems such as these would never have occurred.

The recommendations make provision for improvement of the existing programme through the implementation of the proposed consolidated and robust process addressing three main problem areas as indicated by the research:

- Improved role-player interaction through the creation of a national policy
- Better system utilisation through more appropriate design supported by an improved pre-electrification evaluation and selection process leading to better prioritisation and statistical need analysis of schools
- Enhanced systems sustainability and reliability, through adequate maintenance of systems.

APPENDIX A - PHOTOGRAPHS OF A TYPICAL INSTALLATION

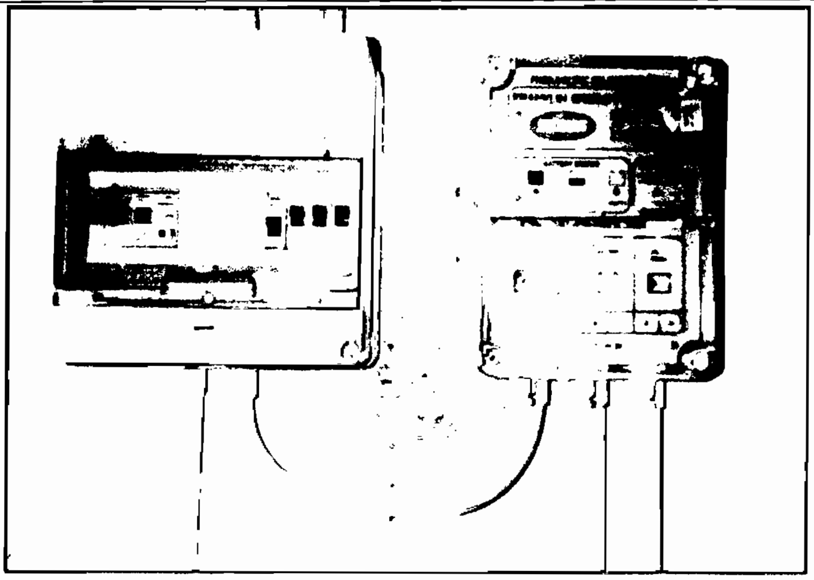

Figure 49 System Regulator and Distribution Board

Figure 50 Battery Enclosure

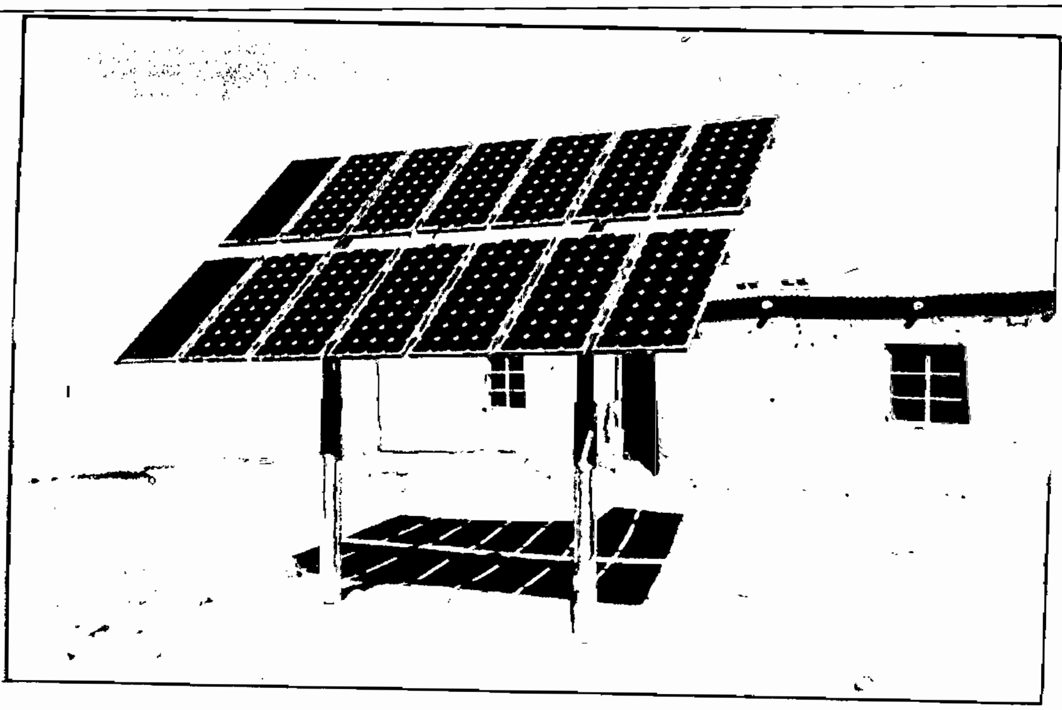

Figure 51 Solar Photovoltaic Array

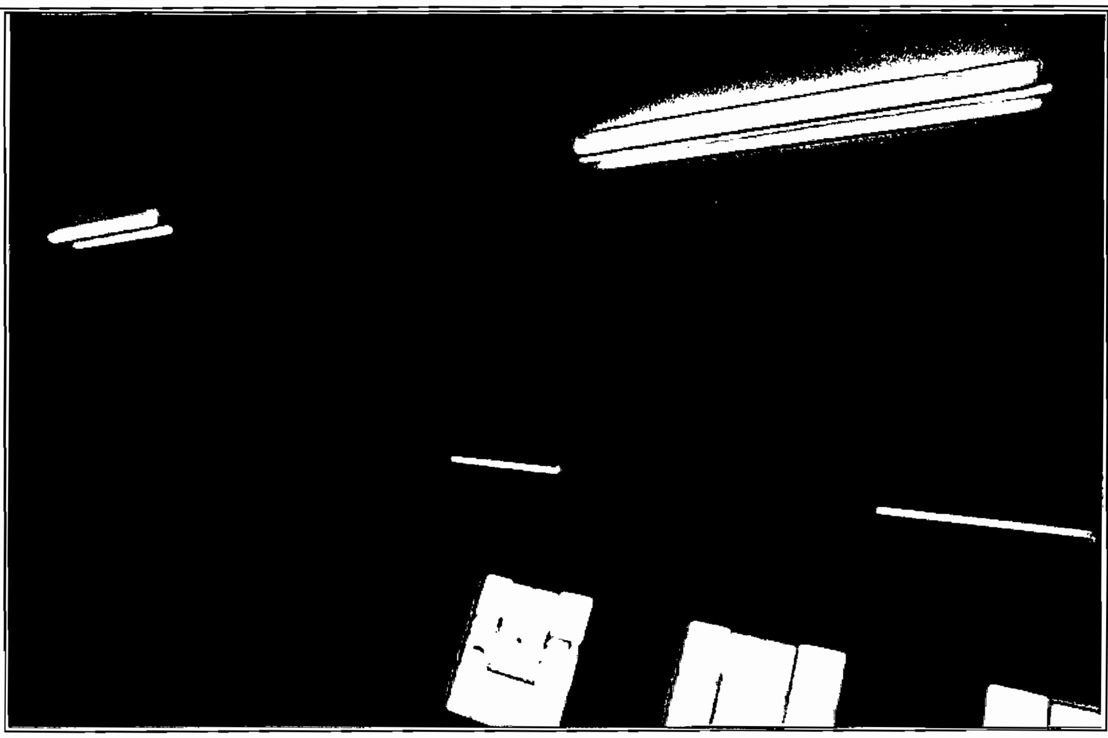

Figure 52 Lights Mounted on Ceiling in Classroom

Figure 53 Students Looking Forward to a Bright Future

APPENDIX B - QUESTIONNAIRE 1

School background – School principal/teacher

1. How many classrooms does your school have?
2. How many students are in your school?
3. How many teachers do you have?
4. What subjects are being taught?
5. Does the school have a boarding facility?
6. What type of energy are you familiar with in your community?
7. When did you first hear of the solar energy system?
8. Provide source of such information.
9. Did you receive any information about the PV system when it was being planned?

9a. If yes, give source of information.

10. When did your school apply for the system?
11. How long did it take to get it installed?
12. When was the system installed?
13. Who supplied the system?
14. Is the system still working?
15. What is the main use of the system?
16. For how long do you use the system per day?
17. Do you see any community benefit from the system?
18. In your opinion, do you see any improvement in the overall performance of the students as a result of the solar system?

18a. If yes, in which way?

19. What are the specifications of the system?
20. Does anyone maintain the system?
21. How often is this maintenance done?
22. Do you seek technical advice on the system?

22a. If yes, from where?

23. Do you know why it is not working?
24. Have your reported the problem to Eskom, Department of Education.
25. Are you satisfied with the response?
26. How far is the nearest Eskom electricity grid?
27. Do you know how much your school system cost?

28. Are you satisfied with the system?

28a. If no, give reasons.

29. In your opinion, what other applications could the system be used for?

30. Given your experience, what improvements do you think are necessary for the solar system to be more user friendly?

31. Would you encourage other schools to use your systems?

Student Views

32. Has the system helped you with your studies?

32a. If yes, how does it help?

33. In what other areas do you think the system could help?

APPENDIX C - QUESTIONNAIRE 2

Teachers and staff

1. Do you know that the school has been electrified?
2. Is the system working?
3. What does the school use the system for?
4. How many times per week do you use the system in the school?
5. How many times do you use the system per day?
6. Does the system help you, the teacher, with the education process?
7. Is there any improvement in the overall performance of the students because of the system?
8. Does the community use the school for evening classes, Adult basic education, fund raising, church services, video shows, community meetings?
9. How far is the nearest Eskom power line from the school?
10. In your opinion, is non-grid electrification an effective energy solution for rural schools?
11. Would you recommend non-grid electrification to other rural schools?
12. If your system is not working, to whom do you report the fault?
13. What other facilities do you need at the school?
14. Who does the maintenance of the system?

Community members

15. Do you know that your school has been electrified with a solar system?
16. Who informed you?
17. Does the system work?
18. Do you use the school for evening classes, Adult basis education, fund raising, video shows, church services, community meetings

APPENDIX D - PROCESS CHECK LIST

Process Check List for the Non-Grid Electrification of Medium-scale Installations

1 Policy

1.1 Department of Minerals and Energy Policy:

1.1.1 Energy choice available/preferred for area:

- Solar ☐
- Mini grid ☐
- Gas ☐
- Biogass ☐

1.1.2 Economic growth requirements:

- Job creation ☐
- Funding ☐

1.1.3 Obtain standards and guidelines:

- Best Practice ☐
- Standards ☐
- Guidelines ☐

1.1.4 Energy Database:

- Access to database ☐
- Fees ☐

1.1.5 Maintenance Required? (yes/no) ☐

1.1.6 Environmental Impact Study required? (yes/no) ☐

1.1.7 DME Public Promotion and Marketing completion date ☐

1.2 Department of Education Policy:

1.2.1 Electrification Planning:

- Schools prioritised? ☐
- Community forums active? ☐
- Needs analysis completed? ☐

1.2.2 Integrated approach:

Other role-players involved in area? (yes/no) ☐

1.2.3 Awareness and ownership:

At Provincial Level? (yes/no) ☐
At Regional Level? (yes/no) ☐
At Community Level? (yes/no) ☐

1.2.4 Payable Connection & Monthly Fee:

Connection fee? ☐
Monthly fee per student? ☐
Community commitment ☐

1.2.5 SMME's in area

Contact Names Obtained? ☐
Previous Training Record/s (non grid) obtained? (yes/no) ☐
Previous Contract History obtained? (yes/no) ☐

1.2.6 Relevant Community Activities:

Sewing ☐
Water purification ☐
Water pumping ☐
Bakery ☐
Clinic ☐
School ☐
DSTV ☐
Video Shows ☐
Church services ☐
Community meetings ☐
Telephones ☐
ABET ☐

2 Implementation

2.1 Electrification Committee Established? (yes/no) ☐

2.2 Pre-electrification criteria completed? (yes/no) – (See Appendix E for application form) ☐

2.3 Contracts awarded ☐

2.4 Training completed ☐

2.5 Design according to needs analysis ☐

3 Post Installation Monitoring

3.1 Maintenance:

Weekly	☐
Monthly	☐
Six monthly	☐

3.2 Evaluation:

Maintenance programme followed	☐
School and community usage	☐
Programme sustainability	☐
Community forum workshop	☐

3.3 Sustainability Report:

Department of Education	☐
Department of Minerals and Energy	☐

APPENDIX E - APPLICATION FORM

APPLICATION FORM CLINIC/SCHOOL

NAME OF CLINIC/SCHOOL		
CLINIC/SCHOOL REGISTRATION CODE:		
SERVICE PROVIDER		
ATTENTION:		
P O BOX:		
	POSTAL CODE:	DATE RECEIVED BY SERVICE PROVIDER:

Dear Sir/Madam

FORMAL APPLICATION FOR POINT OF SUPPLY OF ELECTRICAL INSTALLATION FOR A CLINIC/SCHOOL

Due to shortage of funds I/We as the clinic or responsible Department of Health "Owner" hereby apply to the service provider for the supply of the following:
(Mark the applicable blocks with an X).

	Required	
	Yes	No
• Non-Grid Electrification		
• Other		

Should you be able to electrify our clinic/school at your expense I/We as the above mentioned undertake to be responsible for the following:
(Mark the applicable blocks with X)

(a) Payment of the electricity usage by the clinic/school

(b) Payment of the monthly maintenance fee by the applicable department of ....

(c) Ensure the security of the installation as part of the clinic/school

Yours faithfully

....

DEPARTMENT OF ....

NAME IN PRINT	SIGNATURE	DATE
....	....	....

CLINIC/SCHOOL REPRESENTATIVE

NAME IN PRINT	SIGNATURE	DATE
....	....	....

LOCAL GOVERNMENT REPRESENTATIVE

NAME IN PRINT	SIGNATURE	DATE
....	....	....

NAME OF CLINIC/SCHOOL				
POSTAL ADDRESS				
	POSTAL CODE:			
PHYSICAL/STREET ADDRESS				
	POSTAL CODE:			
TELEPHONE NO:	CODE:	NUMBER:		
FAX NO:	CODE:	NUMBER:		
TYPE OF CLINIC/SCHOOL			YES	NO
	HOSPITAL/SENIOR SECONDARY			
	CLINIC/JUNIOR SECONDARY			
	MOBILE			
	NUMBER OF STOPPING POINTS			
	OTHERS (PLEASE DESCRIBE)			
PROVINCE	EASTERN CAPE			
	MPUMALANGA			
	GAUTENG			
	KWAZULU NATAL			
	NORTH WEST			
	NORTHERN CAPE			
	NORTHERN PROVINCE			
	FREE STATE			
	WESTERN CAPE			
MAGISTERIAL DISTRICT				
TOWN (OR NEAREST)				
VILLAGE/TOWNSHIP NAME				
SITE/ERF/PLOT NUMBER				
DEPARTMENT OF HEALTH/EDUCATION REGION				

(FOR OFFICE USE ONLY)

CUSTOMER SERVICE DISTRICT			
ENGINEERING AREA			
NETWORK AREA			
IS THE CLINIC CONNECTED TO A SOLAR SYSTEM		YES	NO
IF *YES* WHO WAS THE DONOR?			

CONDITIONS OF CLINIC/SCHOOL:				
DESCRIPTION	MATERIAL TYPE	CONDITION		
		GOOD	FAIR	POOR
FLOORS				
WALLS				
CEILINGS				
ROOF TRUSSES				
ROOF COVERING				

NAME OF CLINIC/SCHOOL					
	NUMBER OF ROOMS WITH CEILINGS				
	NUMBER OF DOOR OPENINGS				
	NUMBER OF DOORS FITTED				
	NUMBER OF DOORS OPENINGS FITTED WITH SECURITY BARS/GATES				
	PERCENTAGE OF WINDOW OPENINGS FITTED WITH GLASS				
	PERCENTAGE OF WINDOWS COVERED WITH BURGLAR BARS				
	PROPER SECURITY FENCING INSTALLED				
	DESCRIPTION OF SECURITY FENCING		YES	NO	

INFORMATION	NUMBER	REMARKS
TOTAL NUMBER OF VISITS PER YEAR/TOTAL NUMBER OF STUDENTS		
NUMBER OF ROOMS		
NUMBER OF OFFICES		
NUMBER OF STOREROOMS		
NUMBER OF HALLS		
NUMBER OF ABLUTION BLOCKS – WATER BORNE		
NUMBER OF ABLUTION BLOCKS – NOT WATER BORNE		
OTHER STATE TYPE		
TOTAL NUMBER OF ROOMS		
TOTAL NUMBER OF ROOMS THAT REQUIRE ELECTRIFICATION		
EXAMINATION ROOMS		
OFFICES		
STORE ROOMS		
EQUIPMENT USED AT CLINIC/SCHOOL: SPECIFY		

OTHER USES OF FACILITIES	DESCRIPTION	YES	NO
	COMMUNITY CENTRE		
	VOTING STATION		
	RECREATION		
	RELIGIOUS ACTIVITIES		
	OTHER SPECIFY		

NAME OF CLINIC/SCHOOL			
SOURCE OF WATER:	DESCRIPTION	YES/NO	REMARKS
	IN-HOUSE		
	COMMUNAL TAP		
	ON SITE BOREHOLE		
	OTHER		
APPLIANCES:	DESCRIPTION	QUANTITY	REMARKS
	GEYSERS		
	STOVES		
	URNS		
	HEATERS		
	PUMPS		
	TELEVISION SETS		
	VIDEO RECORDERS		
	FRIDGES		
	PHOTOCOPY MACHINES		
	PERSONAL COMPUTERS (PC)		
	FAX MACHINE		
CONTROLLING BODY/INSTITUTION:	PUBLIC		
	GOVERNMENT		
	COMMUNITY		
	FARM		
	MINE		
	FACTORY		
	HOSPITAL		
	PRIVATE		
	WELFARE		
	CHURCH		
NAME OF CONTROLING BODY			
ADDRESS			
TELEPHONE NUMBER:			
CONTACT PERSON:			

CLINIC/SCHOOL REPRESENTATIVE

I .... certify that the information is true and correct
(Name in print)

....
SIGNATURE DATE

COMMUNITY REPRESENTATIVE

I .... certify that the information is true and correct
(Name in print)

....
SIGNATURE DATE

NAME OF CLINIC/SCHOOL						
1.	**LOCALITY**					
1.1	MAGISTERIAL DISTRICT					
1.2	TOWN OR NEAREST					
1.3	VILLAGE / TOWNSHIP NAME					
1.4	SITE / ERF / PLOT NUMBER					
1.5	TOPO CADASTRAL 1:50 000 SHEET NUMBER					
1.6	CO-ORDINATES	LATITUDE	__D__M____S South			
		LONGITUDE	__D__M____S East			
	COORDINATES TO BE DETERMIEND BY GPS OUTSIDE THE CLINIC OFFICE					
2.	**EXISTING ELECTRICAL INSTALLATION**					
2.1	IS THE CLINIC/SCHOOL TUBED?		YES	NO		
2.2	IS THE CLINIC/SCHOOL WIRED AND HAS FITTINGS?		YES	NO		
2.2.1	IF YES, IS THE INSTALLATION IN GOOD ORDER?					
2.3	NAME OF SUPPLY AUTHORITY	ESKOM	YES	NO		
		MUNCIPALITY (SPECIFY)				
2.4	IS THE CLINIC CONNECTED TO A SOLAR SYSTEM?		YES	NO		
2.4.1	IF YES, WHO WAS THE DONOR?					
3.	**CONDITIONS OF CLINIC/SCHOOL**					
3.1	DESCRIPTION	MATERIAL TYPE	CONDITION			
			GOOD	FAIR	POOR	
	FLOORS					
	WALLS					
	CEILINGS					
	ROOF TRUSSES					
	ROOF COVERING					
3.2	NUMBER OF ROOMS WITH FITTED CEILINGS					
3.3	NUMBER OF DOOR OPENINGS					
3.4	NUMBER OF DOORS FITTED					
3.5	NUMBER OF DOOR OPENINGS FITTED WITH SECURITY BARS/GATES					
3.6	PERCENTAGE OF WINDOW OPENINGS FITTED WITH GLASS					
3.7	PERCENTAGE OF WINDOWS COVERED WITH BURGLAR BARS					
3.8	PROPER SECURITY FENCING INSTALLED		YES	NO		
3.9	DESCRIPTION OF SECURITY FENCING					
3.10	SOIL CONDITIONS	SOFT SOIL	SOFT ROCK	HARD ROCK		
3.11	CAN THE BUILDING(S) BE RECOMMENDED FOR ELECTRIFICATION		YES	NO		
3.11.1	IF NO, STATE THE REASON:					

4.	**BUILDING TO BE WIRED**				
4.1	PREPARE AND ATTACH A LAYOUT PLAN OF THE CLINI/SCHOOL PREMISES				
4.2	CABLE REQUIREMENTS		DISTANCE	CABLE SIZE	TYPE
4.2.1	DISTANCE FROM BOUNDARY BOX TO MAIN DB				
4.2.2	DISTANCE BETWEEN BLOCKS (DB'S)	1 & 2			
		2 & 3			
		&			
		&			
		&			
		&			
		&			
		&			
4.2.3	TOTAL NUMBER OF BLOCKS				

NAME OF CLINIC/SCHOOL					
4.3	ROOM SIZES	NUMBER OF ROOMS	TYPE OF ROOM		
			CLASS	LIBRARY	OFFICE
4.3.1	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
	ROOMS - m^2				
4.3.2	TOTAL NUMBER OF ROOMS				

4.4	INSTALLATION DESIGN AND LAYOUT		
4.4.1	PREPARE AND ATTACH DETAILED INSTALLATION DRAWING		
4.5	LOAD REQUIREMENTS		
4.5.1	CALCULATE AND ATTACHE CALCULATIONS OF CLINIC/SCHOOL LOAD REQUIRMENTS		
4.5.2	SUPPLY SIZE REQUIRED	PHASE	kVA
4.6	ESTIMATED BILL OF MATERIALS AND COSTING		
4.6.1	COMPLETE "ESTIMATED BILL OF MATERIAL FOR WIRING OF CLINI/SCHOOL WITH COST ESTIMATE		
5.	**POINT OF SUPPLY REQUIREMENTS (ESKOM AREA OF SUPPLY)**		
5.1	SITAUTED WITHIN 200m OF A RETICULATED VILLAGE/TOWN/TOWNSHIP NETWORK?	YES	NO
5.1.1	IF YES, ATTACH EXTRACT OF AS-BUILT DRAWING		
5.1.2	IF NO, REFER ITEM 7.1.1 BELOW		
5.2	DETERMINE AND MARK UP ON PLAN TAKE-OFF POINT, RETICULATION LINE ROUTE AND POINT OF SUPPLY POSITION (BRIEF ITEM 5.2)		
5.3	STATE:	TRANSFORMER POSITION NUMBER	
		TAKE-OFF STRUCTURE NUMBER	
		ALTERNATIVE ID NUMBER	
5.4	DETERMINE SYSTEM LOAD (TRANSFORERM AREA) AND ATTACH CALCULATIONS		
5.5	PROVIDE DETAILED LINE AND SUPPLY POINT INSTALLATION DRAWING)		
5.6	PROVIDE BILL OF MATERIALS USING ESKOM STANDARD STRUCTURE PACKAGES		
6.	**POINT OF SUPPLY REQUIREMENTS (NON-ESKOM AREA OF SUPPLY)**		
6.1	PROVIDE DETAIL OF LOCAL AUTHORITY'S REQUIREMENTS FOR PROVIDING SUPPLY		
7.	**IF CLINIC/SCHOOL IS NOT SITUATED WITHIN 200m OF EXISTING POWER SYSTEM**		
7.1	ATTACH EXTRACT OF TOPO CADASTRAL AND NEAREST LINE POSITION INDICATED		
7.2	STATE DISTANCE FROM EXISTING POSSIBLE TAKE-OFF POINT		
7.4	NAME OF PLANNED PROJECT		

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