Rural Electrification Supply Options to support Health, Education and SMME Development

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EXECUTIVE SUMMARY

Context

This paper draws on three other studies which examine the role of electrification in supporting the health, education and SMME[1] sectoral development objectives[2]. The paper explores the extent to which different electricity supply alternatives can achieve the desired impacts, and evaluates whether current electrification programmes are supporting development needs in these sectors effectively.

This paper, as well as the health, education and SMME studies, form part of an Energy and Development Research Centre project entitled '*The role of electricity in the integrated provision of energy to rural areas*', which is aimed at assisting with the development of rural electrification policy.

Objectives

The specific objectives of this study are to:

- review the range of current electricity supply option characteristics and costs (grid and off-grid)
- link important energy inputs (as identified in the sectoral studies) to electricity supply options, and evaluates to what extent these options can support development needs in the health, education and SMME sectors
- consider parallel inputs required to ensure or enhance the impact of electrification strategies
- assess the benefits of electricity supply options relative to supply cost
- analyse current electrification practice to assess whether it is meeting sectoral needs optimally

Main areas where electrification can support sectoral development

The relative importance of electricity

All of the three sectoral studies stress that electricity is only likely to have a significant impact if it is linked with a more integrated approach to service delivery.

In rural clinics, an adequate electricity supply is merely one input into facilitating improved health care, and is typically not the most important input. For example, regarding the cold chain, the health study points out that the vaccine programme is '*most fragile at the points of human interaction rather than solely in the technical implementation of the cold chain*', and regarding improving staff facilities via electricity provision, the study says that '*it would not be wise to assume that electrification per se will ameliorate the working and living conditions that rural health workers will have to deal with*' (although other evidence contends this point).

The rural education sectoral study stresses how '*technology is only one part of a complex system of processes and relationships that make up the education and training system*', and summarises: '*where schools operate with few basic facilities, too few classrooms, and no resources to administer the service, the impact of electricity on teaching and learning is likely to be minimal*'.

The SMME sectoral study indicates that electricity is usually only of secondary importance given the other stronger constraints faced by rural enterprises, and thus '*rural electrification must be accompanied by complimentary inputs such as extension of rural credit and greater access to markets*' if it is to have a positive impact.

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1 small, medium and micro enterprises

2 see Gordon (1997), Ross et al (1997) and Rogerson (1997)

Electricity services to support sectoral development

Even though electrification is only one of a set of necessary inputs to improve services to rural areas, and often impacts are dependent on other more fundamental constraints being addressed, it was possible to identify areas where appropriate electricity supplies could support sectoral development objectives. In some cases the impacts are quite clear, while in many cases they are less clear and are often highly dependent on complimentary activities or on certain conditions being in place. Some of the main electrical services which support sectoral development are listed below.

Health	*Education*	*SMME*
CLINICS vaccine refrigeration 2-way radio indoor clinic lighting staff lighting outdoor lighting staff TV	SCHOOLS indoor lighting outdoor lighting TV/VCR	lighting refrigeration small machines (e.g. sewing) workshop power tools cash register
HOUSEHOLDS refrigeration lighting cooking water heating TV	HOUSEHOLDS lighting cooking TV and radio	

Some of the main electrical services to support sectoral development*

** - this is a highly abbreviated list which does not reflect the full range of electrical service requirements, their relative priority, nor the conditions under which they may or may not have an impact.*

Electricity supply options and programmes covered

This paper covers the electrification technologies of grid connection (including grid extension), solar photovoltaics (PV), and diesel generator sets (gensets). The latter is normally dealt with in a genset-plus-batteries configuration. All of these technologies are currently being used in the different electrification programmes. The electrification programmes discussed in this paper are:

IDT clinic electrification programme: IDT implements the off-grid component of this programme, while Eskom undertakes grid extensions to clinics. The IDT funds the installation of PV systems for clinics further than 5km from the national electricity grid, genset-plus-battery systems for clinics between 1 and 5km from the grid, and grid extension for clinics closer than 1km to the grid.

Eskom schools electrification programme: Eskom is the implementing agency for both the grid and off-grid components of this programme. PV is the only off-grid technology used, and is installed at schools greater than 3km from the grid. The rest are grid connected.

Eskom SMME programme: This programme mainly covers areas targeted for grid electrification by Eskom, and supports small enterprises principally through involving them in the supply of goods and services for the electrification process. The focus is on urban areas, although some support of rural SMMEs also takes place.

In addition to the above programmes, the range of supply options available to households in Eskom's national household grid electrification programme are also evaluated with respect to their ability to impact on health, education and businesses. In this regard the 2.5A, 8A, 20A and 60A grid supplies are considered.

Supply option life-cycle cost comparisons

Different electricity supply options can meet different ranges of services. This paper has undertaken life cycle costing (LCC) of these options, considering the differences in services provided, as a step towards enabling a more equal comparison between systems. To do so it was necessary to add LCCs of meeting thermal loads such as cooking and space heating using LPG (gas) to LCCs of PV and genset-plus-battery systems which generally cannot meet thermal loads, such that they could be compared with grid connection, which can meet these thermal needs. The results are shown in the table below.

Electricity supply option (electrical energy use per day)	*Capital cost (elec system only)*	*LCC (elec system only)*	*Other energy services to be met*	*LCC of other energy services***	*TOTAL LCC (elec & non-elec)*
PV clinic system (2kWh/d)	R 89 200	R 114 000	staff fridge, cooking, space heating	R 28 800	R 142 800
PV school system (2.8kWh/d)*	R 65 000	R 89 000	(uncertain)	(uncertain)	R 89 000
Genset-plus clinic system (4kWh/d)	R 29 500	R 108 000	staff fridge, cooking, space heating	R 28 800	R 136 800
Grid extension:1km (15kWh/d)	R 88 500	R 110 000	-	-	R 110 000
Grid extension:3km (15kWh/d)	R 185 000	R 212 600	-	-	R 212 600

LCC comparison between systems, including non-electricity service needs

** - the school PV system is not designed to provide the same reliability of power supply as the clinic PV systems, thus the two systems cannot be directly compared.*
*** - this is taken as LPG for the purposes of this analysis*

The table illustrates that if electricity supply option decisions are made on electricity system LCC or electrical unit energy costs only, in many cases this will not result in the most cost-effective energy supply for the institution in question. Electricity supply options should be chosen based on a more integrated analysis of total energy use needs and characteristics. This approach may be in conflict with decision-making pressures and abilities within organisations such as IDT and Eskom, who may also not be well placed to consider non-electric energy needs fully. Cost criteria for technology choice are in practice often weighted towards capital cost considerations by these organisations.

Electricity supply option evaluation

Evaluation criteria

Amongst the criteria considered important in evaluating how resources may be more effectively applied in the different electrification programmes, are the following:

- ability to supply specific appliances linked with important services
- ability to be upgraded to accommodate growth over time
- sustainability regarding capacity and resources to provide adequate operation and maintenance support
- the cost-effectiveness of different supply options considering the total energy needs of users
- the reliability of the supply option

These are discussed below as they apply to relevant electrification programmes.

Health

Clinic electrification

- The IDT clinic electrification programme addresses rural health care priorities reasonably well, and all the rural health care service priorities are catered for in the PV, grid and genset-plus options provided. These service priorities are: vaccine refrigeration, 2-way radio, indoor and outdoor lighting, staff lighting and TV plug point, and a medical examination light.

- All of the technologies used in the IDT programme appear to be technically sound, although no detailed independent evaluation of the programme has yet taken place.
- The primary focus of rural health care is through rural health care centres such as clinics, and indications are that future efforts in this field will upgrade increasing numbers of clinics to offer 24-hour services and will increase the clinic capacity to cover adequate neo-natal care and other services. The ability of the power supply to accommodate such upgrading may thus be important. On these grounds grid electricity is more appropriate than PV or genset systems, although the latter has the advantage that it is relatively easily transportable should grid power become available.
- Currently grid connected clinics are provided with 60A single-phase supplies. While this may be excessive for medium and small clinics in the short-term, lower capacity supplies (for example 20A) could constrain electricity use in many clinics in the longer-term.
- The genset-plus system is intended as an interim solution for areas where grid extension is anticipated in the short to medium-term. Given that there is still often uncertainty in grid extension plans, and that the genset systems appear to be meeting clinic needs adequately, this can be considered an appropriate strategy, although who is responsible for relocating such systems should grid be extended to the area, and how effectively this will be done, is still uncertain.
- The IDT clinic programme has so far not ensured that a sustainable maintenance programme for their systems exists beyond the 1-year guarantee provided by the PV system installers. While they have allocated funds for maintenance for the next 10 years, systems by which these funds are utilised have not been institutionalised. The sustainability of the IDT programme will thus remain in question until this issue is addressed.
- If LCCs of PV, grid and genset-plus options for providing electricity to clinics are compared, and costs of meeting thermal and other services are included where they are not provided by the electricity option, indications are that grid extension is likely to be an economically sound choice for between 1.5 and 2km extension distances. Given that grid electricity is the most versatile in its ability to meet future upgrade needs, it therefore appears to make sense that the IDT clinic electrification programme extends its 1km cut-off criterion for grid extension. Because grid extension will be able to accommodate rural health centre upgrading in a way that the other supply options will not, there may be a case for extending the grid extension cut-off further still.

Household electrification and health

- The potential for electricity to be linked with health benefits in the household revolves mainly around the provision of cooking, refrigeration, lighting, and media services. PV systems can meet some of these needs only, and thus potential benefits associated with the use of electricity for cooking and corresponding reductions in indoor air pollution, for example, cannot be realised via the use of such systems. This is also the case for low-capacity grid connections, although upgrading to a higher capacity supply should the need arise is usually far easier with grid than with a PV system (although there is some doubt around whether Eskom will upgrade low-capacity supplies in the foreseeable future). Genset systems are unlikely to be appropriate energy supply sources for households as typical household demand profiles do not suit genset operation, although genset-plus systems could be more appropriate.
- Grid supplies are usually more easily upgraded than other supply options and therefore can most easily cater for increased demands for electricity over the longer-term, with some concomitant increases in benefits.
- It needs to be noted that the provision of an appropriate power supply does in no way directly result in significant benefits, as appliances may be unaffordable by households

(such as refrigerators), and some appliances may only be partially utilised (such as hotplates), thus limiting their benefit.

Education

School electrification

- The Eskom schools electrification programme in general appears to meet at least the short-term education service priorities - indoor and outdoor lighting and TV/VCR - although no outdoor lighting is provided where schools are supplied by PV systems.
- Outside lights can be a factor in making schools more accessible at night, particularly for women, and so this may be an important omission in PV installations.
- While Eskom provides an overhead projector to schools, no evidence was found to indicate that this is in fact a priority.
- Education is an important national focus, and plans are being developed to provide greater access to education in all parts of the country. This means upgrading of rural educational facilities over time, and thus it can be important that supply options to schools are easily upgradeable. Grid supply is more easily upgraded than PV supply, which indicates that it should possibly be given preference over PV even where cost criteria indicate otherwise.
- Currently Eskom extends the grid to schools within 3km of the existing (or planned) grid, and beyond this distance a PV system is installed. For a 3km extension, grid capital and LCC costs are substantially more than for a PV system. This indicates that Eskom may have taken a broader view than merely comparing capital costs or LCC in determining supply technology selection criteria. While current indications are that the grid extension cut-off criterion is appropriate, a more detailed economic analysis covering all energy sources used by schools is necessary to evaluate this more fully.
- Currently, Eskom provides a standard 60A single-phase connection to the majority of schools. This is likely to be excessive for most medium and small rural schools, where a 20A or even an 8A supply would be adequate at least in the short-term, although the costs to upgrade systems in remote locations may justify the use of a higher supply capacity which will be adequate over the longer-term.
- While the Eskom programme appears to be meeting stated national education priorities relatively well, provincial and regional educational authorities are concerned about its effectiveness. It may be important that the programme consults more locally to ensure that individual school's needs are being taken into account.
- There may also be a greater need for informing users on the effective use of electricity.
- There is a need for improved coordination amongst service providers and education authorities, as illustrated by this quote from the education sectoral study: '*there is a real danger that the significant infrastructural development currently taking place in South Africa might end up being of limited value to the education and training system, unless structured relationships are established between the Department of Education and major physical infrastructure providers such as Telkom and Eskom*'.
- A further concern regarding the Eskom off-grid component of the programme is the lack of arrangements for ongoing support and maintenance of PV systems. As large numbers of systems are being installed around the country, the implications on the capacity and funds needed to maintain them is significant. Lack of a clear mechanism to ensure that the necessary capacity and other resources exist within the Department of Education, who become responsible for the systems, raises questions concerning the sustainability of the programme.
- Questions around the appropriateness and sustainability of the Eskom schools programme add an urgency to the need for a detailed evaluation of its effectiveness, particularly given the substantial resources committed to this programme.

Household electrification and education

- Areas where electricity supply can impact on education in the household are linked with provision of lighting for study, access to educational TV and radio, and 'easing the domestic burden' via the use of electrical cooking and other appliances.
- Larger capacity grid supplies can meet all of the above service needs, while PV and 2.5A grid supply will meet all except cooking needs, and thus are also expected to result in clear education benefits.
- Suitable capacity supply does not imply education benefits will result. Access to relevant appliances and degree of appliance use, as well as suitability of educational material in the case of TV, are all important factors for any benefits to occur.

SMMEs and electrification

- As the SMME sector is overwhelmingly survivalist in rural areas, and many rural small businesses operate from households, SMME electrification is closely linked with household electrification.
- PV electricity supply is likely to be able to meet basic energy needs of some small businesses, with 2.5A, 8A and 20A grid supplies being able to meet needs of increasingly larger businesses. PV and 2.5A grid supplies will not be adequate for those requiring anything other than lighting, limited refrigeration, and power for small electric motor-driven devices such as sewing machines.
- Grid power is relatively easily upgradeable in most cases, and thus it can cater for business growth in a way that PV systems may not easily be able to.
- Without financing, PV systems are likely to be unaffordable to many small businesses, while grid connections are usually financed through the tariff.
- Although gensets may be able to meet energy requirements of many businesses, they are often inappropriate because of the need for continual fuel supply, regular maintenance and occasional repair, and their fixed supply capacity can also limit business growth.
- Grid connection is in general likely to be the most convenient and versatile option, and can be the most cost effective where extension distances are not excessive.
- It is noteworthy that Eskom's SMME programme does not extend to any significant degree into areas where grid extension is not planned. Enterprises in remote areas therefore usually cannot access support regarding appropriate electricity or energy supplies for their needs, and this will need to be addressed given the importance of SMMEs in national development plans.

Maximising benefits via integrated planning and implementation

- All of the sectoral studies covered in this report stressed limitations on the sectoral electrification initiatives due to ineffective coordination between implementers and relevant government departments or other institutions involved with the sectors.
- Neither the Department of Health nor the Department of Education are considered to have been adequately involved in planning and implementing of the clinics and schools electrification programmes respectively, nor is Eskom coordinating adequately with other key organisations involved in supporting SMMEs in their SMME programme.
- All of the studies have also stressed that electrification needs to be a part of a coordinated service provision implementation plan if benefits are to be maximised or even realised.
- Not only is there inadequate integration between the electricity sub-sector and the health, education and SMME sectors, but coordination is lacking within the energy sector. Energy needs of schools and clinics, for example, are not considered as a whole, but the tendency is to focus on electricity provision, which can lead to inappropriate electricity supply technology selection criteria which do not optimise total energy LCC

for the relevant institution.

- It is also necessary for electrification technology selection criteria to consider the electricity needs of other electrification programmes (for example clinic electrification planning should be integrated with that of the schools electrification programme), as well as to integrate the needs of other businesses and communities in the areas in question.

The need for a more integrated approach is thus clearly illustrated, both between the sectors, and within the energy sector.

Table of Contents

1 BACKGROUND AND OBJECTIVES

This document is largely a synthesis and extension of three other papers which were written as a part of the same project. The three papers covered the Small Business, Education and Health sectors respectively[3]. This paper does not synthesize all aspects of the sectoral papers, but focuses on areas more directly relevant to electrification practices. An overview of the sectoral paper objectives and the energy synthesis paper objectives are given below. All of these papers feed into the Energy and Development Research Centre's (EDRC) project called '*The role of electricity in the integrated provision of energy to rural areas*'. The broad objective of EDRC's project is '*to assist with the development of rural electrification policy which is consistent with national and regional development goals and which will provide sustainable benefits to users of electricity in rural areas and to society as a whole. Priority is given to the policy needs of both government and of implementing agencies such as Eskom*'. The sectoral papers and this synthesis paper are intended to contribute to EDRC's project by assisting in formulating '*a development rationale for rural electrification*'.

1.1 Objectives of the sectoral studies

Broadly, the sectoral studies aimed to undertake the following:

- to identify the primary rural development objectives in the specific sector
- to investigate the role of energy (and particularly grid and non-grid electrification) in achieving development goals in these sectors
- to identify other essential inputs which may need to be applied in parallel to electrification for impacts to be realised, and to discuss environments which are conducive to maximising impacts
- to investigate the current institutional framework within which electricity supply takes place, and to identify obstacles in this framework which contribute to electrification practice not supporting sectoral development goals optimally
- to make explicit the different implications of the above for various socio-economic and gender groups

1.2 Objectives of the energy synthesis paper

This paper undertakes the following:

- reviews the range of current electricity supply option characteristics and costs (grid & off grid)
- links important energy inputs (as identified in the sectoral papers) to electricity supply options, and evaluates to what extent these options can support development needs within the context of sectoral priorities
- considers parallel inputs required in order for electrification strategies to have an impact
- assesses the benefits of electricity supply options relative to supply cost, considering 'hidden' costs where possible (e.g. environmental, social, overhead costs)
- analyses current electrification practice to assess whether it is meeting sectoral needs optimally

1.3 Structure of this paper

This paper has three parts. The first summarises potential areas of benefit linked to electrification as extracted from the three sectoral studies, and explores the electricity and energy use implications related to these benefits. This covers sections 2, 3 and 4, which deal with the health, education and SMME sectors respectively. The second part (section 5) provides general information on some of the main characteristics of grid electricity, solar photovoltaic (PV) and diesel generator set (genset) electricity supply options, and analyses life cycle costs (LCC) of these options. It concludes with an evaluation of the appropriateness of the selection criteria used by the IDT and Eskom in the clinic and school electrification

[3] see Ross et al (1997), Gordon (1997), and Rogerson (1997)

projects respectively, based on LCCs. The last part (section 6 and 7) examines the extent to which the current school, clinic and SMME electrification programmes are meeting sectoral development objectives, and evaluates the extent to which different supply technologies can support these objectives. Finally, areas where resources may be more effectively used in promoting sectoral development objectives are discussed, including the need for increased integration between different government departments and electrification programme implementing agencies.

1.4 Establishing the impacts of rural electrification

Although there seems to be substantial inconsistency concerning the benefits of rural electrification (RE) amongst the many studies of this field, what is apparent is that under certain sets of conditions, RE clearly has an impact. The papers on the health, small business and education sectors on which this paper draws have investigated the impacts and the conditions under which these may occur in some detail. In some cases impacts are relatively clear given certain conditions, but in the majority of instances the complex set of social and economic dynamics in developing areas leaves the role of electrification in development unclear. Linking electrification practices with sectoral development impacts is thus usually not a simple task. In addition to the above complexities, all of the three sectoral papers show that studies concerning the impact of rural electrification on specific sectors are generally not of sufficient detail nor covering sufficient periods of time to allow adequate clarity on the place of RE in supporting sectoral development objectives. The focus of RE impact studies has been predominantly on households to date. It is interesting that, in spite of the numerous studies by some of the most experienced researchers and development analysts since the early 1980s, and in spite of the huge resources which governments and donors have poured into RE, there are still substantial knowledge gaps regarding the role of RE in development. However it must also be said that impacts seem to be very context specific, and thus detailed studies of one RE programme would not enable observed trends to be easily transportable to other countries, or even projects.

In spite of the above complexities and uncertainties, the sectoral papers have clarified many issues regarding the relevance of RE to sectoral development, and hopefully some useful recommendations for electrification practice and planning will emerge from this synthesis paper.

2 HEALTH BENEFITS AND RURAL ELECTRIFICATION

2.1 Summary of Health Priorities

Sections 2.1, 2.2 and 2.3 draw extensively on the paper by Ross et al (1997), where impacts of RE on health are discussed in more detail. References are only provided where sources other than this paper were used.

As with all the sectoral papers, benefits of RE may be divided into two categories - direct benefits and indirect benefits. Direct benefits on health are those where electricity supports a health service. For example, electricity to power a vaccine fridge in a rural clinic, which is a necessary component of the immunization programme. Indirect benefits are where electricity achieves an impact via an intermediary goal. For example, electricity may facilitate more effective water pumping, with resulting health benefits on the local community. Both need to be considered. As Ross et al (1997) point out, *health is primarily a household product,* and thus health implications of electricity need to be examined at a household level as well as at the level of rural health care (e.g. clinics and hospitals).

It is claimed that RE has a number of potential health benefits, although Ross et al point out that many of these claims are not supported by sufficient evidence, and counter claims also exist in many cases. Some of the potential health benefits of RE are listed below.

Reduce domestic air pollution through the provision of a safe cooking and heating alternative

As women and children are generally most exposed to particulate matter from cooking fuels, they may benefit in particular from an alternative cooking energy source. Space heating with biomass or coal is also a significant cause of household pollution. This is a particularly important area of potential benefit, as Acute Respiratory Infection (ARI) is the greatest cause of infant mortality alongside diarrhoea. However, achieving a benefit here assumes that households with electricity will start to cook and/or heat the house with it, which research shows does not happen as much as initially anticipated. Improving the thermal performance of houses is another important intervention which may have an impact on the amount of biomass or coal burned in households.

Improved nutrition due to improved food storage via refrigeration

Refrigeration preserves food value. However, refrigerators are only likely to be acquired by wealthier households, which would limit the benefits to the poorer households who are arguably the most appropriate targets for health impacts, although all households may benefit if fridges are acquired by local shops. In unelectrified areas, the ability of shops to deal in perishables is substantially reduced. A study in Northern Botswana showed a great increase in the use of refrigerators in shops since electrification, and thus fresh dairy products, fruit and vegetables were more accessible to the population in general. In one shop refrigerated or frozen goods accounted for one third of the total turnover. It seems logical that this will have some nutritional benefit for the local population (see Borchers et al, 1994), although no detailed study to this effect was undertaken (for example it may be possible that the incomes or eating habits of the poorest households - who are generally those most in need of improved nutrition - preclude them from benefits of refrigerated produce).

Improved nutrition through reduced cooking times

Cooking food more quickly - which is possible using energy sources such as electricity - reduces food value loss. Reducing cooking times using electricity again assumes that households will start to cook with electricity, which is often not the case to any significant degree. In addition, evidence exists which suggests that people cooking with electricity tend to have higher intakes of high carbohydrate and fat foods, with resulting adverse health implications.

Facilitate the provision of safe water supply and sanitation

Provision of safe water supply and sanitation at a household level has been shown to be the most effective infrastructural intervention in the promotion of health. These two interventions have been shown to have the highest rate of return in reducing the incidence of diarrhoea - which is amongst the greatest causes of infant mortality, and are thus to be considered as amongst the most important potential health interventions which electricity supply can facilitate via the provision of efficient pumping technologies. Other areas of impact include alleviation of women's (typically) burden of fetching water, which is particularly onerous on the elderly.

Reduce injuries from paraffin poisoning and paraffin and candle caused fires

This is an important potential area of impact for electricity. In several parts of the country paraffin or candle-caused fires are alarmingly frequent, for example in the Marconi Beam settlement in the Western Cape and Duncan Village in Eastern Cape (Bank et al, 1993), and are the cause of numerous burns and deaths. Paraffin poisoning in known to be widespread, with at least 16 000 reported poisonings per year (MRC, 1995), and this has led to the nationwide 'safe-cap' programme[4]. The degree to which electrification impacts here depends on the extent to which electricity use displaces paraffin use. This appears to happen much slower than expected, and in poorer households may not happen to any great degree. This displacement does occur to some extent in most electrified households, however, and thus some impact in this area of health may be expected.

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4 The free provision of safety caps for common bottles used to carry paraffin.

Improve education and literacy through adequate lighting and through access to educational TV programmes

Research indicates that higher maternal education level correlates with improvements in child rearing practices. Electricity has the potential role of facilitating night classes and home study via the provision of adequate lighting, and enabling the use of TV sets. Evidence linking TV and education is, however, inconclusive, and some studies suggest that children may study less and watch TV more, and also link increased violence with TV. For TV to have an educational impact, specially developed and targeted programmes are necessary. The Soul City TV series is one such example, and reasonably detailed evaluation studies show that its impact is significant (Everatt et al. no date)[5]. Adult literacy classes are facilitated by electric lighting, but also have an unclear impact as women may not be able to attend such classes.

Reduce urban-rural migration

This is an often-used justification for RE, and in the health context has implications for the spread of HIV. However, some evidence exists to show that the opposite may happen, although it appears that the impact of electrification on population movement may be highly country or region-specific. In South Africa there does not appear to be sufficient information to indicate how electrification affects such migration patterns.

Reduce fertility rates

The health implications in reduction of fertility relates to problems associated with overpopulation. The evidence to support this impact of RE is, however, not conclusive.

Enable the improvement of services offered by rural clinics and other health services

The potential benefits of electrifying rural health services include the ability to use better technologies, offering longer opening hours including 24-hour or emergency services, better maintenance of the vaccine cold chain, offering educational opportunities to visitors and patients, increased clinic security, and improved ability to attract staff.

To illustrate this, at clinics presently offering antenatal care, mothers-to-be will often move into a clinic ward a few days before giving birth, and have to use candles and paraffin where no electricity is available. They also often make fires to cook for themselves as there may be inadequate facilities available to them. Deliveries may happen at night without adequate lighting, and in some cases without radio communication with a hospital in case of emergencies. In some instances, nurses may be reluctant to live on site where there is no electricity, and thus antenatal services cannot be offered, nor can any form of emergency services. In parts of the country, resident nurses have refused to provide after-hours emergency services due to security concerns (Morris, pers comm, 1997). Here security lighting could help. The provision of electricity would certainly contribute to improving the ability of the clinic to provide an extended range of services. However some studies stress that health services revolve around well trained staff, and adequate communication, transport, water supply and sanitation infrastructure rather than electricity supply (see Ross et al, 1997). This is discussed in more detail later.

The Department of Health's essential equipment list

The Department of Health (DoH) has an essential equipment list covering clinics from two to six consulting rooms, as well as those that are expected to double as recreational/education centres and community halls. This list is described in table 2.1.

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5 - the TV series (called *Soul City*) was shown to reach a slightly greater proportion of the population than the equivalent radio series (called *Healing Hearts*). It reached a greater proportion of the population in metro, urban and rural areas, while the radio series reached more people in informal settlements.

Location/purpose	Appliances
General	fan in each room heater in each room staff fridge staff kettle
Procedure rooms	steriliser (autoclave or boiler type) vaccine fridge medical examination lamps cardiac resuscitation set (can be battery operated) suction machine (vacuum operated off its own gas supply)
Clinics offering maternal health care and neo-natal services	incubators (need to be run continuously)
Larger clinics and those that double as community centres	TV&VCR set for educational purposes

Table 2.1: The Department of Health's essential equipment list

Ross et al (1997) point out that the need for effective communications (conventional or radio-telephone) is not mentioned. They also point out that it should not be assumed that the provision of suitable technology and an appropriate energy supply is the major factor in improving rural health services. For example, in relation to the cold chain they suggest that *the vaccination programme is most fragile at the points of human interaction rather than solely in the technical implementation of the cold chain process.*

In practice, the equipment within rural clinics appears to be quite different to the 'essential equipment list'. Experience from visits to hundreds of clinics in the Northern Province, Mpumalanga, Kwazulu-Natal and Eastern Cape shows that fans, sterilisers, cardiac resuscitation sets and TV/VCRs are absent in almost all clinics, although nurses often have private TV sets where electricity is available. Heaters are present in some clinics, and nurses sterilise equipment using chemicals or simply by boiling water on a stove. Staff fridges and stoves use either electricity or LPG[6], and suction machines are foot operated or are powered by small electric pumps (Morris, pers comm, 1997).

Vaccine fridges: Cold chain fridges are an essential part of any vaccination programme. They need a highly reliable energy source to power them, and electricity is amongst the most suitable. In many clinics LPG (gas) has been used successfully, although they are dependent on the reliability of the gas delivery network, which is not infallible in some rural areas. Solar PV electricity supply can provide electricity of adequate reliability provided they are designed and installed to a high standard (e.g. the World Health Organisation standard). The WHO has a list of tested and approved vaccine fridges for use in clinics, and amongst these are LPG, PV, grid, and even paraffin models (although paraffin is considered a second choice). There is no clear evidence which favours either PV or LPG vaccine fridges (Borchers, 1993), and possibly the main factor to be considered in choosing between them is the existence of an appropriate support infrastructure. However, a reliable fridge does not lead directly to an effective vaccination programme. Factors which can compromise the effectiveness of the programme include lack of recording of fridge temperatures, storage of staff's personal food in the vaccine fridge (with the associated increase in fridge opening and resultant loss of cold air), inappropriate vaccine use and storage techniques, and difficulties in ensuring that mothers return to complete their child's vaccination series. The implication is that the vaccine programmes are highly reliant on staff training and the extent to which the staff have facilities for their own use (Ross et al, 1997).

Staff facilities: Some studies indicate that it is important to electrify staff accommodation as a part of any clinic electrification programme. Important needs of staff include security (the provision of outside lights), and lights and TV in their rooms. The essential equipment list clearly regards provision of staff facilities as important. However, Ross et al have the following to say regarding the link between staff facility electrification and circumstances of

6 Liquid Petroleum Gas. also known as 'handigas' or just 'gas'

the staff: '*There is no doubt that staff perceive the lack of basic amenities (including electricity) as negative, but it would not be wise to assume that electrification per se will ameliorate the working and living conditions that rural health workers will have to deal with.*' Against this should be weighed the experience of the Energy and Development Group with staff at hundreds of clinics in four different provinces, which indicates that the importance of electricity to staff members should not be underrated. For example, in unelectrified clinics staff have been known to move out of their accommodation to areas where electricity is available (Morris, pers comm, 1997).

Water supply and purification: Clinics obviously need a reliable and safe water supply, and energy can have a role in providing pumping power. Water purification also requires a heating energy source, and in many rural clinics this is done simply by boiling on a stove when necessary.

Incubators: These are necessary in clinics offering neo-natal services, and they are usually powered by electricity.

Lighting: Lighting is obviously essential for the provision of a 24-hour service or any emergency services. Outdoor security lighting is also important, as crime is a problem in many rural areas. Medical examination lights are on the DoH essential equipment list.

Disease surveillance

South Africa is currently developing a rural surveillance system to record trauma, and may include disease surveillance in future. Electricity allows for the use of computers, which may facilitate the implementation of this programme.

Community security lighting to reduce violence

Community lighting has been suggested as being a factor in reducing violence, although Ross et al see it as having a relatively minor role.

Poverty-related disease alleviation through impacting positively on the local economy

Support for the local economy and the formation of home businesses may decrease the prevalence of poverty and thus poverty related diseases. However, there is still much debate about the impact of electricity on economic activities. A recent thorough assessment on this subject in the South African context indicates that the impact on the poor is likely to be minimal (Rogerson, 1997). The links with health are thus still unsubstantiated, and are certainly not straightforward.

Drawbacks of electrification

Recently, a debate concerning the negative impact on health of living near high voltage power lines has emerged, and although evidence is still inconclusive, as a precaution it is nevertheless recommended that power lines should not run through residential areas

Electrification obviously also increases the risk of electrocution, although this is not considered nearly as prevalent as the extremely high rates of childhood fatalities caused by burns.

Overall scope for rural electrification to support health care

The debates around the potential impact of electricity on health are by no means fully represented above, but the arguments presented hopefully illustrate that in many areas impacts are likely to be significant, although evidence of benefits is, at best, not fully substantiating, and at worst, not at all conclusive. Whatever the case, it is important to note that impacts are generally highly dependant on other conditions being met. This paper will try and focus on areas where the links with health are relatively clear.

2.2 Health priorities and their relevance to electrification and energy supply

The principal Ministry of Health (MoH) priorities are as follows:

- Nutrition
- Maternal, child and women's health
- Free health care policies
- HIV and AIDS
- Violence
- Control of communicable diseases

While these are not the same as those laid out in the RDP documents on health, there are many overlaps. Ross et al note that '*the notions of PHC*[7] *as having an integral link to household infrastructural development seems to have been replaced in part with a focus on immediate interventions. One consequence of this has been the decreased emphasis on diseases such as Acute Respiratory Infections (ARI) and their prevention through infrastructural development'*. This absence of programmes directly aimed at lowering the ARI rate amongst children is considered a significant omission which they say should be made '*an immediate priority'*. Poor housing and lack of electricity have been found to be significant risk factors in childhood ARI.

The links between energy supply and some of the stated MoH health priorities are discussed below.

Nutrition

Cooking with electricity may preserve food value better than slow-cooking practices, although evidence exists which suggests that higher income households, who are often amongst the first to convert to electric cooking, aspire to fattier, more refined foods. The link between electric cooking and health is thus not clear. The ability to refrigerate food and thus preserve its food value is more likely to have an impact on nutrition, although only wealthier households are likely to buy fridges. Some studies indicate that electrification is likely to increase the number of refrigerators at shops (Borchers et al, 1994), and as this would allow increased trading in perishables, it seems logical that this would impact on nutrition to some degree. However, evidence which links increased use of fridges at shops with nutritional benefits is not available.

Maternal and child health

Vaccination data in African children show that coverage rates in rural areas is significantly lower than in urban areas. Increased attention to improving the coverage of the vaccination programme implies a well functioning cold chain. Electric vaccine fridges are amongst the most effective for this application, although it must be remembered the programme is reliant on a range of factors and inputs (see earlier discussions) and thus the supply of electricity and effective fridges does not necessarily improve a vaccination programme. A new vaccination against childhood diarrhoea caused by the rotavirus is soon to be tested in South Africa, and as diarrhoea is estimated to be responsible for 28% of childhood mortality, this is potentially a crucial area of attention, and again reinforces the importance of an effective cold chain.

Maternal morbidity or mortality is linked to a number of pregnancy or birth complications, and most die because they are unable to access health facility in time. Electricity supply facilitates the provision of emergency services and increased ability for antenatal care (although again many other factors need to be in place for this to happen, and location and appropriate staffing of clinics, for example, are likely to be key factors).

HIV and AIDS

The MoH emphasises the role of education in prevention of HIV. TV may be able to play a role in such education, although benefits will depend on programme availability, timing and language (see earlier). TV obviously implies electricity of some sort.

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[7] Primary Health Care

Interventions via rural clinics

A number of interventions around other health priorities imply greater access to rural health care facilities, such as the control of communicable diseases (such as HIV and TB) and free health care policies for children under 6 and pregnant women. Electricity certainly supports clinics and facilitates their ability to perform tasks more effectively, although it may not be a core factor in improving PHC.

2.3 Summary: electrification priorities to support health priorities

In South Africa, all rural hospitals are electrified, or are high priority targets[8]. It is accepted that hospitals need an adequate and reliable electricity supply to function effectively. Electricity supply to hospitals is therefore not focused on here.

The most important health impacts of electricity are summarised below. Importance can be rated on both how likely or clear the benefit is expected to be, and on how important the impact is given the health priorities in the country.

Summary of impacts of electricity on health in households:

Reduce domestic air pollution: Because ARI is such an acute problem, particularly amongst children and women, the potential for electricity to provide safer cooking and space heating energy sources must be taken very seriously[9]. This rates highly as a national health priority. The impact is tempered by the low rate of conversion of newly electrified households to electric cooking and heating, particularly in rural areas, where other fuels may be (or may be perceived to be) more cost effective, or where cultural preferences mitigate against the use of electricity.

Nutrition benefits via refrigeration of foods: The evidence here is not conclusive, yet it appears as though the impact may be significant. Although only wealthier households are likely to have direct access to refrigerators, all households can derive some benefit due to increased ability of shops to store perishables using refrigerators. Nutrition in one of the principal health objectives for MoH.

Provision of safe water and sanitation: This has been shown to be the most effective infrastructural intervention in the promotion of health. Electricity can only have a facilitating role in the supply of water and sanitation services, and while it is important to consider this role in electrification planning, the benefit will only be realised if effective coordination takes place with other service providers such that adequate delivery occurs. Electricity has a role in household sanitation in urban or peri-urban areas which have piped sewerage, where it is used in sewerage processing plants, but in rural areas piped sewerage is uncommon, and thus its principal contribution to sanitation is through facilitating adequate water provision. This intervention is not only important at a household level, but rural clinics also require adequate water supplies. Recent fieldwork undertaken by the Energy and Development Group in the Eastern Cape found many clinics without a regular or safe water supply (Purcell, pers comm, 1997).

Reduce burns and paraffin poisoning: Although this is not specified as a priority focus area for national health care, it is an important potential area of impact for electricity. The low rate of displacement of paraffin particularly with electrification is a limiting factor here, particularly amongst the poorer households.

Education and literacy through TV: The impact here is highly dependent on the availability of suitable education programmes at appropriate times in appropriate languages. The favourable evaluations of the Soul City TV series is promising evidence of the potential for this medium to have an impact. Aside from the availability of material, the main constraining factor is likely to be the currently limited access

8 The IDT health programme is focusing on electrifying rural hospitals as well as upgrading their facilities.

9 although cooking with electricity is only one of the energy options for ameliorating this problem

rural populations have to a TV set. Although the potential impact may be limited, the area is stressed by the MoH as an important tool in the prevention of HIV, and it is thus an important area for electrification to consider.

Summary of impact of electricity at the rural health care level:

Increase access to clinics (providing 24 hr and emergency services): Electricity is necessary if clinics are to offer 24 hour or emergency after-hours services, although obviously appropriate staff and facilities need to be provided if day clinics are to extend their services, which implies that this has to be factored into health planning at a provincial or regional level. Coordination with electrification planning is thus also important. A number of MoH principal objectives imply greater access to rural clinics, which may translate into more clinics and greater accessibility to existing clinics (i.e. after hours). Amongst these are improved maternal health care, where overnight facilities become important.

Immunization: The integrity of the cold chain, and thus of vaccine fridges, is a critical component of the immunization programme. This programme is at the heart of child health care, which is in turn at the heart of the national health priorities. It has, however, been pointed out that a number of other factors are also critical to the success of an immunization programme (see earlier discussions). Electricity (PV or grid) is one of the most favoured energy sources for vaccine fridges, although LPG is also widely used. Whatever the energy source, the supply must be highly reliable. Provision of a suitable fridge for the staff may also be an important cold chain intervention, as otherwise they tend to use vaccine fridges for their personal goods.

Staff welfare: Although electricity supply for staff lighting and TV is undoubtedly important, it is unclear how important. It is nevertheless safe to say that it contributes to their welfare to a significant degree, and since they are at the heart of PHC, it is suggested that addressing their needs should be regarded as important (although Ross et al consider that it is difficult to see how electrifying health staff accommodation at clinics can be justified while surrounding community households are without power).

Communications: Although this strangely does not appear on the DoH clinic 'essential equipment' list, it has an important role in PHC. Communications may either be provided by a 2-way radio or a telephone. Typically, the more remote clinics have no telephone. An electricity supply is needed for the radio, and many clinics throughout the country were provided with a small PV system for this purpose, which in many cases are dysfunctional, probably because of poor maintenance and/or installation.

Increasing range of procedures performed at clinics: Certain procedures require equipment which needs to be electrically powered. Clinics offering a neo-natal service may need incubators, which require a highly reliable electricity source. The DoH 'essential equipment' list for clinics includes equipment which can only be run off electricity (cardiac resuscitation set, medical examination lamps, suction pumps, fans for nurses and TV/VCRs in larger clinics), as well as much equipment which may be powered by an adequate electricity supply, but which also may be supplied by LPG (heater, staff fridge, staff stove, sterilising, and vaccine refrigeration). ORT (Oral Rehydration Therapy) is used in the treatment of diarrhoea, which is a major cause of child mortality, and requires that water is purified. This is commonly done simply by boiling it on electric or LPG stoves. It should be noted that in practice the core set of equipment at rural equipment differs from the 'essential equipment list', and usually excludes fans, TV/VCRs, sterilisers and resuscitation sets.

Area of impact	*Energy service requirements*	*Equipment implication*	*Electricity supply implications**
HOUSEHOLD			
Reduce domestic air pollution	cooking	elec hotplate stove/oven gas stove	4kWh 4kWh
Nutrition benefits via refrigeration	refrigeration	elec domestic fridge elec small fridge LPG fridge	2kWh 1kWh
Provision of safe water and sanitation	water pumping	elec pump (1/3 hp) diesel pumps wind?	0.9kWh
Reduce burns and paraffin poisoning	lighting, cooking alternative	elec hotplate elec lights (incand.x4) elec lights (fluor.x4)	4kWh 0.96kWh 0.48kWh
Education and literacy through TV	TV/VCR	elec TV/VCR (colour)	0.44kWh
RURAL HEALTH CARE			
Increase access to clinics	lighting indoor & outdoor	elec lights (hi-eff.x10)	0.6kWh
Immunisation	refrigeration (very reliable)	elec vaccine fridges LPG vaccine fridges	0.42kWh
Staff welfare	entertainment, lighting, heating/ cooling, food storage, personal	staff lights (hi-eff.x5) outside light (hi-effx2) powerpoint (for TV) elec fridge (AC,200l) LPG fridge elec fan (x2) elec heater (x2) LPG heater	0.3kWh 0.12kWh 0.44kWh 3kWh 0.2kWh 8kWh
Communications	comms	radio (2-way)	0.025kWh
Increase range of procedures performed at clinics	(reliable elec needed)	incubator (basic) steriliser suction pump	2kWh 1kWh 0.025kWh

TABLE 2.2: Electricity supply implications

** - Information on which this is based is given in appendix A. Electricity consumption is based on typical values, and may vary substantially for different models of appliances.*

Supply capacity to meet health priorities

From table 2.2 an estimate can be made of the supply capacities (energy and power demand) required to meet rural health priorities. This is shown in table 2.3. While the table includes many assumptions which will not be valid in many cases, it provides a ballpark estimate of supply capacities which will be needed for various rural health linked services, and thus allows some analysis of which energy supply options can meet these needs.

	Energy use estimates (kWh/day)	Peak demand estimates (Watts)
Important household services:		
refrigeration	1.0 - 2.0	100 - 200
lighting	0.48 - 0.96	60 - 240
cooking & water heating	4.0	2000
TV	0.44	110
TOTAL	5.92 - 7.4kWh/day	2270 - 2550W (~10A@240V)
Important rural health care services:		
lighting - indoor & outdoor	0.6	150
vaccine refrigeration	0.42	60
radio	0.025	100
staff lighting	0.42	105
staff TV	0.44	110
TOTAL	1.9 kWh/day	525 W (~2.2A@240V)
Service provision for full rural health care:		
lighting - indoor & outdoor	0.6	150
vaccine refrigeration	0.42	60
radio	0.025	100
incubators	2	200
sterilises	1	1000
Suction pumps	0.025	50
Staff : lighting	0.42	105
TV	0.44	110
elec fridge	3	300
elec heater	8	2000
fan	0.2	50
TOTAL	16.1kWh/day	4095W (17A@240V)

Table 2.3: Energy and demand estimates for electricity to meet priority health services

Notes:

1. *Use patterns of equipment can be expected to vary greatly, as does their electricity demand. The above table therefore provides a guide only.*
2. *The total demand shown is for all appliances at once, and the internal clinic or household After Diversity Maximum Demand (ADMD) will probably be substantially less than this.*
3. *The energy use assumes that appliances are used fully, not only occasionally. The level of impact is partly dependent on 'full' use of appliances.*
4. *15W per light, which is a typical consumption of a fluorescent light, is used in this table. In rural areas incandescent lights can be expected to be more prevalent, thus values in the table above should be considered as a minimum.*

2.4 Description of the Eskom and the IDT's clinic electrification programme

Launched in 1992, the original Independent Development Trust (IDT) clinic electrification programme was *'small with a tight focus on providing electricity to health facilities in rural areas'* (Viljoen, pers comm, 1997). IDT's approach is now changing and their role is expanding: both in terms of the scope of the pre-electrification data collection and the services provided for in the implementation programme. This is partially due to IDT restructuring, which has resulted in a single management structure for a number of the services, and the development of IDT provincial capacity. There are 4000 rural health facilities without access to electricity (McAllister, pers comm, 1997). It is IDT's intention to cover 85% of these.

The number of clinics in rural areas is growing. Included in the IDT programme are new IDT-built clinics, National Department of Health 'fast track' clinics, clinics being built by provincial governments and RDP[10] clinics (Viljoen, pers comm, 1997). It is intended to provide electricity to clinics of between two and six rooms, including those with nurses homes of between two and five rooms. Electricity is also provided to larger health centres and hospitals.

By the end of 1996, 150 clinics had received a PV supply, 12 a genset-plus-battery system (with LPG vaccine refrigeration) and 150 had been connected to the grid. Currently a further 50 PV systems and 18 genset-plus connections are due to be installed, and 60 clinics are to be connected to the grid.

Implementation process

In the past, pre-electrification surveys have concentrated on site layout and needs assessment surveys of health institutions. A new approach is being launched in the Northern Cape which will include all national, provincial and local government buildings and land, and the water and electricity infrastructure situation - including bulk supply information. (Viljoen, pers comm, 1997).

Currently, health facility surveys are undertaken by IDT and Department of Health fieldworkers and managed by consultants. They provide information on the distance from the grid, the size and layout of the site and buildings, and electricity service needs. The information is used to select an electricity supply option and to design systems and estimate expected supply costs. IDT has embarked on electricity network mapping and have assisted with funding the development of Remis - a regional health information database designed to manage regional health infrastructure and epidemiological profile. *'Developing comprehensive infrastructural information is an important aspect of IDT's future'* (Viljoen, pers comm, 1997).

Initial electrification projects were confined to supplying electricity (and in some cases appliances and LPG equipment) to health facilities. Programmes are now being expanded to include water, sanitation, and remedial building. New genset-plus installations also include a community battery charging facility. Previously electrified clinics will be revisited and included in the new approach (Viljoen, pers comm, 1997).

Consultants undertake system design and manage projects. Contractors are appointed via a tender process. Completed installations are handed-over to Department of Health, who are responsible for ongoing operation and maintenance, although the IDT includes one year's operation and maintenance (O&M) as a part of the contractor's obligations.

Technology choices & supply level

The choice of electrification technology is based largely on distance from the grid, and also considers Eskom's electrification plans. Clinics are connected to the grid if they are less than 1km from the network, while genset-plus and LPG systems are usually provided for clinics 1 to 5km away (depending on Eskom's electrification planning and the size of the clinic), and clinics more than 5km away are provided with PV-electricity. The genset-plus systems are not intended to be permanent, but it is anticipated that they will be moved as the grid is extended to clinics where they are installed.

Grid-supplies

IDT's involvement in grid connected clinics covers the following: a standard 60amp single-phase connection, and wiring for lights and plug-points in the clinic and nurses home if present. More recently the following are also provided: outside entrance/street lighting, a medical examination light and pumping and plumbing to extend the water supply to a hot water cylinder, which is also provided. Vaccine fridges are not supplied in grid connected

10 Reconstruction and Development Programme

clinics (Albrecht, pers comm, 1997). Previously 25kVA[11] transformers were used, but this was found to be excessive so now 15kVA is mostly used.

PV electricity supply

The PV electricity supply level is dependent on size of the clinic. There are generally three main sizes of PV systems. The first is for the large RDP clinics, which includes two parallel systems linked by a solar-bus. The first of the parallel system supplies electricity for a DC[12] fridge and radio, and the other provides AC power for up to 40 lights, a medical examination lamp, and a power-point in each nurses home for TV. The second system size is for smaller clinics typically built by the provincial departments, and comprises two parallel systems as with the RDP clinic system, although the lighting system is smaller. The third system size is for smaller, typically non-residential clinics, and is one integrated system rather than two parallel systems. It also provides DC power for the vaccine fridge and radio, and provides AC power for up to 20 lights. Installation includes the provision of a DC vaccine-fridge. The level of supply also depends on the state of the building. For example a small temporary system is put in place if the building is to be renovated at some stage. The approach adopted by the IDT for system design is rigorous and prescriptive, and the appointed contractors are carefully supervised to ensure that they install systems to the necessary standard (McAlister, pers comm, 1997).

Genset electricity supply

Electrification of IDT clinics using DC-genset-plus systems provide 4kWh[13] per day, and have 580Ah[14] of battery capacity installed. Electricity services include general and security lighting, TV, radio, and radio communication. The vaccine refrigeration system is run on LPG, not electricity, and a fridge and two LPG cylinders with an automatic switch-over are provided. New genset installations also include a community battery charging facility from which the expected income is R2000/month (van der Vyver, pers comm, 1997). DC-systems are provided because these are considered cheaper and more cost-effective, reduce maintenance requirements, and because the system *'needs DC to charge batteries, so why provide AC and then convert back to DC?'* (van der Vyver, pers comm, 1997)[15].

Training, operation and maintenance arrangements

The maintenance of the grid supplies are the responsibility of Eskom (for the power lines) and the Department of Health (the on site supply). The grid-electrification process provides no user operation or maintenance training. Off-grid system operation and first-line maintenance is the responsibility of the user, and off-grid installations include user-training (by the installer) and provision of a user-manual. A one-year maintenance contract and a comprehensive supply of spares is provided for in the off-grid programme as a part of the installation contract. All installations include a standard defects liability warrantee from the installation contractor.

Funds and budgets

Funds allocated by the IDT to date for clinic electrification amount to R54 million for capital system costs and R4.5 million for O&M costs, all from internal IDT funds. These have all been committed to projects, and about 60% has already been paid out. New sources of funds are internal IDT funds reallocated from other programmes, and funds from

11 kVA is a measure of power, as is kilowatts (kW). The relationship is typically: 0.8kVA rating = kW rating

12 Direct Current, often 12 Volts, as opposed to 240 Volt Alternating Current (AC) which is the type of electricity supplied by the conventional Eskom grid.

13 kilowatt-hours - one kWh is one kW used for one hour.

14 ampere-hours - one amp of current drawn for one hour. Battery capacity is typically rated in ampere-hours.

15 Although this approach results in a lower capital cost, it may not be the most appropriate over the longer term. On the PV clinic systems, for example, DC systems were initially provided, but this was changed to AC largely for consistency and versatility reasons.

the previous RDP office (now Department of Finance) which includes both international and local funding sources.

IDT funds the data capturing processes (survey etc.) undertaken prior to electrification. IDT covers total project cost, except in partnerships between IDT provincial offices and provincial governments, and in the RDP programme - where IDT are the implementing agency and the other party provides funds. A new approach to IDT programme costing is the recent introduction of 'zero-based' budgets, which includes IDT internal operational overheads as a part of the project costs.

Costs

The pre-electrification survey, data collation, and plan drafting are estimated to cost about R1500 per clinic (Maare, pers comm, 1997).

Cost figures based on electrification in the Ciskei are provided below. New tenders are currently closing for the Transkei - which will shortly provide more up-to-date cost information (Albrecht, pers comm, 1997).

1 Connection fee - Eskom Landrate	R 770
2 Installation: Appliances	R 2 000
Water supply	R 4 500
Wiring & lighting	R 8 500
P&Gs**, labour etc	R 15 000
3 Consultant fees at 16%	R 4 900
TOTAL (1+2+3)	**R 35 670**
Three-phase line extension costs	R 45 000/km

Table 2.4: Costs* per clinic -1996/7 Ciskei IDT grid-electrification programme

** - Costs exclude VAT*

*** - Preliminary and General costs - this includes all contractor preparation and setup costs*

The cost of providing PV electricity is provided below. The electrification process is too recent to define long-term maintenance and repair costs, the key statistic being mean time between failure. IDT have started collecting this information to enable accurate assessments (Viljoen, pers comm, 1997).

450Wp PV panel, 275Ah battery system		*600Wp PV panel, 300Ah battery system*	
System hardware	R 52 242	System hardware	R 66 332
P&Gs**	R 2 096	P&Gs**	R 2 096
Installation	R 7 894	Installation	R 7 894
Maintenance / yr	R 1 754	Maintenance / yr	R 1 754
Battery replacement /yr	R 366	Battery replacement /yr	R 366
TOTAL	**R 64 352**	**TOTAL**	**R 78 442**

Table 2.5: IDT clinic PV electrification cost information per clinic (1997 prices)*

** - consultant fees are excluded (typically around 10% of total cost).*

*** - Preliminary and General costs - this includes all contractor preparation and setup costs*

Note: VAT is excluded.

Diesel-costs

The estimated clinic genset cost is provided below. The electrification process is too recent and there is not sufficient information on system performance to assess actual O&M costs (van der Vyver, pers comm, 1997).

Installation: Genset & accessories	R 13 000
Batteries (580Ah) & accessories	R 4 000
LPG vaccine refrigeration equipment and other appliances*	R 7 500
Installation & transport	R 3 500
Consultant's fees (approx)	R 3 000
TOTAL installation	R 31 000
O&M costs: LPG vaccine fridge (48kg for 6 mths R80-R100) (R 15 / month)	R 180 / year
Genset diesel running costs (R 240 / month)	R 2 880 / year
Genset maintenance, spares and labour (R 12 / month)	R 144 / year
TOTAL annual O&M cost**	R 3 204 / year

Table 2.6: IDT genset-plus system and LPG vaccine refrigeration system cost information

Source: van der Vyver

** - other appliances include lights, TV/VCR, and 2-way radio.*

*** - note that the O&M costs are low compared with figures from other gensets, as they do not include minor or major services, nor periodic overhauls*

Note: VAT is excluded.

Assessment of the IDT programme

An in-house IDT assessment of the systems installed indicates that they are of high quality, reliable and robust - in keeping with the needs of clinic loads. Technical solutions have been appropriately fine-tuned during the course of the programme and the prescriptive approach of the IDT particularly regarding technical specifications has lead to a challenging situation for solar companies in particular and a high level of system reliability. There may, however, be a need to improve the quality of locally-made PV vaccine fridges. Clinic staff appear happier since systems have been installed and *'staff retention rates may well have improved'* (McAlister, pers comm, 1997).

There are still concerns over sustainability of systems once the year long maintenance contract - which forms part of the installation contract - has expired. Further arrangements regarding ownership, training, and maintenance funding appear necessary. There is also a question regarding the moving of genset-plus systems to other sites should the grid be extended to the clinics where they are installed, namely who will undertake this removal, how effectively will it be done, and where will these systems be moved to? These issues can impact on the appropriateness of the selection criteria for this supply option. Also there is a need to improve feedback mechanisms to the IDT during and following installation - given that systems are being installed in remote areas with low technical capacity. Systematic and longitudinal monitoring is needed for more comprehensive assessment of the programme and its impact.

3 EDUCATIONAL BENEFITS AND RURAL ELECTRIFICATION

Sections 3.1 to 3.4 draws freely on a paper by Adele Gordon (1997) titled 'Facilitating education in rural areas of South Africa: The role of electricity and other sources of energy'. Where information is drawn from other sources, references are provided.

3.1 Characteristics of rural education in South Africa

Gordon (1997) considers that education in rural areas of South Africa is in a 'parlous state', with both community schools (in the former homelands) and farm schools (on commercial farms) being under resourced. Many do not have access to water, sanitation, electricity or necessary teaching aids. Farms schools in particular are the poorest and worst resourced in the country.

Farm schools comprise 7%, and community schools 30% of the total number of schools in South Africa. Farm schools have historically been controlled and resourced largely by the farmer, while community schools were sometimes established by the local department of education and sometimes by communities. These schools were administered by the local department, and were subsidised to varying degrees.

Amongst the problems faced by rural schools are overcrowding (50 learners per classroom is apparently not uncommon), long distances for pupils to walk to school, inadequate living conditions for teachers, and poor access to infrastructure and resources. The level of school electrification in urban and rural areas varies from about 20% (Eastern Cape) to about 80% (Northern Cape).

3.2 Summary of areas where electricity can impact on education

Very little international or local work appears to have been done from which the impact of electrification on education can be ascertained in any detail. The few studies that exist are often relatively superficial, and none provide any longitudinal picture of the relationship between electricity supply and education. Information on how household electrification relates to education through household activities is even more limited. So, in summary, little is known about this link, and thus it is of added importance to examine the area in more detail before additional resources are committed to rural school electrification, such as in the Eskom school electrification project.

In general, it appears that electricity is currently not an important input to many rural schools, and other critical infrastructure (such as water, more classrooms, improved transport for learners, teaching aids) should rather be the focus of national attention. Where such resource shortages exist at schools, electrification is likely to have limited impact.

The studies that have dealt with electrification impact at schools indicate that impacts have been limited, and are highly dependent on the context and complimentary measures surrounding electrification. One study of PV electrification in schools in the old Boputhatswana for educational TV showed little impact partly because the capacity within the school and education system was inadequate to utilise the technology properly. In another case, it was found that newly electrified schools made sporadic use of lighting, but otherwise the impact was small, and a study in Namibia found electricity to have little impact on primary school functioning. Lighting of both the school and teachers accommodation was considered to be important to the functioning of schools in Northern Botswana, however, as it allowed classrooms to be used by pupils and adults at night for reading and study, and teachers found that lighting facilitated their jobs by allowing them to prepare lessons and mark papers at night - tasks which they could not easily fit into their day (Borchers et al, 1994).

Electricity is therefore not without impact, although it is clearly limited and should not be seen as a high priority for improving rural education. Gordon cites studies which stress how '*technology is only one part of a complex system of processes and relationships that make up the education and training system*', She summarises: '*where schools operate with few basic facilities, too few classrooms, and no resources to administer the service, the impact of electricity on teaching and learning is likely to be minimal*'.

3.3 Specific impacts of electric services

Lighting of classrooms and offices

Lighting allows night time activities to be carried out at schools, such as holding adult education activities or potentially even educational TV for the community. While the potential impact is generally accepted as substantial, the observed impact of such lighting on education is less clear. It has been observed in one case that night use of some newly electrified schools is 'sporadic', and one researcher mentions that in practice women may not be able to attend night classes for various reasons. The real benefit of lighting is likely to be dependent on the organisation of suitable activities at the schools, on suitable staffing, and on reducing the variety of social and logistical constraints people face in attending evening events.

Outdoor or security lighting may facilitate access to schools at night, and may also increase the security of equipment at schools, making it more feasible for schools to keep certain equipment.

Lighting in staff offices or staff homes may also enable staff to undertake work at night, which may improve the effectiveness of the school. However, the reported incidence of staff finding lighting useful for after-hours work are few, and thus the impact of such lighting is uncertain.

Media

The use of radio and TV in particular can be powerful enhancements to education in rural areas. This is currently being done via radio with the Open Learning Systems Education Trust. SABC's[16] Education Broadcasting Service TV programmes are due to come on-line before mid-1997, and this service will cover radio as well. The Department of Education is planning to utilise technology enhanced learning to a greater extent in future, although this raises equity concerns in the short term, as wealthier, better equipped schools will be better able to take advantage of such programmes. There are indications that batteries for radio are prohibitively expensive for some schools currently utilising the Open Learning Systems Educational Trust radio service, and thus a source of electricity which can be used to power radios may increase the use of educational radio. A source of electricity is of course only one part in the effective use of media in education - the material also has to be appropriate, the media equipment must be accessible to the school and use thereof must be affordable, and school staff may need to integrate it appropriately into learning curricula. Household electrification can also facilitate access to educational media, and thus it may also impact on education outside of the school.

International studies also indicate that appropriate media can have a role in rural education, and examples are cited in Gordon (1997) where computer aided learning and two-way radio interactive learning have been successfully used in first and third world contexts.

Overhead projectors

Although overhead projectors are often considered an important teaching aid (and are standard 'issue' with Eskom's off-grid school electrification project for example), there is almost no information on how and where they are used and whether they are generally considered important by teachers. Their impact is likely to be dependent on a range of factors, not least of which may be the continual availability of basic supplies such as overhead pens and transparencies.

Computers

Computers may be used by the staff for school administration, by learners for a number of applications, and by everyone to access and learn from the seemingly infinite resources on the Internet. While their potential to enhance education seems enormous, there are no known examples of their use in rural schools in this country. However, there are plans to equip all schools with computers in the medium term, to enable them to use email amongst other things (Gordon 1997).

Electrical laboratory equipment and other technology

Electrical equipment can enhance laboratory learning, particularly on the topic of electricity, which is currently a significant part of the science syllabus and is likely to remain so in future (Gordon, 1997, Appendix A). Exposure to electrical technologies would increase learners general awareness about these items and overall knowledge of electricity.

Household electrification easing domestic burden

Electrification of households could ease the domestic burden endured by women and often children by enabling the use of certain appliances (e.g. using electric cookers in place of wood for cooking). Electricity is also a component of many water provision projects, and thus may have a role in reducing water carrying time by women and children. It is suggested that electrification thus has a role in giving women and children more time to study and could increase school attendance, although the evidence supporting this link is inconclusive and is dependent on a range of complimentary inputs and infrastructural

16 South African Broadcasting Corporation

developments.

Facilities for teachers

Some evidence indicates that teachers are more likely to remain in rural areas if their houses are electrified, although the strength of this link is unknown.

Office equipment

Equipment such as fans, faxes, photocopiers and computers may make school administration and staff facilities more effective and less tedious. However, such equipment does not appear to be an immediate priority or a realisable acquisition for the vast majority of rural schools given the critical resource shortages faced by these schools in general.

Cooking

The RDP Primary School Nutrition Programme apparently experiences wood shortages in some areas, and sometimes children are asked to provide wood - which can cut into their study time. It may be feasible to substitute electricity for wood in electrified rural schools.

3.4 National education priorities relevant to electrification

National education priorities

Gordon lists the following principles which are *'central to the vision underpinning education policies'*:

- *a commitment to providing access to quality education, and a right to basic education as enshrined in the Bill of Rights;*
- *a commitment to developing the full potential of South Africa's people for their active participation in all processes of a democratic society and their contribution to the economic growth and development of the country;*
- *redressing imbalances of the past through the implementation of new teaching and learning strategies for the effective and flexible delivery of services within various learning contexts and through the equitable distribution of technological and other resources;*
- *implementing learner-centred and outcomes-based approaches to education and training in order to achieve quality learning based on recognized national standards;*
- *enabling all people to value, have access to and succeed in lifelong education and training;*
- *developing a problem-solving and creative environment in which new technologies are harnessed to produce knowledge, products, and services;*
- *integrating technology into the strategies intended to reach these goals so as to advance South Africa's ability to harness new technologies in its growth and development.*

Restoring the culture of teaching and learning depends on ensuring accountability; this will be effected by devolving decision-making to parents, the principal and teachers.

There are a number of initiatives and approaches planned or being considered to implement the new education vision. The White Paper on Education (February 1995) advocates Open Learning as an approach to increase access to education and to improve the quality of education:

> *Open learning is an approach which combines the principles of learner-centredness, lifelong learning, flexibility of learning provision, the removal of barriers to access learning, ...South Africa is able to gain from world-wide experience over several decades in the development of innovative methods of education including the use of guided self-study, and the appropriate use of a variety of media, which give practical expression to open learning principles*

(White Paper on Education and Training, Government Gazette No 16312 of 1995, p 28).

An important part of renovating the education system in the country is curriculum restructuring. The approach of the planned curriculum (Curriculum 2005) stresses the need to be able to solve problems and interact with a fast changing world, rather than placing priority on '*content as a major goal of learning*'. Amongst the important outcomes of the new education approach is the ability to use science and technology, and to communicate effectively.

Other initiatives and approaches which form part of the new approach to education in South Africa include:

- *Technology Enhanced Learning* (TEL): this covers learning via the range of media options, including audio, audio-visual (TV/VCR) and computer (to access the internet amongst other things). The initiative by the Education Broadcasting Service (SABC), which will come on-line by mid 1997 on TV and radio, fall within this broad category.
- *Adult Basic Education Training* (ABET), which aims to provide adults who have not had access to adequate education the opportunity to learn various skills. Gordon indicates that in rural areas schools are likely to become centres offering adult education after hours.
- *Multiple Resource Community Centres*: these are partly linked to TEL, as it is considered that they would provide central points through which rural communities could access TEL. They are also intended to have a role in ongoing teacher training and to provide a centralised resource base to service schools in the area. They would thus include equipment such as TV/VCR, computers, telephone, fax, and equipment needed for some secretarial services (e.g. typewriters/printers and photocopiers/duplication machines).

Area of impact	*Energy service requirements*	*Equipment implication*	*Electricity supply implications**
SCHOOL			
Evening/adult education classes	indoor lighting	elec lights (hi-eff x10)	0.6kWh
Facilitate access to schools at night	outdoor lighting	elec lights (hi-eff x2)	0.12kWh
Security of equipment	outdoor lighting	elec lights	0.12kWh
Access to media	TV/VCR, radio	elec TV/VCR	0.44kWh
Teaching aids	OHP**	elec OHP (AC) elec OHP (DC)	1.2kWh 0.6kWh
Teaching aids - lab equipment	elec lab equipment	elec plugs, selected equipment (x15)	9kWh
Teaching aids - computers	computer	computer, printer (basic) comp, printer (modern)	0.68kWh 2.4kWh
School administration facilitation via computers and email	computer	computer, printer (basic) comp, printer (modern)	0.68kWh 2.4kWh
School administration facilitation via office equipment	faxing, photocopying	fax photocopier	0.06Wh 2.0kWh
Nutrition of pupils	cooking	elec cooker (large) LPG cooking	8Wh
HOUSEHOLD AND STAFF ACCOMMODATION			
Teachers comfort	lighting, cooking, media	elec lights (hi-eff.x4) elec hotplate TV	0.24kWh 4kWh 0.32kWh
Evening work	lighting	elec lighting (hi-eff.x4)	0.24kWh
Easing domestic burden	elec cooking (and other appliances)	elec hotplate LPG cooker	4kWh LPG
Access to media	TV/VCR, radio	elec TV/VCR	0.44kWh

TABLE 3.1: Electricity supply implications of rural education needs

** - Information on which this is based is given in Appendix A. Electricity consumption is based on typical values, and may vary substantially for different models of appliances.*
*** - overhead projector*

Electrification impacts relative to education priorities

Electrical technologies in general: the new education focus places substantial emphasis on technology-related training and education, which implies that learners need access to such technologies. A working knowledge of electricity and electric technologies is likely to be a meaningful part of this process, and thus schools should be equipped correspondingly.

Lighting: both indoor and outdoor (security) lighting is essential for evening education activities such as within the rural ABET programme, as adult education and training in this initiative will use schools in many rural areas. Lighting may be particularly important in enabling women to attend evening activities, although other factors (social and transport related, for example) are likely to be strong determinants of ABET's impact on women.

Media (radio, TV/VCR): this allows schools to access the vast potential for enhancing education via these media, including the SABC's educational services due to come on-line shortly. This applies to households as well as schools.

Computer: In the medium term, computers are likely to become increasingly important to connect schools to email, enable internet access, and also to facilitate school administration.

All of the above are areas where electricity can contribute to education, although it needs to be stressed that equipment only becomes effective when appropriate education material is available, where the capacity exists to utilise the technologies effectively, and where the services provided by the technology can be integrated into education adequately by teachers. It also needs to be remembered that, considering the extreme absence of resources in most rural schools and tight education budgets, in the short term schools are unlikely to have access to or benefit substantially from equipment such as media and computer technology. In practice it is considered that print media is still likely to be the used extensively. Having said this, on equity grounds it is almost of added importance that rural schools have adequate service provision, including access to media equipment, as redressing education disparities is one of the underlying principles of new education policies.

Level of service supply	*Energy use estimates (kWh/day)*	*Demand estimates (Watts)*
Important short term services:		
basic indoor and outdoor lighting	0.43	90W
limited TV/VCR	0.22	110W
TOTAL	0.65kWh/day	200W (0.8A@240V)
Important medium term services:		
full indoor/outdoor lighting	0.72	180W
TV/VCR	0.44	110W
computer & printer (modem)	2.4	1000W
TOTAL	3.56kWh/day	1290W (5.4A@240V)
Full electrical service supply:		
lighting	0.72	180W
TV/VCR	0.44	110W
computer	2.4	1000W
fax	0.06	60W
photocopier	2.0	1000W
OHP (DC)	0.6	150W
elec lab equipment	9.0	3000W
TOTAL	15.2 kWh/day	5500 W (23A@240V)

Table 3.2: Energy and demand estimates for electricity to meet priority services for a small (3 or 4 roomed) rural school

Notes:

1. *Use patterns of equipment can be expected to vary greatly, as does their electricity demand. The above table therefore provides a guide only.*
2. *The total demand shown is for all appliances at once, and the internal school After Diversity Maximum Demand (ADMD) will probably be substantially less than this.*
3. *The energy use assumes that appliances are used fully, not only occasionally. The level of impact is partly dependent on 'full' use of appliances.*
4. *15W per light, which is a typical consumption of a fluorescent light, is used in this table. In rural areas incandescent lights can be expected to be more prevalent, thus values in the table above should be considered as a minimum.*

3.5 Description of the Eskom school electrification programme

Started in 1991, the initial school electrification targets were ambitious: 2000 schools per year, and 9500 grid and 16400 off-grid by the year 2001. Currently there is the realisation that these targets will not be met, largely because of a shortage of human and financial resources.

From 1991 to 1996, 2955 schools were connected to grid electricity (Gordon, 1997). The off-grid schools electrification programme was started in 1994, and electrified 1050 schools by the end of 1996. The target for 1997 (grid and off-grid schools) has been reduced from 1005 to 312 due to budget limitations, although no clarity exists on how many of these are rural (Seleta, pers comm, 1997). With such reductions in targets, large numbers of schools are likely to remain unelectrified by the year 2000.

A list of schools from the Human Sciences Research Council (HSRC) database is used as the basis for identifying schools and choosing between a grid or an off-grid supply. Eskom's 5-year network expansion plan is also taken into account. Because of high line-extension costs, schools within 3 km of the current grid (or the 5-year network expansion plan) are considered eligible for a grid supply. Schools not within these parameters may be eligible for an off-grid supply and are referred to Eskom's off-grid Technology Group, who handle off-grid school electrification. Further arrangements for grid and off-grid options are separate, such as raising and allocating funds, system installation, and operation and maintenance arrangements.

Eskom is currently developing a GIS[17] planning database using information from their pre-electrification investigation for the development of an electrification master plan. This includes for example distance to the electricity network, the number of schools, clinics, the number and size of stands, and the SMMEs identified (Sterley, pers comm, 1997).

Grid-electrification

Process

Grid electrification is undertaken according to a 24 month plan. Schools are identified by Eskom. Consultants undertake surveys (using an Eskom questionnaire), to assess the size of the site and the position and size of buildings. Also included is an assessment of the energy sources used and services available. Consultants draw up site and building plans, design systems, and estimate the cost of providing an electricity supply. Installation contractors are appointed from a list of contractors registered with Eskom (Sepharatla, pers comm, 1997).

Supply-level

Rural schools being electrified vary from one to twelve rooms (Bouwer, pers comm, 1997). Most schools are provided with a 60amp single-phase supply - less than 2% get a three-phase supply and transformer of more that 25kVA. Schools are wired, and each room is provided with internal lighting and plug-points. Installations also include external lighting. Currently, aside from light fittings, no appliances are provided. In Gauteng, Eskom's regional School Electrification Project (SEP) are considering including a TV, VCR and an overhead projector[18] (Sepharatla, pers comm, 1997).

Payment

Customers pay Eskom's Landrate tariff. The Department of Education are responsible for electricity payments. The standard Landrate single-phase tariff applies, but schools do not pay a connection fee (Bruwer, pers comm, 1997). Electricity is paid for by either pre-payment and billing systems. According to Gordon both have their place: prepayment is preferred for control and flexibility, billing is preferred when there are cash flow problems.

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17 Geographic Information System - a geographically referenced database system

18 As is being done with the off-grid schools electrification programme.

Funds & budgets

Sources of funds include Eskom's Community Development Fund, international donors and the RDP. In total R45million had been spent by the end of 1996 (Gordon 1997). RDP funds are administered by the Department of Minerals and Energy (DME), and other funds by the Eskom schools electrification programme (SEP). Eskom's SEP budget pays for the last kilometre of line-extension, and connection and wiring. Funds for a further two kilometres are provided by the DME. Eskom charge a 4% management fee on DME funds.

The 1997 budget - R14million - is entirely from Eskom's Community Development Fund. Budgets are based on average costs. Operational overheads are absorbed into Eskom expenses and are *'never actually costed'* (Hambly, pers comm, 1997). Eskom's standard operation and maintenance cost (for MV and LV lines) is estimated at R22 per customer per month (Nowasat, pers comm, 1997). Eskom are working with the RDP to source further funds from overseas donors (Seleta, pers comm, 1997).

Cost

The cost per school depends on the distance of the school from the grid and the cost of wiring and lighting, which is dependent on the size of the site and the number of buildings and rooms. There is a distribution board for every four to five classrooms, and a 7x8m^2 classroom is fitted with double fluorescent light fittings and a double plug-point.

The average cost of wiring and fittings per classroom is R2400 to R2500, including outside lighting. Eskom have looked at high mast security lighting but found it to be too expensive (Bruwer, pers comm, 1997). One meter is supplied per school. The cost of consultants makes up about 4% the total school electrification cost.

Pre-electrification survey	R 1 667 - external R 800 - internal (by Eskom)
Line extension/km	R 56 840 -MV* R 37 340 - LV**
Connection - 60A single-phase	R 2 000
Wiring (lighting, plug-point & outside lights)	approx R 2 500 per classroom

Table 3.3: Eskom schools grid electrification information (1996/7)

· *Source: Bruwer, pers comm, 1997*
* *- medium voltage, typically 11kV or 22kV*
** *- low voltage, typically 380V or 240V.*
Note: VAT is excluded.

Costs of schools grid electrification are currently being finalised (Dell, pers comm, 1997), however according to Bouwer (pers comm, 1997) *'there are an infinite number of different sizes and types of schools, (so) it is impossible to quantify costs other than in broad averages'.*

Off-grid (PV)

Process

After being referred to Eskom's Technology Group, schools to receive an off-grid supply are chosen in consultation with the Provincial Department of Education (Raseki, pers comm, 1997). Planning is undertaken on an 18 month basis. Targets are not fixed but defined within projects and depend on Eskom's network plan and the number of schools identified, as well as the availability of resources such as funds and manpower.

Eskom fieldworkers survey schools. Plans are drawn and systems are designed in-house and put out to tender. The choice of contractor depends firstly on the technical specifications of the proposed equipment, and secondly on the price (Raseki, pers comm, 1997). Numbers of schools electrified to date are: Eastern Cape (900), and Northern Cape and North West Province (150). The next electrification projects are in the Northern Province and KwaZulu Natal. Completed installations are handed-over to the regional

Department of Education, who are responsible for operation and maintenance (O&M). It is not clear whether any measures are in place to ensure that the Departments have the necessary capacity to undertake this task effectively, and this issue may need to be addressed urgently to ensure the sustainability of the programme.

Training support provided by Eskom includes an installers programme at the Port Elizabeth Technicon. User-training forms part of the commissioning procedure and is included in the contractor's installation costs (Griesel, pers comm, 1997). School staff are trained to undertake first-line maintenance and are provided with a maintenance kit.

The provision of water is *'being looked at if there is a borehole Eskom may assist with electricity for pumping'*. A schools off-grid database, presently confined to information on schools making an application for electricity, is being extended to include project information such as technical detail and a monitoring system to log faults (Raseki, pers comm, 1997).

Technology choice & supply-level

Most off-grid electricity supplies are via PV electricity. Gensets are considered not suitable, because while the capital costs may be lower, O&M costs tend to be *'a problem'* (Raseki, pers comm, 1997). Eskom is however exploring the use of other technologies, and the feasibility of a pilot hydro-power project providing electricity to five schools in the Drakensberg is currently being assessed, and finance is being sought to initiate a wind-electric pilot. Eskom is developing a data-base on hydro and wind resources (Buttle, pers comm, 1997).

System capacity (PV panel Wp)	*500Wp system*		*700Wp system*		*900Wp system*	
	Cost	% of total	Cost	% of total	Cost	% of total
PV equipment	R 20 967	38	R 23 426	40	R 25 162	41
Appliances & other*	R 7760	14	R 8390	16	R 9020	15
Wiring	R 4046	7	R 4222	7	R 4570	7
Installation	R 9100	17	R 9100	16	R 9100	15
Project management	R 6000	11	R 6000	10	R 6000	10
Vat	R 6702	12	R 7159	12	R 7539	12
TOTAL	**R 54 575**		**R 58 297**		**R 61 391**	

Table 3.4: Eskom Eastern Cape schools PV electrification information (1996/7)

Source: Griesel, pers comm, 1997
** - luminaires, sockets, switches, maintenance kit*
Note: VAT included

The supply level provided to schools depends on school size and number of lights required. All are provided with the same additional equipment - a TV, VCR and overhead projector. Currently PV arrays for school systems are sized at 0.5kWp[19] to 1kWp, and total battery capacity provided is between 150Ah to 300Ah. Lighting levels provided are 90 lux[20] per classroom. No security lighting is installed.

Funds, Budget & Cost

In total R56million had been spent since the onset of the programme and a further R15million allocated. Funding sources are the RDP and DME, much of which was originally international donor money. Budgets do not include Eskom operational overheads.

19 kilowatt-peak - the peak kilowatts produced by a PV panel under specified conditions. This is a standard rating specification for PV panels.

20 lux is a standard lighting level measure - 1 lux = 1 lumen/m^2; 1 lumen = 0.057W

Security

Security appears to be a problem as *'equipment is disappearing'* (van der Vyver, pers comm, 1997) and *'systems have been robbed shortly after installation'* (McAlister, pers comm, 1997). Yet there appears to be no plan within the SEP or between schools and the Department of Education for dealing with this. According to both Sepharatla and Raseki (pers comm, 1997) the level of security of school systems depends on the extent of ownership of systems by beneficiaries. This in turn depends on their involvement in the electrification process. To deal with this communities have in some cases organised their own security such as by employing a night watchmen.

Programme assessment and institutional coordination

The SEP has largely concentrated on technology and installation aspects of delivery to date, although procedures for addressing maintenance are being initiated. The more social and qualitative issues such as cooperation with education officials, parent associations and communities, appears to be dealt with inconsistently and depends on individuals within Eskom's regional structures. However, Eskom is increasingly engaging the Department of Education in some areas (e.g. Gauteng) regarding planning, payment and responsibility for systems.

In general, the impact and cost-effectiveness of the programme is not known. Further information is needed to assess system performance and suitability of supply levels, and the use and impact of electricity - on for example the level of education and actual learning process or quality of life perceptions of pupils and teachers. Eskom has recently commissioned an evaluation of their programme.

4 RURAL ELECTRIFICATION AND SMME SECTOR BENEFITS

Sections 4.1 to 4.3 draw freely on a paper by Rogerson (1997), titled 'Rural electrification and the SMME economy in South Africa'. Where information is not sourced from this paper, a reference is provided.

While there has been much research on both SMME development and rural electrification, few studies focus on linking the two directly. These links are generally only studied as a sideline to the main study theme, for example while examining the general impact of rural electrification on communities. The paper by Rogerson (1997) is thus one of the few seeking to explore this link as its main theme.

4.1 Characteristics of SMMEs in South Africa

Some of the most common types of rural SMMEs in South Africa:

Retail activities	***Services***	***Manufacture/construction***
general dealers	hair salons	beer brewers
cafes	transport activities	brick making
tuckshops	motor-car repairs	metal work
spaza shops	panel beating	clothing
shebeens	shoe repairs	dressmaking
bottle stores	electric repairs	knitting
hardware stores		bakeries
		small-scale maize millers
		wood working/carpentry

Rogerson points out that the rural SMME economy is not homogenous. The following categories of SMMEs appear to be the most generally accepted, and provide a useful framework for dealing with some of their differences:

1 survivalist enterprises in the informal economy
2 micro enterprises

3 formal SME economy

The literature on South African SMMEs is consistent in its finding that the rural SMME sector is overwhelmingly dominated by survivalist activities, typically of a retail nature (e.g. running small spaza shops). The value added activities of manufacturing, processing and construction are in the minority. For example, one study of 34 villages in Northern and NW Province found 77% of SMMEs to be survivalist, with only a handful of 'value added' activities in existence. Research shows that this picture is also true for the Eastern Cape, Mpumalanga, and Kwazulu Natal. In general, it has been found that isolated rural areas do not offer anything more than minimal opportunities for money making.

4.2 Summary of RE impacts on SMMEs

Rogerson, in reviewing literature on the impact of rural electrification relevant to SMMEs, notes that while there are relatively strong statements made concerning the positive benefits of RE on this sector, these are often quite generalised (for example noting 'a positive correlation between electrification and commercial establishment growth'), and the question of how exactly RE fits into the range of SMME needs is often not examined in adequate detail. He further notes that there is a significant silence on the importance of electrification for SMMEs in most research on this sector, and in '*the core of international writings and debates on the internal and external constraints on rural SMME development scant attention is given to electrification as a salient issue*'. Issues such as access to capital, finance and markets have been generally found to be the key blockages in SMME development. Rogerson points out that both finance and markets were accessible to SMMEs in the areas covered by the influential research of Barnes (1988), who provides amongst the most favourable reviews of the impact of RE on SMMEs. It appears that there is some consensus amongst later researchers on RE that the catalytic effect of RE on SMME development is not clear ('*research is not at a stage where any such conclusions can be drawn*' Pearce and Webb, 1987), and that provision of infrastructure (including electricity) for rural SMMEs is in many cases not a sensible investment to promote growth in this sector (Elkan, 1989). RE will have more of an impact on SMMEs in areas where there is an already dynamic economy, and will benefit medium and large industries more than small scale industries. Also, there is little evidence to suggest that RE promotes the establishment of new SMMEs. At very least, '*rural electrification must be accompanied by complimentary inputs such as extension of rural credit and greater access to markets*' if it is to have a positive impact.

Studies of SMMEs in South Africa also generally indicate that electricity is in fact presently of very limited importance to their development in the face of the myriad of stronger constraints. For example, one comprehensive study of problems faced by SMMEs in Mpumalanga found that '*of 46 business problems, lack of electricity was ranked only 34, confirming it as a factor of minor significance in the overall spectrum of SMME development in South Africa*'.

Core constraints faced by the sector are also generally consistent in the substantial amount of SMME research undertaken to date in this country. These invariably relate to:

- access to finance, including for start-up loans,
- access to markets and information, and
- access to training

Although the expectations of electrification providing a boost to SMMEs often appears to be highly optimistic, there is also a reasonable body of evidence to suggest that in certain defined situations electricity is likely to have an impact. Although RE can be expected to benefit mainly larger already established enterprises, it appears that in the small-scale retail sector (e.g. spaza shops, cafes and shebeens) electrification can have a significant impact on smaller ventures, and even stimulate the creation of new ones, principally through the benefits of electrical refrigeration, and also through lighting. Local as well as international research concurs on this count, although Rogerson stresses the importance of other factors (such as increased survivalist activities due to rising unemployment) in shaping this picture.

While RE does not appear to promote the creation of new productive SMMEs to any significant degree, it appears to allow existing ones to improve their productivity by enabling them to upgrade to more effective technology. One study mentioned garment makers, block and brickmakers specifically. Another study indicated that electricity was particularly effective in stimulating activities in the service sector, mentioning beauty parlours, ice making, photocopying, battery charging and retailing as examples.

In general, the impact of electrification appears highly differentiated - being important to some enterprises and irrelevant to others.

One researcher notes the potential benefits of access to electricity for women-run survivalist enterprises, where vital infrastructure (including electricity) can offer relief from the onerous tasks involved in running a house and family.[21]

Negative impacts of rural electrification

In some cases RE may have a negative impact on women's welfare in particular, as extended working hours in cottage industries made possible by electrical lighting may decrease their welfare by simply increasing their working day, and they may derive little benefit from the increased income depending on the gender roles within the household (i.e. the male 'head of household' may control how the household income is spent). Rogerson considers this a 'crucially neglected' by-product of improved lighting using electricity.

4.3 Specific impacts of RE on the SMME sector

Very little detailed research has been undertaken on the specific benefits or disbenefits of electricity for SMMEs in rural areas, and it appears that often only the most blatant of impacts have been documented. Rogerson indicates areas where some of the clearer benefits have been observed, such as facilitating access to refrigerators, but in other areas, such as the impact of electricity on different types of workshops, very little specific research has been done. The sections below summarise what is known about impacts of electricity in the provision of different services. It is not intended to suggest that electricity has a major role to play in SMME development in South Africa - this does not appear to be the case - but rather tries to be more specific in the areas where some impacts have been observed.

Refrigeration for shops

Facilitating access to refrigeration appears to be amongst the clearest impacts of electricity. Electric refrigeration is generally more cost effective than LPG fridges[22], and is often perceived to be more effective and convenient. A marked increase in the number of refrigerators has been observed in some post-electrification research, and this is at least partly attributable to electrification. Amongst the main users of fridges are shops, who are thus able to increase their product range from canned foods to fresh produce and cold drinks. Shops with refrigerators clearly have a competitive advantage over those without. Electric refrigeration thus is a factor in enabling retailers to grow. In Northern Botswana, a butchery became feasible after the area was electrified due to the availability of adequate refrigeration power. While electric refrigeration allows established shops to expand their operation, and in one research project (DRA,1996) evidence exists of the establishment of a number of new small shops due partly to electric refrigeration, the cost of refrigerators (approx R2500 for a new 200 litre unit) may still exclude some of the small survivalist spaza shops, placing them at an increased disadvantage relative to larger shops. Power supplies for refrigeration need to be reliable, and expensive stock losses have been reported in some shops due to power outages.

Lighting

Electricity allows for improved lighting for SMMEs operating from offices, shops, workshops and households. Alongside refrigeration, it is considered amongst the most

21 - The existence and extent of this benefit is, however, still contended, as evidence to support such claims is typically not conclusive.

22 LPG is considered the primary alternative to electric refrigeration in rural areas, as paraffin fridges seem to be widely considered ineffective and inconvenient

important benefits of electricity for this sector. It allows for extended opening or operating hours, which may impact positively on productivity, although this may well be burdensome to women, as discussed earlier. In a number of areas theft is a concern for SMMEs, and thus the provision of outdoor lighting may ameliorate this problem.

Technology upgrading

Electrical equipment, particularly motor driven devices, provide an efficient means of powering numerous tasks, and thus can boost productivity in SMMEs undertaking specific activities. Great productivity increases have been noted for sewing and knitting businesses changing from hand powered to electric machines, the ability to run power tools improves the functioning of metalwork, carpentry, and panel beating workshops substantially, and electric welders appear to be more convenient and appropriate for certain tasks (although gas welders are more versatile). Some service businesses, such as hair salons, can offer a greatly improved range of services if supplied with electricity.

Because electricity is so useful to certain businesses, some workshops run diesel or petrol gensets in order to be able to use power tools. In one instance in Northern Botswana (Borchers, 1994), which illustrates the problems of this approach, the use of a genset resulted in high fuel expenditure, periodic breakdowns, and strict limits to the machinery that could be run at any one time. The genset was also considered inconvenient to operate.

It seems, however, that the benefits of using electrical technology is mainly realised by the wealthier, more established, larger enterprises who can afford such equipment. Smaller survivalist or micro-enterprises could therefore be placed at an increased disadvantage unless inputs (such as financing) are introduced to ensure that they can also access improved technology. It also needs to be noted that electrical technology may be irrelevant to a number of businesses, for example where human labour and heat energy from biomass are the main inputs needed (such as a small-scale bakery).

Cooling (air conditioning, fans)

Electricity allows the use of fans and air conditioners, which may be considered necessary in premises of larger enterprises in hot climates. This technology is unlikely to be important to most SMMEs.

Office equipment

Electricity facilitates the use of cash registers, computers, and faxes. Power supplies for computers particularly need to be reliable. In one instance, a shop in rural Natal used a car battery to power a cash register, illustrating the value placed on this appliance. Again this technology is unlikely to be relevant to most SMMEs, although inability to use this equipment could constrain the development of larger enterprises.

TV & entertainment

Clientele may be more attracted to bars, nightclubs and shops which have a colour TV, and in one case the use of video games also provided an attraction to a Bar in Northern Botswana (Borchers, 1994). The use of all of this equipment is facilitated by electricity. Again, small enterprises will not be able to access such equipment as easily as larger established ventures, and thus may be placed at an added disadvantage.

4.4 Electrification priorities to support SMME priorities

The SMME priorities

The overall objective in the Small Business White Paper is as follows: *Create an enabling environment for SMME development via appropriate policy frameworks at all levels.*

Rogerson identifies six specific policy objectives within the White Paper:

1. Facilitate the greater equalisation of income, wealth and economic opportunities which includes
    - a strengthening of the labour absorptive process in the micro-enterprise and survivalist segments, and

- the redressing of discrimination with respect to blacks as well as women's access to economic opportunities and poor, and
- the facilitation of growth in black and small enterprises in rural areas.

2. Create long-term jobs which demand policy interventions designed to upgrade human resource skills and to strengthen the use of modern appropriate technologies.
3. Stimulate economic growth through addressing the obstacles and constraints that prevent SMMEs contributing to overall growth.
4. Strengthening cohesion between SMMEs by promoting networking to build collective efficiency, address development obstacles and to take up opportunities.
5. Level the playing fields between large enterprises and SMMEs and between rural and urban businesses
6. Enhance the capacity of small businesses to comply with the challenges of an internationally competitive economy.

In addition, the following objective is raised in the Discussion Paper on Rural Development:

> *address apartheid legacy of disempowerment of marginalised groups (particularly women and rural entrepreneurs) largely by stimulating the capacity of rural entrepreneurs to move beyond survivalist enterprise (which dominates the SMME sector).* (South Africa, 1995)

In addition to the above objectives, provincial SMME desks are developing specific core objectives of their own based on those in the White Paper.

Electrification impacts relative to SMME priorities

Given the composition of the South African rural SMMEs (overwhelmingly survivalist, with little productive activity), a preliminary conclusion from Rogerson's work may be that RE's principal areas of impact revolve around:

- potential to facilitate increased production in the few existing larger concerns
- potential to improve the operations in some service-based SMMEs
- promoting the establishment of small scale often survivalist retailing in certain circumstances partly through the use of electric refrigerators

Little evidence exists to indicate that it has a major role to play in:

- providing a general boost to the local rural economy
- generating noteworthy increases in income
- reducing unemployment
- facilitating a general movement of SMMEs from survivalist activities into the formal economy
- empowering marginalised groups (blacks and women)

The importance of addressing other constraints needs to be stressed again, as problems such as lack of financing are not only generally much more central to SMME development, but they may also result in increased disparities between businesses that can afford electrical technologies without financing and small survivalist enterprises which are unlikely to be able to acquire potentially beneficial electrical technology. Electrification may thus entrench some of the problems which the White Paper is trying to address, rather than alleviate them.

Although electricity supply in itself does not appear to be a major constraint to SMME development in most rural areas of South Africa, it should not be forgotten that in many cases the benefits of electricity appear to be significant, and lack of access is even likely to become a serious hindrance to growth in the case of larger productive or retail enterprises. From the perspective of electrification planning, it can be said that electricity supplies need to cater for the following services:

- Refrigeration, including at small (spaza) shops.
- Lighting for all SMMEs.

- Power tools (grinders, welders, compressors, sanding machines, planing machines, electric saws, drill, etc)
- Sewing/knitting machines for home industries.

It needs to be kept in mind that many businesses will be run from the homes of the owners, even relatively large businesses such as metalwork and other workshops, and thus SMME electricity supply should not be considered as an activity separate from household electrification. The importance of providing appropriate financing packages again needs to be stressed if the benefits are to be made accessible to the smaller, poorer businesses.

Area of impact	*Energy service requirements*	*Equipment implication*	*Electricity supply implications**
Cold storage for shops	refrigeration and freezing	refrigerator - 200l AC refrigerator - small AC refrigerator - 225l DC refrigerator -large/display freezer - commercial	3kWh 1kWh 0.5kWh 6kWh 8kWh
Night activities	indoor lighting	indoor lights (hi-eff x4)	0.24kWh
Security	outdoor lighting	outdoor light (hi-eff x2)	0.12kWh
Productive technology	motor-driven equipment, power tools etc.	sewing machine knitting machine grinder elec welder gas welder compressor elec saw elec sander lathe	0.32kWh 0.4kWh 0.6kWh 4kWh [illegible] 1kWh 1.6kWh 0.3kWh 1.4kWh
Comfortable environment	space cooling, heating	air conditioner fan heater	3.4kWh 0.1kWh 4kWh
'Office' efficiency	Communications, accounting, data storage systems, money handling	cash register computer & printer (modern) computer & printer (basic) fax	0.12kWh 2.4kWh 0.68kWh 0.06kWh
Entertainment	media, games	TV video games	0.44kWh 0.3kWh

TABLE 4.1: Electricity supply implications

** - Information on which this is based is given in appendix A. Electricity consumption is based on typical values, and may vary substantially for different models of appliances.*

Level of service supply for different size and type enterprises	*Energy use estimates (kWh/day)*	*Demand estimates (Watts)*
SURVIVALIST ENTERPRISES		
Retailer (spaza)		
lighting - indoor (basic)	0.12kWh	30W
refrigeration - small DC or AC	0.5 - 1.0 kWh	50 - 100W
TOTAL	*0.62 - 1.12 kWh/day*	*80-130W (0.3-0.5A@240V)*
Sewing/knitting business		
lighting - indoor (basic)	0.12kWh	30W
sewing/knitting machines	0.32-0.4 kWh	80-100W
TOTAL	*0.44 - 0.52 kWh/day*	*110-130W (0.4-0.5A@240V)*
MICRO-ENTERPRISES		
Retailer		
lighting - indoor & outdoor	0.24 kWh	60W
refrigeration (AC)	3 kWh	300W
cash register	0.12 kWh	15W
TOTAL	*3.36 kWh/day*	*375W (1.6A@240V)*
Workshop		
lights - indoor & outdoor	0.24kWh	60W
grinder	0.6kWh	300W
welder	4kWh	2000W
TOTAL	*4.8 kWh/day*	*2360 W (10 A@240V)*
ESTABLISHED ENTERPRISES		
Retailer		
lighting - indoor & outdoor	0.48kWh	120W
refrigeration - large	6kWh	600W
freezer	8kWh	800W
TV	0.44 kWh	110W
cash register	0.12 kWh	15W
TOTAL	*14.96kWh/day*	*1645W (6.8A@240V)*
Metalwork business/workshop		
lights - indoor & outdoor	0.48kWh	120W
grinder	0.6kWh	300W
welder	4kWh	2000W
compressor	1kWh	500W
TOTAL	*6.1kWh/day*	*2920W (12 A@240V)*
Carpentry workshop		
lights - indoor & outdoor	0.48Wh	120W
saw	1.6kWh	800W
sander	0.3kWh	300W
lathe	1.4kWh	700W
TOTAL	*3.78 kWh/day*	*1920 W (8 A@240V)*

Table 4.2: Energy and demand estimates for electricity to meet service needs of some different size enterprises

Notes:

1. *Use patterns of equipment can be expected to vary greatly, as does their electricity demand. The above table therefore provides a guide only.*
2. *The total demand shown is for all appliances at once, and the After Diversity Maximum Demand (ADMD) will probably be substantially less than this.*
3. *The energy use assumes that appliances are used fully, not only occasionally. The level of impact is partly dependent on 'full' use of appliances.*
4. *15W per light, which is a typical consumption of a fluorescent light, is used in this table. In rural areas incandescent lights can be expected to be more prevalent, thus values in the table above should be considered as a minimum.*

4.4 Description of the Eskom SMME electrification programme

The Eskom SMME Department was launched in 1993 when the evaluation of the low-income household electrification programme indicated that, due to poverty and unemployment, consumption levels were not reaching necessary levels for connection cost recovery. Eskom set-up an SMME Department *'to augment the level of economic activity and electricity consumption in newly electrified areas'* (Eskom in Rogerson, 1997), and hence increase the potential for a financially viable electrification programme.

The national annual Eskom SMME Department budget is R 4 million, and is drawn from Eskom's Community Development Fund. This only covers project costs - department operational overheads are not included but are accounted for in national Eskom overheads.

Eskom SMME Department functions and operations

The SMME department's function is mainly to facilitate support for SMME businesses development. Areas of operation include supporting existing businesses as well as initiating and supporting the development of new business.

Eskom actively seeks out businesses already functioning and new business opportunities during pre-electrification investigations and through the electrification process. The Eskom SMME programme's most powerful tool, according to de Kok (pers comm, 1997), is targeting black businesses for procurement of goods and provision of services during electrification projects. This is estimated to encompass 80% of the Mpumalanga SMME department's activities, and takes place largely in urban or peri-urban areas. Potential entrepreneurs are reached by holding seminars in areas to be electrified, and, increasingly, via black commerce organisations rather than accessing small businesses directly. Existing SMMEs and new opportunities identified are referred to the SMME Department (Sterley, pers comm, 1997). Businesses covered include home-industries as well as those operating from businesses premises.

Activities of the SMME department include training electricity installers and developing franchises with local entrepreneurs in a range of activities such as for the provision of refrigeration, laundry, and bakery services. Franchises are supported with packages which include advice, equipment and credit. Eskom screens potential franchise applicants, assess their viability and then facilitates suitable finance. For example Eskom have a standard arrangement with Airomatic to supply customers with refrigeration equipment (Mashile, pers comm, 1997). Eskom also has a close relationship with the Future Bank and the old Small Business Development Corporation (Rogerson, 1997).

SMME electrification process

Electrification is facilitated by directing all businesses that are part of the SMME programme to Eskom's electrification department. Marketing officers visit the sites to identify the equipment used and electricity services needs and advises on suitable equipment and supply level (Sterley, pers comm, 1997). SMME 'aftercare' includes providing advice and facilitating maintenance of electricity supplies and electrical equipment. The same electrification process is followed for a domestic supply, home-industry or franchise business. Standard connection costs and tariffs are paid according to the supply and consumption levels.

Supply-level

In the majority of cases, electricity supplies to small businesses are standard 20A or 60A single-phase domestic connections with a three-plug ready-board, a single overhead light and a pre-payment meter. The supply characteristics of a particular business will depend on its service needs. For example, business connections in rural areas rarely need more than 60A single-phase (Davel, pers comm, 1997). In the urban areas business supplies are more likely to be 60A 3-phase, *'commercial fridge suppliers prefer three-phase'* (Mashile, pers comm, 1997).

Spatial activities

Of the nine provinces, about four regions have developed SMME departments with well defined functions, although all nine are meant to be able to provide these services. *'It depends on the individuals and on Eskom internal history. The intention is there but in reality not all [provincial SMME departments] are fully functional'* (de Kok, pers comm, 1997).

Most SMMEs being developed with Eskom support are urban-based. Here there *are 'too many projects and not enough resources to identify them all. We try to concentrate on potential manufacturing opportunities, although currently the services sector is in over supply. Unfortunately most opportunities are related to service industries'* (de Kok, pers comm, 1997). Although the SMME programme focuses on urban areas, activities also extend into rural areas as a part of their overall objective to support economic development in all areas to increase the affordability of services such as electricity in the longer-term. These support activities are often not linked to energy or electricity issues. Types of small rural business supported include cooperatives, bakeries, knitting clubs, chicken farms and brickmaking (de Kok, pers comm, 1997).

Institutional linkages and programme effectiveness

Eskom SMME Departments are only marginally linked to key institutional structures in the national programme for SMME upgrading - though on a regional level it appears that Eskom does have greater links with SMME structures in areas where they are active on projects (Rogerson 1997). Greater co-operation between Eskom and other SMME initiatives may assist in addressing SMME needs more effectively.

There have also been reports of inappropriate supply levels (Thom, 1996), resulting in inefficient and sometimes costly businesses practices, indicating the need to build stronger links between business and electrification sectors. Eskom's SMME Department is a new initiative, so it is too early to evaluate its impact. Most of the information received on the impact of this programme is from urban areas. A more detailed assessment of the programme seems to be merited.

5 ELECTRICITY SUPPLY OPTION OVERVIEW AND ANALYSIS

5.1 Key characteristics of different electricity supply technologies

Grid extension supply

Grid extension supply into rural areas has traditionally been limited largely to 'white' commercial farmers using 3 phase 11kV overhead lines. The capacity of these lines is generally far greater than required for many users, and due to the diversity and quantity of users being connected in rural areas at present, a much broader range of extension options are now being used or piloted in order to minimise system overdesign. Current supply capacities being offered or considered for households include 2.5A (recently piloted for domestic supplies), 20A, and 60A single phase. Although 40A supplies exist, they are uncommon and are not a standard Eskom supply option. At one stage Eskom was also considering using 8A as a low-capacity supply, but are not expected to adopt this option. They are rather moving to adopt the 2.5A supply as standard practice, and are expected to install significant numbers of these connections (James, pers comm, 1997). The 2.5A supply is unmetered and users pay a flat rate of about R10/month. The 20A and 60A supplies are generally installed with prepayment meters, and the customer is charged only for energy used. However, a connection cost is levied, which is approximately R50 for the 20A supply, and R300 for the 60A supply in urban areas.. In low-density rural areas, the Eskom Landrate tariff generally applies, which includes a connection cost, monthly basic charge, and a monthly energy charge. The Landrate tariff applies to all users with less than 100kVA demand, and thus generally applies to schools and clinics. Three-phase electricity connection is less commonly needed in rural areas.

	S1 standard 20A supply****		2.5A supply***
Reticulation	*3-phase ABC**	*3-phase bare wire*	*1-phase bare wire*
materials	R 915	R 685	R 467
labour	R 360	R 385	R300
Connection	*1-phase*	*1-phase*	*1-phase*
materials	R 362	R 362	R 362
meter (prepayment)	R 500	R 500	-
labour & transport	R 150	R 143	R 124
P&Gs**	R 20	R 20	R 20
Surveying	R 14	R 14	R 14
Total cost (excl. meter)	*R 1 821*	*R 1 609*	*R 1 287*
Overheads & finance costs (19%)	R 346	R 306	R 245
TOTAL (excl. meter)	*R 2 167*	*R 1 915*	*R 1 531*
Total cost (incl. meter)	*R 2 321*	*R 2 109*	-
Overheads & finance costs (19%)	R 441	R 401	
TOTAL (incl. meter)	*R 2 762*	*R 2 510*	

Table 5.1: Cost per stand for different grid electricity supply types

Source: Eskom 1995a, Eskom 1995b
** - Aerial Bundle Conductor*
*** - all preparation and setup costs*
**** - provisional costs (this supply option is still being piloted by Eskom)*
***** - the 20A supply is given as the default for the Homelight tariff in the 1996 Eskom tariff brochure*
Note: VAT excluded

Supply reliability in rural areas is area dependent, and is very variable. While the supply appears to be considered reliable in most cases, in some areas it is less reliable. Reliability is partly dependent on system age and design. Where networks are old and reaching the limit of their design capacity, they can be unreliable. This has particularly been the case in some of the old 'homelands' where small supply authorities have had difficulty maintaining networks in remote areas due to financial and capacity problems. Electricity grid extensions undertaken by Eskom as a part of the more recent rural clinic and school electrification programmes are likely to be reliable as they have generally been more carefully integrated into overall network extension planning.

Grid supplies are often easily upgradeable from lower capacity supplies to 60A supplies for example, although this depends on how systems have been designed. It is common practice to use standard conductors for grid extension, and limit supply capacity via transformer size and internal circuit-breaker capacity. Where the entire network (i.e. conductors and/or sub-stations) is not overloaded, upgrading is a relatively simple task and merely involves changing the circuit breaker or at most the transformer (standard charges for this are about R700 in each case according to the Eskom 1996 Landrate Tariff schedule). Changing from single phase to 3-phase is also relatively simple if 3-phase MV or LV lines are close by (the standard charge for this is about R700 as well), but if the user is at the end of a single phase grid extension, upgrading to 3-phase will not be easily done without substantial extra expense. Where the network is nearing its design capacity, upgrading the supply capacity may not be feasible, as this may involve substation upgrading and MV line voltage increase (many MV lines are 11kV in rural areas, while Eskom is now moving to standardise on 22kV, with concomitant capacity increases).

PV systems

PV systems are generally designed according to the daily energy requirement of the site and the supply reliability criteria. The more reliable the supply required, the greater the design margins will be and thus the more expensive the system hardware will be. Systems can be designed to deliver almost any daily energy use. However, cost is generally the limiting factor, and thus systems tend to be designed for energy use of under 3kWh/day, and most systems supply under 1kWh/day. Within this energy use limit, systems can cope with a range of power requirements, although designers generally size wiring and other components (regulators, circuit breakers, fuses) for a maximum of a few hundred watts. For example, a 2kWh/day system may be installed to handle a peak load of 200 to 400W (or 15-30A @12V). This is dependent on the appliance requirements.

Systems can be designed to provide 12, 24, 36V DC or 220V AC power. Smaller systems are generally 12V DC, while larger systems may be 24V or even 36V DC, or 220V AC. AC systems require an inverter to change the DC electricity produced by the PV panels and stored by the batteries into AC. Inverters add to system costs because of both their purchase costs and their inefficiencies - so systems with inverters will usually have a slightly larger PV array and battery bank to meet the same daily energy use requirements. It is thus important that inverters are of the highest efficiency possible over the likely demand range.

While AC PV systems are slightly more expensive (typically by 10 to 20% depending on the inverter chosen), with applications such as clinics or schools they have the advantage that they can more easily fall within normal maintenance regimes of these institutions. Also, clinics and schools are generally provided with AC wiring when they are built, even when unelectrified, and thus it simplifies system installation to provide AC power (wiring may comprise 10% of total system capital costs). Also, AC appliances are more readily available. Faulty DC components may not be as easily replaced.

Systems may be designed for a range or reliabilities, ranging from 0.1% LOPP[23] to 10% LOPP. The higher the reliability, the higher the cost. A 0.1% LOPP system may cost about 15% more than a 1% LOPP system, and 40% more than a 10% LOPP system (capital cost). Household systems may be designed with a 5-10% LOPP, while clinic systems may be designed with a 0.1% LOPP.

Clinics being provided with PV systems under the IDT programme have an interesting feature included in their design - called a 'solar buss'. The PV system comprises two parallel systems - one is highly reliable (according to WHO standards) to provide DC electricity for the vaccine refrigerator and 2-way radio, and the other is slightly less reliable and supplies the clinic lights and nurses homes. The solar buss allows excess energy from the overdesigned vaccine refrigerator system to be used in the other system, thus providing nurses with extended lighting and TV hours.

PV systems may usually be upgraded by simply increasing the number of PV panels and batteries in the system, although if peak power demand is to be increased much, other components such as regulators, circuit breakers, fuses, inverters and even some of the wiring may also need replacement. Upgrading could only be undertaken by a qualified solar specialist and can be expensive, involving transport, hardware and added installation costs. It is possible that upgrading the PV system may result in a total system cost more expensive than grid extension would have been, and thus this needs to be kept in mind when choosing appropriate supply systems.

Diesel genset-based supplies

Diesel generated electricity supplies have been widely used in rural areas for many years, and technical skills for their maintenance and repair are relatively widespread. Diesel sets require regular servicing, which can be undertaken by relatively unskilled system owners, and periodic major servicing and engine overhauls, for which skilled technicians are necessary. Diesels are sometimes not used in remote applications because fuel deliveries are not always reliable, and money to pay for fuel and repairs or servicing may not be continually available. Most development workers have come across diesel gensets provided by aid organisations standing rusty and unused because the owner or community could not afford or organise to have the necessary repairs done or to purchase fuel. Electricity supply reliability from a genset is thus dependent on an adequate maintenance regime and also on obtaining regular fuel supplies.

23 LOPP - Loss of Power Probability - loss of power occurs when the system has insufficient energy to supply the load. A LOPP of 1% means that for 1 day out of 100 (or 3.65 days per year) it is expected to not be able to supply the load.

Diesel sets range from 1kW to hundreds of kW output capacity. Sets are sized according to the peak load they need to meet, and therefore where they are being used for a number of different loads of different power, such as for a household, school or clinic, they tend to run at very low capacity factors for much of the time, resulting in poor fuel efficiency and relatively high energy costs. In many rural households gensets are usually inappropriate due to the typically low electricity requirements and poor load factors of such households. Diesel-plus-battery (genset-plus) systems overcome this problem to some extent by allowing the higher loads to be met directly by the genset, any spare genset capacity to be used in charging the batteries, and smaller loads to be met by batteries while the genset is switched off. This can often provide a more cost effective option than only a genset by itself, but this depends on the load profile of the site. Current research status and experience in South Africa does not allow a clear assessment of where exactly such systems may be more cost effective, nor are there evaluations of the field performance of such systems over time. In the IDT clinic electrification programme, a genset-plus system is used in some clinics where grid extension is expected in the medium to long-term, as these systems are more easily transportable to another site in the event of grid connection. The IDT genset-plus system has recently included a community battery charging facility, although the effectiveness of this has yet to be evaluated.

Diesel sets are generally not easily upgradeable, as this typically requires the purchase of a larger genset, although they are more easily replaced by grid extension than is the case for PV systems for example.

5.2 Cost criteria for choosing electricity supply technologies

Energy life cycle costing principles

The use of unit energy costs (in cents per kWh) through life cycle costing (LCC) provide a more economically and logically sound basis for comparison of different systems than merely examining system capital costs. However it is difficult to compare electricity supply options based on LCC, because different systems provide different service levels. For example, PV, low-capacity grid supplies (such as the 2.5Amp supply) and genset-plus systems usually cannot meet thermal loads of cooking and space heating, whereas higher capacity grid supply can meet these loads. Grid connected clinics may use an electric heater, while where PV systems are installed, other sources of heating energy must be used, such as LPG or paraffin heaters, or staff must do without space heating. Unit energy costs calculated on electricity supply systems alone, as they are likely to be used in practice, thus does not provide an equal basis for comparison. Where electricity supply systems cannot meet various energy needs and alternative energy sources are likely to be used, these logically also need to be included in the LCC analysis. In addition, where users are likely to (or have to) live without a certain energy service because it is not easily provided by the electricity supply option, this should also be considered in comparing the options, although this cannot be in included in LCC-type analyses.

Life cycle costing and unit energy costs

Life cycle costing (LCC) includes all costs over a specified system lifetime. It is calculated by adding all capital costs to the present value of all operation, maintenance and component or system replacement costs over this lifetime. It forms a useful basis for comparison between different systems, as some systems have high capital costs and low running costs (e.g. PV systems), while others have relatively low capital costs and higher running costs (e.g. diesel genset systems). The system LCC allows these systems to be compared on an equal basis.

Capital costs can include the following:

- hardware purchase costs (including wires, connectors, PV panel or genset mountings etc)
- appliance costs (if these are included for all systems to be compared)
- installation labour and consumables
- transport of equipment and labour to site
- connection fees (for grid electricity)
- data survey costs (this is often undertaken to enable the choice of supply system to be made)
- consultant fees
- taxes (VAT)

Operation, maintenance and replacement costs can include:

- fuel costs (for gensets)
- routine maintenance/service consumables costs
- maintenance labour costs
- component or even system replacement costs
- transport of technicians to site

Lifetimes over which the LCC is compared typically varies between 10 and 25 years, depending on whether a medium or long-term perspective is required. In comparing grid, PV and genset energy supply systems, the lifetime chosen is often that of the system with the longest lifetime amongst those being compared. With these systems 20 years is typically used, as PV panels are expected to last for this time. Diesel genset systems are unlikely to last this long, and engines will need a few major overhauls and even complete replacement within the 20 year period. LCC includes all of these costs. Grid extension hardware is expected to last 20 years, although replacements of some of the hardware may be needed over this period (e.g. poles).

Unit energy costs

The unit energy cost is based on the LCC cost, and provide an indication of the cost of energy produced by a particular system in cents per kWh. It is often preferred as a comparative indicator over LCC because the latter does not give an indication of the cost of the service provided (i.e. the energy, or kWh). Unit energy cost is calculated by amortising the LCC into equal amounts over the chosen lifetime and dividing this *annualised* amount by the expected annual energy consumption of the system to give a cost per kWh.

It needs to be noted that the *actual* unit energy cost of a PV system is sensitive to actual energy use, and if less energy than expected is used from the system then the unit energy cost increases proportionately (because the LCC is largely comprised of capital costs which do not decrease with reduced energy use). The same applies to a grid extension supply, which also has a high component of the LCC as capital costs. If users supplied by a genset-based system use less energy, the unit energy cost reduces more than with the other systems because operating costs, which form a large part of the LCC, reduce proportionately. When using the unit energy cost as a basis for choosing appropriate supply options, it is therefore important to be aware that uncertainties in the actual energy to be used will impact on the various supply systems differently.

Table 5.2 provides an indication of service needs that different electricity supply options can and cannot meet, and thus where alternative energy sources may need to be costed to enable a more realistic comparison using the LCC method. To cost such energy use requires a detailed knowledge of energy use characteristics in applications such as clinics, schools and SMMEs. Little is known of such characteristics, and therefore a proper comparative costing is difficult. The approach used in this report is to first cost the electricity provision, around which there is some confidence, and thereafter to consider the impact of the use of other sources of energy on the LCC.

	*PV**	*Genset***	*Grid 2.5A*	*Grid 8A*	*Grid 20A*
Cooking, water heating	no	no	no	yes, limited	yes
Space heating	no	no	no	yes, limited	yes
Refrigeration	limited	yes***	yes	yes	yes
Lighting	yes	yes***	yes	yes	yes
Media (TV/VCR)	yes	yes	yes	yes	yes
Motor driven appliances	small motors	yes	small motors	yes	yes
Computers, printers	limited use	yes***	yes	yes	yes

Table 5.2: General services which different electricity supply options can and cannot provide

** - theoretically, PV can provide any service needs if systems are sized accordingly, but in practice systems providing more than about 3kWh/day are prohibitively expensive, and this is used as a constraint in this table.*
*** - based on a genset-plus system of 1.1 kW rating as is used in the clinics programme.*
**** - provided systems are designed to handle relatively continuous loads as needed for refrigerators and other appliances*

Life cycle costing of grid extension, PV and diesel genset electricity supply systems[24]

In general, both grid extension and PV system electricity supply options can be considered capital intensive - i.e. the largest proportion of the LCC is the capital component of the PV system or grid extension and installation (except where grid extension distances are very short). This is illustrated in figures 1 and 2. With genset-based systems the situation is reversed, and capital costs are often only 20 to 30% of life cycle costs (figure 3). One of the advantages of genset systems revolves around this - if energy is not used then operating costs are reduced, while with both grid and PV systems energy use reductions do usually not reduce the LCC as much. However, a genset will require regular servicing, major overhauls and even set replacements periodically, which will require substantial amounts of money on a regular basis.

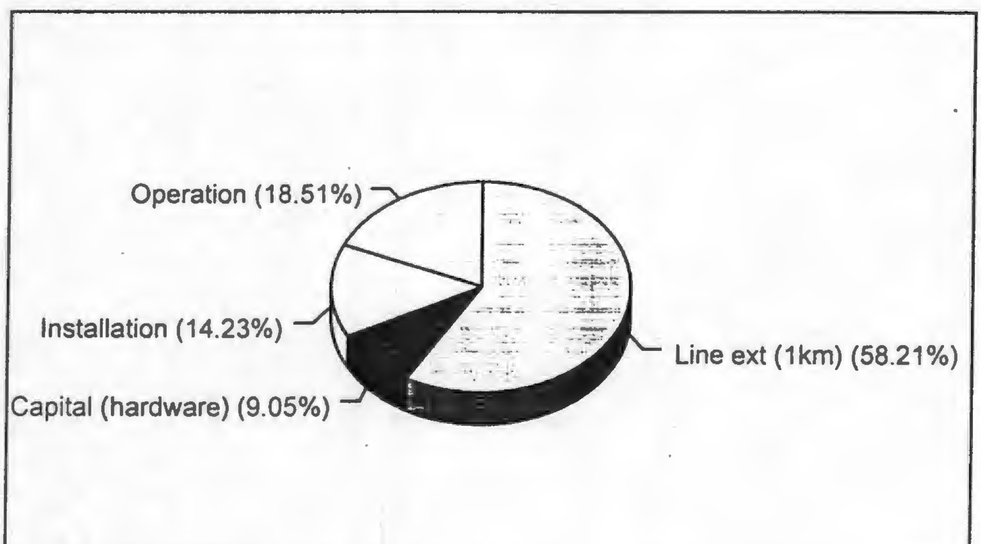

Figure 1: Grid extension (1km) LCC breakdown

24 Details of assumptions used in this section of the paper are given in Appendix B.

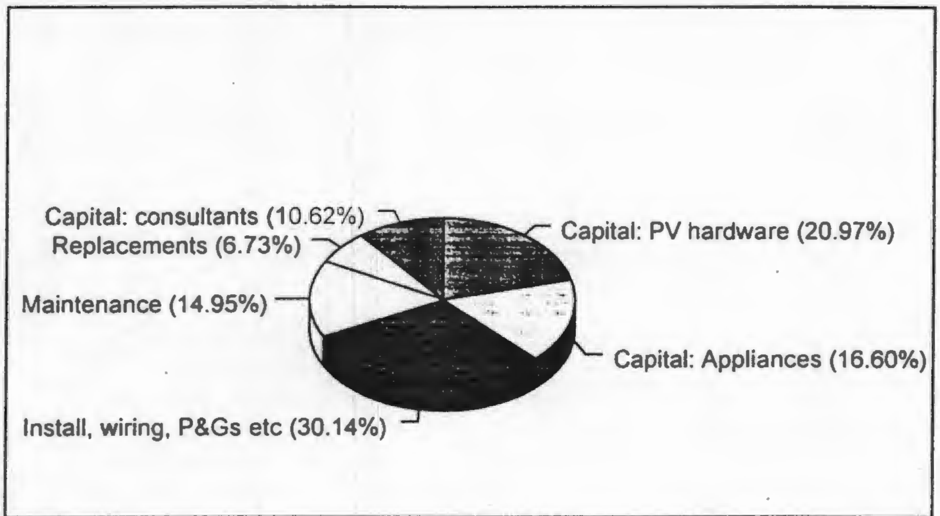

Figure 2: Typical PV system LCC breakdown (2kWh/day system)

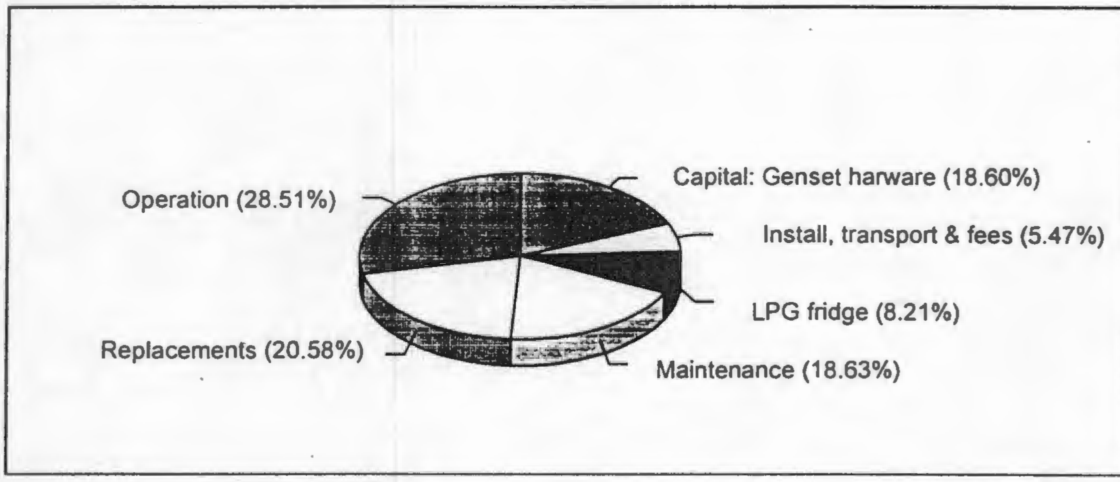

Figure 3: Typical genset-plus system LCC breakdown (1.1kW clinic system)

Table 5.3, which uses actual costs from installed systems, gives an indication of capital cost versus monthly payment implications for different systems currently being used for clinic electricity supply. However, is should be noted that it is difficult to directly compare actual system costs from existing programmes, because different supply options are suited to meeting different ranges of loads. For example, costs for vaccine refrigeration are excluded from the genset system costs, as refrigeration uses LPG, while other system costs include vaccine refrigeration. Also, the range of appliances which are included in the capital costs are not the same.

Supply option	*Design load*	*Capital costs*	*Monthly payments*
Grid extension (1km)	15kWh/day, 15kVA max	R 88 543	R 210/month
PV system	2kWh/day	R 89 218	R 240/month
Genset-plus-batteries	4kWh/day, 900W peak demand	R 29 500	R 650/month*

Table 5.3: Typical cost information for different electricity supply systems installed at clinics.

** - an averaged figure including all services, component replacements, overhauls and even set replacements*

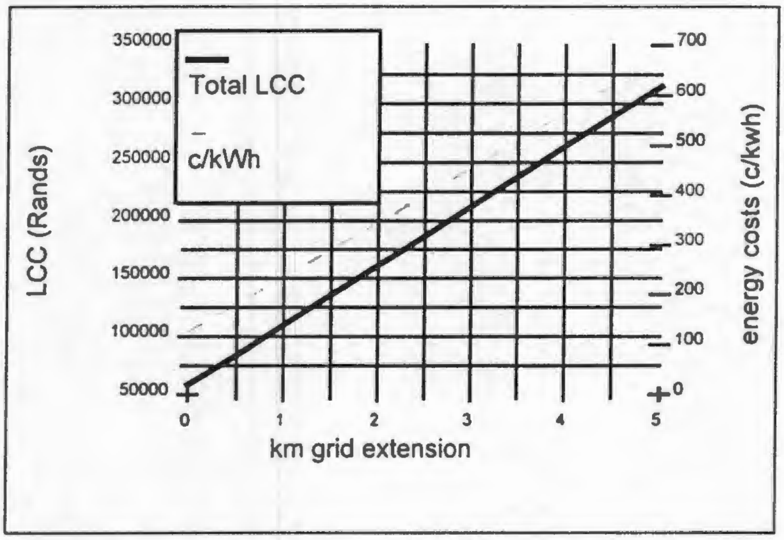

Figure 4: Grid extension LCC and energy costs for different extension distances (15kWh/day energy use assumed)

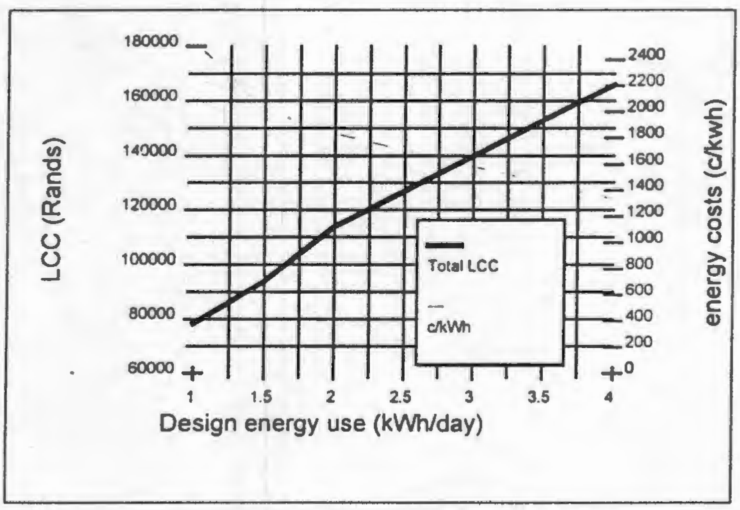

Figure 5: PV system LCC variation with different kWh/day systems (example: clinic PV system)

Figures 4 to 6 illustrate the impact of some of the main variables on LCC and energy costs of PV, grid extension and genset-plus systems. The dark line indicates changes in LCC for changes in the X-axis variable (LCC is shown on the left-hand Y-axis), while the dotted line illustrates how the energy costs are affected by the change in LCC (energy costs are shown on the right-hand Y-axis). Figure 4 shows how increased grid extension distance increases grid LCC and energy costs almost linearly. With PV systems (shown in figure 5), increased system design capacity obviously increases LCC, but decreases unit energy costs steadily. This is because transport and installation costs do not increase proportionally to system size. Genset systems exhibit clear reductions in energy costs for higher energy use if the same size genset is used, as shown in figure 6. This is because gensets operate more efficiently at higher capacity factors, and thus the higher the average load being met by the genset, the higher the fuel efficiency[25]. Larger gensets are also more cost effective than

25 Optimum fuel efficiency is considered to occur at a capacity factor of around 75%.

smaller sets, as they tend to last longer and operate more efficiently (although cost-effectiveness of different size sets is not illustrated by figure 6, as the graph is for one size genset only). It should be noted, however, that the information on which figure 6 is based is much less certain than for figures 4 and 5, as it is drawn from estimates by the supplier and does not draw on longer-term field experience of these systems.

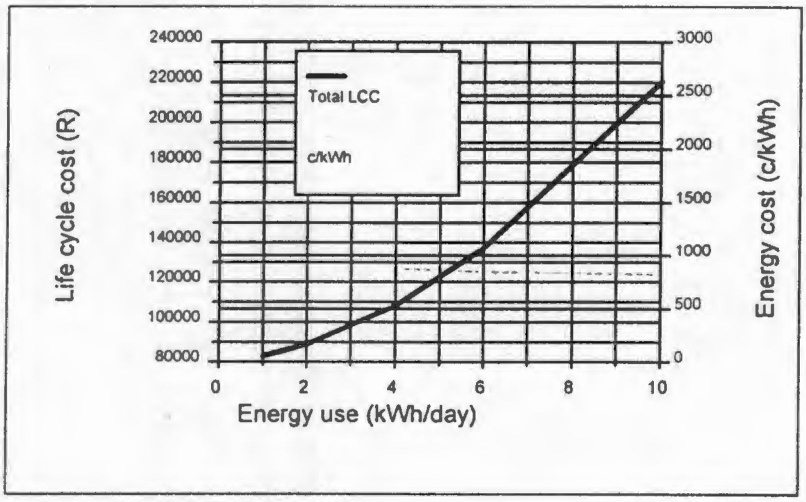

Figure 6: Genset-plus LCC and energy costs for different kWh use (for a 1.1kW genset). *Note that if the peak demand increased beyond about 1kW the genset size would need to increase, and thus the cost profiles would change significantly.*

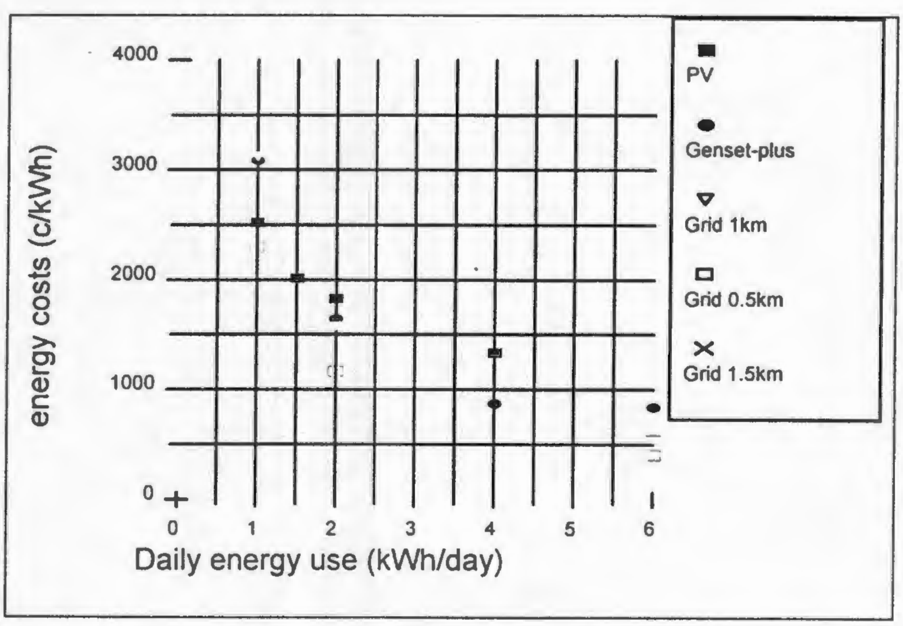

Figure 7: LCC energy cost comparison for different clinic energy supply systems (actual costs used)

Figure 7 shows changes in energy costs for different electricity supply options where the amount of energy being used changes. It is interesting to note that between about 1 and 3kWh/day energy use, estimated energy costs from systems installed at clinics are expected to be similar for PV, diesel genset-plus, and 1 to 1.5km grid extensions. Figure 8 shows that expected energy costs from systems installed at schools are expected to be similar for PV and 0.5 to 1km grid extensions. The figures also indicates that for higher energy demands, grid extension, and to a lesser extent genset systems, yield substantially decreased energy costs. PV system energy costs would not decrease to the same extent.

However, these comparative figures have some significant limitations: Grid connected systems are likely to have much higher energy demands than PV systems, simply because PV systems are designed for a specific load use pattern which cannot generally be exceeded, while where grid power is available, it limits energy use much less and thermal loads can be met. Genset systems are less limiting than PV systems, in that higher energy use characteristics can be accommodated up to a point by simply running the genset for longer hours, although running costs will of course increase.

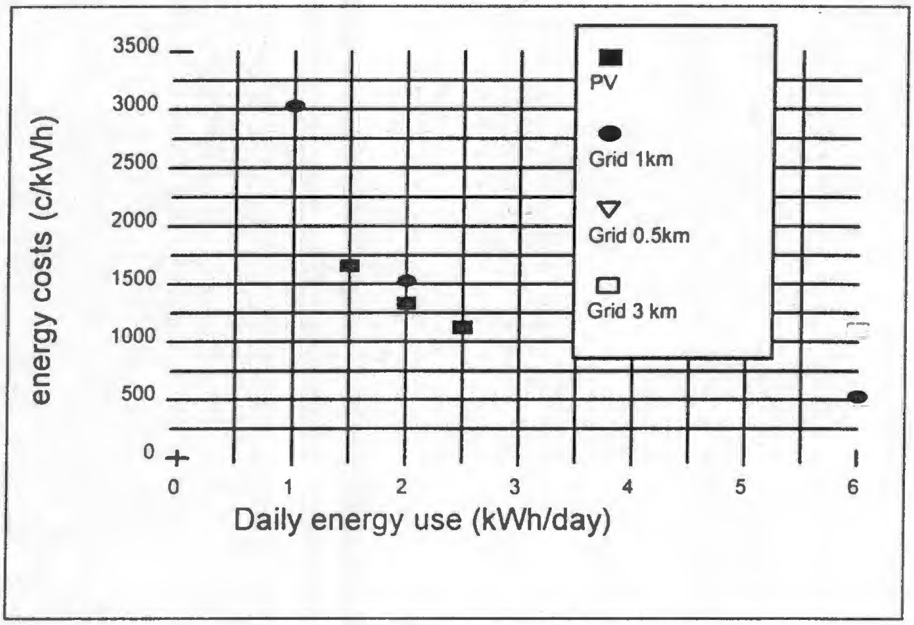

Figure 8: LCC energy cost comparison for different school electricity supply options used (actual costs used)

Hidden costs

The life-cycle costing exercise used earlier in this section does not include all costs involved in the delivery of systems. The notable exclusion is that of the overheads of organisations which implement schemes. For example, costs of Eskom staff involved in the school electrification and SMME programmes[26], and of IDT personnel running the clinic electrification programme are not considered.

Both the Eskom grid and off-grid schools electrification programmes do not consider operational overheads. IDT is moving to 'zero-based' budgets, which include operational overheads, but so far these costs are not known and have been excluded from any calculations on programme costs. The Eskom SMME programme has a 1997 project budget of R 4 million, but this does not include operational overheads.

To estimate these 'hidden' costs is difficult, particularly because organisations such as TRI[27], who manage the Eskom schools electrification programme, and IDT's 'Urban and Rural Development' section who are responsible for the clinic electrification programme, are involved in a number of initiatives and activities simultaneously, making it difficult to determine staff and office overhead resources allocated to a particular programme.

26 While it could be argued that the standard Eskom tariff covers Eskom overheads, special programmes such as the schools SMME grid electrification are cross-subsidised from general Eskom revenues from other sources to a significant degree, and thus it is improbable that revenues from these tariffs will ever cover these extra overheads.

27 TRI: Technology Research and Investigations - a division of Eskom

Non-cost criteria: Reliability

Reliability is not just a function of a sound technical solution, but also of the ability to maintain and repair systems. This is particularly the case with off-grid systems. Where off-grid electrification programmes do not ensure that the capacity and channels exist for continued technical support, they are jeopardising the reliability of the systems.

Reliability is important for some applications within clinics, most notably for vaccine refrigeration and 2-way radio in current programmes[28]. The Eskom school PV electrification programme also rates reliability as important[29]. The IDT clinic electrification programme uses PV in remote areas unlikely to be connected to the grid, and genset-plus systems (with LPG vaccine refrigeration) where grid extension is likely in the medium to long-term. The rationale here is that the genset systems can easily be replaced by grid connection when the grid is extended to the area. They are thus regarded as interim solutions, while PV systems, which are used in clinics unlikely to be grid connected in the long-term, are regarded as permanent supply systems suitable for remote use. The reasons behind this are that well designed and installed PV systems are likely to be more reliable in remote areas due to their relatively small maintenance requirements, while genset-based systems require continual fuel supplies and regular servicing. Also, vaccine refrigeration, which is an important component of an effective immunisation programme[30], requires a very reliable energy supply, and PV systems are considered to be able to meet this requirement better than LPG, which is the energy source used for this load with the genset-plus systems. This is because LPG distribution networks are unproven in many remote areas. The IDT nevertheless realises that PV systems are not maintenance free, and includes short-term maintenance contracts with installation contracts. The Eskom schools electrification programme uses PV in areas remote from the grid in preference to genset-based systems for the same reasons. In general, therefore, genset based systems are considered less reliable than PV systems, and thus less suitable for important remote applications.

5.3 Appropriateness of current technology selection criteria for schools and clinics programmes

Different institutions will place different emphasis on capital or life cycle costs when making decisions on appropriate supply systems. Where budgets are limited, the choice may be more weighted to lower capital cost systems such as genset-based systems, even though running costs will be higher. Many development aid organisations consider life-cycle costs in their decision making process, although considerations such as technical backup requirements in remote areas are generally powerful factors in the decision making process.

Typically donors are happy to carry capital costs, but are often less comfortable paying for O&M costs over the years. The relevant government department that will take long-term responsibility for the systems (typically Department of Health, Education or Works) may be more concerned about LCC. In practice, decision making concerning the supply option to be used tends to rest with the implementing organisation. With the IDT clinic electrification programme, for example, supply options were decided on by IDT in consultation with energy specialists, and LCC was amongst the factors considered. The Departments of Health were not heavily involved in this process. In the Eskom schools

28 While these are amongst the two most important loads in the current IDT clinic PV electrification programme, some larger clinics also have other loads which require high reliability supplies, such as incubators.

29 The school PV systems are designed using the 'amp-hour' method, which considers average daily load, average solar radiation and 'days of autonomy' required, and uses a safety factor (20% in this case) to account for wiring and degradation losses. It doe not allow for exact prediction of reliability, which is determined by the 'days of autonomy' used in panel and battery sizing.

30 although Ross et al (1997) would be quick to point out that effective vaccine refrigeration does not necessarily result in an effective cold-chain. They rather emphasise the fragility of the cold chain 'at the points of human interaction'.

electrification programme, Eskom decided on appropriate supply options, and again the Department of Education was not heavily involved in the process (Gordon,1997).

Both the IDT clinic programme and the Eskom schools electrification programme have established to their satisfaction which technology types are appropriate in specific conditions. Grid connection is the first choice, as it is recognised as having benefits to the users with which other supply options cannot compete. PV systems are considered the most appropriate for remote areas which will not be connected to the grid in the medium-term, as they can be highly reliable and relatively maintenance free if well designed and installed, although ongoing technical support is necessary. In the IDT clinic programme only, genset-plus battery systems are used in areas where grid extension is likely or possible in the short to medium-term, because this system can relatively easily be moved to another site should the grid arrive in the area.

A key selection criteria for both the IDT and Eskom is capital cost, and distance from the grid is the key variable here. IDT clinics less than 1km from the grid are given grid connections, those between 1 and 5km from the grid are usually supplied by a genset-plus system, and those beyond 5km by a PV system. In the Eskom off-grid schools programme, schools greater than 3km from the grid, or from the 5 year grid extension plan, are given PV systems.

Considering the cost of non-electric energy

In an attempt to enable a more direct comparison between electricity supply options, Table 5.4 provides some estimates of LCCs for energy services which PV, genset-plus and low-capacity grid supplies usually cannot meet. LPG has been used as the energy source for these loads, as it is often considered to provide a similar quality of service as that of electricity, although in practice other energy sources may be used to meet these needs.

	Appliance cost	*Running cost (R/day)*	*approx LCC*
Cooking & water heating	R 1 200	R1.50/mealx2 = R3.00/day	R 10 500
Space heating*	R 320	0.6kg/day = R 2.70/day	R 8 400
Refrigeration	R 1 800	0.5kg/day = R2.50/day	R 9 900

Table 5.4: Life cycle cost estimates on non-electric energy use: LPG

Notes:

1 *LPG costs used are those found in deep rural areas (R 4.50/kg), and thus include transport.*

2 *Appliance replacements over lifetime excluded (consistent with costing of electricity supply options)*

** - heating costed for winter only*

Just examining electricity supply energy costs, figures 4, 5 and 6 suggest that grid extension is the most cost effective for extension distances up to about 5 or 6km. Unit energy costs are then about 700c/kWh (assuming 15kWh/day energy usage[31]), where genset plus systems start becoming competitive with grid in energy cost terms (see genset energy costs shown in figure 6). PV system costs remain higher than about 1000c/kWh (see figure 5), and are only competitive in energy cost terms for kWh use of about 2kWh/day or less. However such an energy cost comparison is of very limited use as does not compare systems on an equal service provision basis. To compensate for this, if costs from Table 5.4 are added to electricity provision LCC (see Table 5.5), costs for the provision of similar energy services change substantially.

31 15kWh/day is considered a representative figure for schools, clinics and some SMMEs (see tables 2.3, 3.2 and 4.2).

Supply option	*Capital cost (elec system only)*	*LCC (elec system only)*	*Other energy services to be met*	*LCC of other energy services****	*TOTAL LCC (elec & non-elec)*
PV clinic system (2kWh/d)	R 89 200	R 114 000	staff fridge, cooking, space heating	R 28 800	R 142 800
PV school system (2.8kWh/d)*	R 65 000	R 89 000	**	(uncertain)	R 89 000
Genset-plus clinic system (4kWh/d)	R 29 500	R 108 000	staff fridge, cooking, space heating	R 28 800	R 136 800
Grid extension:1km (15kWh/d)	R 88 500	R 110 000	-	-	R 110 000
Grid extension:3km (15kWh/d)	R 185 000	R 212 600	-	-	R 212 600

Table 5.5: Capital and LCC comparison between systems

** - the school PV system is not designed to provide the same reliability of power supply as the clinic PV systems, thus the two systems cannot be directly compared.*
*** - space heating, refrigeration or cooking needs at schools are uncertain*
**** - from Table 5.4.*

Considering the above table, the following points emerge:

- For clinic energy use, PV and genset-plus options combined with LPG use provide similar LCCs for grid extensions of around 1.5 to 2km. This suggests that extending the IDT grid extension cut-off distance of 1km should be considered.
- Energy needs and use patterns for cooking, staff refrigeration and space heating at schools are uncertain, thus proper cost comparisons between the different electricity supply options is difficult.
- At schools, requirements for space heating, cooking and staff refrigeration have not been included in the above analysis. If these are to be considered in the costing exercise, the cost of LPG use will need to be added to the cost of a PV supply system, and thus total LCC of the PV/LPG supply option may increase to roughly the same LCC as that of a 1.5 to 2km grid extension. This is less than the current grid extension cut-off distance of 3km used by Eskom in the schools electrification programme.
- Other needs which clinics, schools or SMMEs are likely to do without if not provided with an adequate capacity electricity supply, such as laboratory power points or photocopiers at schools, can be important in supporting sectoral needs. Costing exercises such as those undertaken here cannot account for such lacks, yet they need to be considered by electricity and energy supply option decision-makers.
- Low-capacity (2.5A) grid connection will not be able to meet thermal loads particularly, and thus the cost of energy to meet these needs should in many cases be added onto the LCC of such an electricity supply. Depending on the magnitude of these needs, this may increase LCC up to R 20 000 or R 30 000 (see Table 5.4), which may often be more than the cost saving achieved by reducing the supply capacity (compare the costs of the 20A and 2.5A supplies shown in Table 5.1). In practice, while this will hold true for households who would use grid electricity to cook if connected to an adequate supply, it will not reflect the situation of households who may in any case use a non-electric cooking energy source. It is therefore not clear that the 2.5A supply would result in higher energy costs to the user than would otherwise have been the case.
- Large uncertainties exist in the energy use characteristics of clinics, schools and SMMEs (particularly non-electric energy needs), and as a result it is difficult to determine realistic costs of energy use. This area requires further research before such comparisons can be made with any certainty. For example, in practice grid connected clinics may continue to use LPG rather than electricity for cooking and space heating, because LPG supply systems are already in existence for many clinics, and LPG appliances are already installed. The total cost of energy provision to such clinics will be higher than has been estimated in this costing exercise, where it is assumed that all of these needs are being met by grid electricity.

It is apparent that if electricity supply option decisions are made on electricity system LCC or unit energy costs only, this will in many cases not result in the most cost-effective energy supply for the institution in question. Electricity supply options should be chosen based on a more integrated analysis of total energy use needs and characteristics. This approach may be in conflict with decision-making pressures and abilities within organisations such as IDT and Eskom. As they are partly target-driven (i.e. number of clinics or schools electrified is seen as important) and operate off finite budgets, they may place added weight on capital costs of electricity supply as a selection criterion. They may also not be well placed to consider non-electric energy needs fully, partly because of their electrification-focus, and partly because little is known concerning such needs and they may not be in a position to research them fully. The development of guidelines for a more integrated approach to rural electrification should probably be facilitated by the Department of Minerals and Energy.

6 CURRENT ELECTRIFICATION PROGRAMMES: HOW WELL DO THEY SUPPORT SECTORAL OBJECTIVES?

6.1 Health

The analysis in section 2.4 (see table 2.3), identified important rural health care services based on the health sector priorities. Table 6.1 shows the services which are currently considered by IDT as priorities in relation to the health sector priorities. It can be seen that the IDT programme meets the requirements of all the priority services.

*IDT electrification service provision**		*Health sector priorities*	
PV electrification service provision	*Genset electrification service provision*	*Rural health care service priorities*	*Rural health care full service provision*
vaccine refrigeration	vaccine refrigeration (LPG)	vaccine refrigeration	vaccine refrigeration
2-way radio	2-way radio	2-way radio	2-way radio
lighting - indoor lighting - outdoor	lighting - indoor lighting - outdoor	lighting - indoor lighting - outdoor	lighting - indoor lighting - outdoor
Staff: lighting TV plug	Staff: lighting TV plug	Staff: lighting TV plug	Staff: lighting TV plug fridge heater fan
			incubator steriliser suction pump
examination light	examination light		examination light

Table 6.1: IDT programme service provision compared with Health sector priorities

** - the clinics for which IDT funds grid connections are provided with all the services listed under the PV and genset columns, except that vaccine fridges are not provided. The Department of Health provides these.*

While the current IDT programme appears to be supporting rural health care objectives well by providing power for an appropriate set of services, efforts to improve rural health care will be ongoing. As rural health care centres are a core focus in implementing health priorities, the range of services provided by clinics are likely to be extended in future. Amongst these services are 24-hour emergency services, in-patient facilities, and adequate neo-natal care. This implies extended lighting hours and power for a greater range of medical appliances such as incubators and sterilizers, as well as possibly extra staff facilities.

From table 6.1 it is estimated that this would imply the provision of at least 16kWh/day, and might require a supply capacity of 20A (@240V). Currently, IDT PV systems provide about 2kWh/day (peak demand capacity is about 500W), and grid systems are 60A, 240V single phase connections. Three-phase electricity is unlikely to be needed by clinics for any important health services. It is well within the capability of the grid systems to handle substantial increases in service provision at clinics, but it is far beyond what a PV system could be expected to provide[32]. PV systems could thus become inadequate electricity supply systems over the longer-term for rural clinics which are upgraded to 24-hour health centres. It should be noted however, that while such an upgrading of rural clinics is a logical target given the national health priorities, whether and when this may be done is unclear, and thus it is far from certain that PV systems will ever in practice be a constraint to such upgrading. Thus while the possible limitations of PV systems must be noted, they should not be seen as rendering PV an unsuitable choice for rural clinics.

Genset-plus systems installed by the IDT are currently sized to provide 4kWh/day to rural clinics, and have a maximum power output of about 1.1kW. They are currently DC systems, and operate at 12V. These systems would not easily be upgraded to cope with energy demands of a substantially upgraded rural clinic (about 16kWh/day) because of limitations on the energy able to be supplied by the genset, peak load limitations, and because an inverter would probably need to be installed to convert the voltage to 240V AC, the voltage which standard medical appliances require. A further disadvantage of genset systems is their reliance of fuel deliveries, and the relatively high operating costs which health departments would have to bear.

The IDT never intended the genset-plus system to be permanent, however, as they are installed in areas where grid extension is anticipated in the short or medium-term. They are thus relatively easily removed for installation at other sites in the event of grid electrification, although who will do this and how effectively it will be done is yet to be determined. Any plans for substantial clinic upgrading of genset-plus supplied clinics would therefore usually need to link this with grid electricity connection.

Non-electric energy

Vaccine refrigeration can use LPG as an energy source, which can be as reliable as solar or grid electric options, depending on the reliability of the gas distribution networks (which in some rural areas appears to be questionable). Gas may also be used for heating applications such as space heating, cooking or sterilising, which PV systems or gensets may not be able to provide. The adequate provision of such energy needs should therefore be considered alongside upgrading of clinic electricity provision via PV or genset-plus options by the planning agency concerned. The relevant agency should at least facilitate the coordination of different supply options by the various energy service providers.

Household electrification and health

Important household electrical services relevant to health care from section 2.4 are repeated in table 6.2 and compared with the supply characteristics of different supply options.

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32 Technically PV systems can provide for any energy needs, they simply have to be sized accordingly, but capital costs usually become prohibitive for systems designed to provide more than about 3 or 4 kWh/day, where costs start to rise above about R80 000.

*Important household services**	*Can PV supply these?*	*Can gensets supply these?*	*Can grid 2.5A supply these?*	*Can grid 8A supply these?*	*Can grid 20A supply these?*
Refrigeration (2kWh, 200W)	only small fridges, otherwise costs prohibitive	gensets can meet all of these loads, but rural household load profiles and small electricity needs may result in poor cost-effectiveness. Genset-plus may be a better option in some cases	yes	yes	yes
Lighting (0.24kWh,240W)	yes		yes	yes	yes
Cooking, water heating** (4kWh, 2000W)	no		no	limited cooking	yes
TV (0.6kWh, 150W)	yes, but usually only small B&W TV, otherwise costs can be prohibitive		yes	yes	yes

Table 6.2: Household electricity service needs compared with supply system capabilities

** - estimates of kWh and Watts used for each service assume that the relevant appliances are relatively fully used, not intermittently. Benefits will usually be linked to degree of appliance use. It should nevertheless be noted that they are merely typical values, and can vary substantially. Appendix A provides more information on ranges of consumption for some types of appliances.*

*** - water heating is considered by Ross et al (1997) as amongst the most important household energy services from a health perspective*

The table shows that while larger capacity grid supplies can meet all of the above service needs, PV and small capacity grid supplies can only meet some of these. PV cannot meet cooking needs, and while systems can provide for some refrigeration needs, costs for such a system would generally be outside the reach of most rural households[33]. PV systems will therefore not be able to provide high priority health benefits linked to cooking with electricity, such as reducing domestic air pollution and paraffin burns and poisoning, and can only be expected to result in limited nutritional benefits linked to the use of refrigerators.

Genset systems may be able to meet all service needs indicated in the table, although it is expected that the poor load factors and typically low electricity needs of many rural households would result in relatively high energy costs. Where generators are used by rural households, the tendency is to use them for short periods in the evening, and thus resultant health benefits would be limited and they would not be suitable to power refrigerators which require more continual electricity supply. Genset-plus systems are likely to present better technical solutions to rural household electricity requirements, but as they have no proven track record in this application their suitability in practice is uncertain.

The lowest capacity grid supply being considered - the 2.5A connection - is suitable for all the needs in table 6.2 except cooking. Potential health benefits thus include nutritional benefits, reductions in burns and fires due to reduced paraffin and candle use for lighting, and education and literacy promotion through access to TV. PV has no potential to impact on indoor air pollution. The 8A supply will allow limited cooking[34], while the 20A supply

33 As an example, a simple 2 light plus radio PV system would cost about R1800 installed, while one to provide 4 lights and power for a small refrigerator may cost R6500 including installation.

34 8A allows the use of appliances which draw up to about 1.9kW. Typical power demand of cooking appliances are: oven-2.6kW; one-plate hotplate-1.2kW; two-plate hotplate-2.4kW; electric fryer-1.2kW.

is likely to enable households to meet all the service needs described in table 6.2. Of all the supply options considered, low capacity grid connections are usually the most easily upgraded, as the user generally only has to pay the upgrading fee. PV systems are upgradeable but this requires considerable effort and expense, while genset-based systems are still less easily upgradeable.

It needs to be noted that a suitable supply capacity does not correlate directly with health benefits, as users do not necessarily use appliances fully or at all. This is certainly the case with cooking, where research shows relatively few newly electrified households cook with electricity (see Davis et al, 1995; van Horen 1994; Williams, 1994). Facilitating access to appliances such as hotplates or refrigerators therefore may be an important complimentary activity to electrification programmes, although this does not necessarily result in full utilisation of appliances[35]. The relationship between appliance availability and the use thereof is thus not straightforward.

Community electrification and health

A critically important health benefit at a community level relates to the provision of a safe water supply and sanitation, in which electricity has a role. Communities which are large and established enough to have piped sanitation installed would generally also have grid power, and thus motivating for electricity supply to improve sanitation is usually not a practical concern. The link between health and electricity is more relevant to safe water provision for more remote rural communities.

Electricity from the grid and from PV, as well as direct-drive diesel pumping (generally not electric) may all be appropriate pumping power supply options. Grid electricity powered pumping is generally considered the most versatile, reliable and maintenance free and often also the most cost effective. This is dependent on the grid extension distance. PV pumping is considered cost competitive[36] with diesel pumping for water demands of up to about $2000m^4$ (e.g. $200m^3$ at a 10m pumping head) per day (Borchers & Morris, 1996). For larger demands diesel pumps are usually more cost effective. PV pumping systems are generally more maintenance free than diesel systems and do not require continual fuel supplies. They are thus sometimes considered more appropriate than diesels for even larger demands than $2000m^4$.

6.2 Education

Table 6.3 shows that the Eskom grid electrification programme meets at least the short-term service requirements, and the supply capacity[37] also has the potential to meet all other long-term service requirements. In addition, plug points are provided for additional appliances, although the only appliance provided in addition to the TV/VCR is an OHP. If anything, the supply capacity is excessive for schools of 3 or 4 rooms, as these schools may only use a fraction of the supply capacity into the medium-term. A supply capacity of 8A is likely to serve the purposes of many schools[38]. Three-phase electricity is unlikely to be required by rural schools, unless powerful electric cookers are installed.

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35 For example, one Eskom distributor provided a free hotplate to newly connected households in order to encourage them to cook with electricity, but found that the use of the hotplate was much less than expected.

36 Considering life cycle costs, not merely initial costs.

37 25kVA transformer, 60 Amp supply

38 although it needs to be remembered that little is known about actual use of electricity or other energy sources at schools. It is possible, for example, that electric bar heaters are considered priority appliances by teachers in some parts of the country, in which case an 8A supply quickly becomes inadequate.

Eskom programme		*Education sector priorities*		
Grid electrification service provision	*PV electrification service provision*	*Important short-term services*	*Important medium-term services*	*Full electrical service supply*
lighting - indoor lighting - outdoor	lighting - indoor	lighting - indoor lighting - outdoor	lighting - indoor lighting - outdoor	lighting - indoor lighting - outdoor
TV/VCR	TV/VCR	limited TV/VCR	TV/VCR	TV/VCR
			computer & printer	computer & printer
OHP	OHP			fax photocopier OHP
				elec lab equipment
plug-points in each room				

Table 6.3: Eskom schools electrification service provision compared with education priorities

PV electrification of schools by Eskom meets some of the immediate education priorities, but not outside lighting. This should be addressed, as outside lighting is considered important for security purposes and for facilitating access to schools at night as a part of the ABET initiative. PV systems could be upgraded to allow the use of additional appliances such as computers, although this would involve substantial added expense and effort, but costs associated with upgrading PV systems to a point where they could supply the longer-term needs of schools are likely to be prohibitive. It is thus possible that they may constrain services able to be offered by rural schools in the long-term, although it is unclear how or when schools will be receive the necessary attention and resources such that they can utilise more substantial power supplies. They should therefore not be considered inappropriate choices for schools at present.

The supply of an OHP with the Eskom school electrification programme may be questioned, as it is not specifically identified by Gordon (1997) as being important in the short-term, nor does it link directly with immediate national education priorities. Computers or even photocopiers could be more appropriate appliances.

School electricity needs could also be met by diesel genset, or diesel genset-plus-batteries systems. School load profiles are likely to be unsuitable for gensets, as low demand loads (e.g. lights) are likely to be run for extended periods, resulting in poor load factors. Gensets are knows to be expensive options at poor load factors in terms of life cycle costing. The genset-plus-batteries option is likely to be more economic in view of the anticipated poor load factors, although a detailed analysis would need to be done to determine cost competitiveness with PV. Factors such as regularity of fuel deliveries and ability to pay for fuel, maintenance capacity, as well as security of gensets will also need to be examined in comparing these systems. Genset-based systems have the advantage that they can be moved to other locations should the grid be extended to the school in the future, and thus may be favoured over PV in areas where the grid may extend in the medium term. However, Eskom are apparently considering the 5-year grid extension plans in their evaluation of supply options, and thus there may be limited scope for 'interim' systems such as gensets, although the reason given by Eskom for not using gensets is the high operation and maintenance costs (Raseki, pers comm, 1997).

Other energy needs of schools

Energy for cooking in the Primary School Nutrition Programme may be provided by grid electricity or LPG. It is unclear which of these may be more appropriate without further information on the nature of the programme, its problems, and the cooking volumes required. In some cases LPG may be inappropriate due to supply inconsistency and payment problems. Although it is possible that schools will have space heating and staff refrigeration energy needs, for example, little is known about these requirements.

Household electrification and education

Electrical service needs linked to education benefits revolve around lighting (working/studying/reading at night), media (educational TV and radio), and cooking and other appliance use (easing the domestic burden), which overlap to a large degree with services linked to health benefits. The main points relating to the ability of different household electricity supply options to impact on education are thus similar to those discussed in the health section of the report. These are:

- larger capacity grid supplies can meet all relevant service needs.
- PV and 2.5A grid supply will meet all except cooking needs, and thus have the potential to provide substantial education benefits.
- grid supplies are most easily upgraded and therefore can most easily cater for upgrading of rural education facilities over the longer-term.
- genset systems are unlikely to be appropriate energy supply sources for households, although genset-plus systems could be more appropriate.

It must again be noted that suitable capacity supply does not link directly with education benefits, as access to relevant appliances and degree of appliance use, as well as suitability of educational material in the case of TV, are all prerequisites to any benefits being realised.

6.3 SMME

Table 4.2 (in section 4.4) shows some of the typical appliances used by different size and types of businesses, and estimates resulting energy use characteristics. It shows that PV systems could provide the power needs of many survivalist businesses, although the refrigeration needs may well require a system too expensive for many small spaza shop owners. Because of the high energy demand and thus PV system cost, it is also unlikely to be a suitable system for businesses requiring any substantial refrigeration or freezing requirements, or running any workshop equipment. Its use for SMMEs is therefore likely to be restricted to lighting applications, running small motor driven applications such as sewing machines, TV, and possibly limited refrigeration. While smaller capacity grid electricity supply would also limit appliance use in a similar way to PV, the larger capacity grid supplies would be able to provide the requirements of even substantial workshops. This is illustrated in Table 6.4.

Gensets could be used to power any scale of business if sized appropriately, but where electricity is required for any length of time set capacity factors are likely to be low and thus fuel efficiency poor. This is the case with most genset applications. Genset-plus systems may be better options in such cases, although their cost-effectiveness is expected to be highly site specific and their suitability is still unproven. Gensets are often the only option for businesses requiring any substantial amount of power where the grid is far away. They are, however, clearly less sought after than grid, as they are considered inconvenient and can limit the growth of businesses by their capacity limits.

Size and type of enterprises	*PV supply suitability*	*Genset supply suitability*	*Grid 2.5A suitability*	*Grid 8A suitability*	*Grid 20A suitability*
SURVIVALIST ENTERPRISES		suitability depends on load profile, convenience, fuel availability, etc.			
Retailer (spaza)	yes		yes	yes	yes
Sewing/knitting business	yes		yes	yes	yes
MICRO-ENTERPRISES					
Retailer	unlikely		yes	yes	yes
Workshop	no		no	maybe	yes
ESTABLISHED ENTERPRISES					
Retailer	no		no	yes	yes
Metalwork business/workshop	no		no	maybe	yes
Carpentry workshop	no		no	yes	yes

Table 6.4: Energy and demand estimates for electricity to meet service needs of some different size enterprises

Since the vast majority of small businesses in rural areas are survivalist, PV systems may have substantial application here, although capital costs of these systems would be prohibitive in most cases. This reinforces the need for financing packages which can be accessed by such businesses if they are to be given the support implied in the Rural Development Strategy (South Africa, 1995).

Grid supply has the advantage that it is usually easily and relatively cheaply upgradeable, and thus can accommodate business growth. PV systems, or genset systems would normally accommodate expansion less easily. As it is an important national objective to facilitate the growth of SMMEs from survivalist to established businesses, the ability of the power system to accommodate such growth is an important consideration, although in practice it seems that most survivalist enterprises in remote areas will usually not grow to any significant degree due to other constraints (see section 4).

Grid supplies of 60A capacity and 3-phase electricity is only likely to be required by large established businesses using heavy duty equipment, and thus is unlikely to be a common need of the rural SMME sector.

6.4 Integration of planning for rural electrification

So far in this paper the health, education and SMME sectors have been dealt with separately. This section will examine the need for integration between electrification planning and implementation in these sectors, as well as considering the links between household electrification and impacts on health, education and SMME activities in an integrated manner.

Integration can be achieved at a number of levels. Ideally, electrification should be located within an integrated energy planning framework, which should in turn be located within an integrated development framework. Although there have been moves to establish an integrated development framework, for example via the RDP Rural Development Task Team, there currently exists no effective coordinating framework to fulfill this function. Integrated energy planning is nominally the responsibility of the Department of Minerals and Energy (DME), which started the implementation of a programme called the Integrated Energy Demonstration Programme in 1993, which involved stakeholders from Eskom and petroleum companies amongst others (Loon, 1996). One pilot project was implemented under this programme before it was effectively disbanded. Currently DME does not have the structures nor the capacity to fulfill this integrating role adequately, and so implementation of energy projects is effectively not coordinated within any integrated framework.

Integration of electrification planning for clinic, schools and SMME programmes

Electrification within the health, education and SMME sectors is also not coordinated to any significant degree. The only apparent coordination is the consideration of Eskom's 5-year grid extension plans before deciding on electrification options for schools or clinics. For example the IDT clinic electrification programme obtains information from Eskom on the position of their current grid, and 5 year extension plans, and based on this information applies their criteria to decide whether they will fund grid extension, genset-plus systems or PV systems for particular clinics. There is no formal mechanism within the IDT programme to consider the schools in the area which Eskom is electrifying independently using a different set of technology choice criteria, nor which businesses, farms or settlements are in the area which may influence the economic viability of the selection criteria. This can and does result in inefficient application of resources.

To facilitate such integrated electrification planning, effective information systems are necessary. The GIS database being jointly developed by the Human Sciences Research Council (HSRC), Education Foundation and Research Institute for Education planning for the Department of Education has extensive information on schools locations and service provision status, although information availability differs amongst the different provinces. The IDT is developing a GIS database for clinics which shows the location of the national electricity grid, and Eskom is developing a GIS database with information on schools, clinics and SMMEs. It is thus not a great step to combine this information and use it to plan electrification in a more integrated manner. For this integration to be established as standard practice, however, would probably require that it be formally located in an organisation such as the DME. This should be encouraged in the interests of using national resources more effectively.

A further step is to integrate electrification planning with energy planning in order to see that the total energy requirements of schools, clinics and other applications are met effectively, and that an optimum mix of electric and non-electric energy is provided as far as possible. Presently, organisations such as Eskom (both the schools electrification and SMME programmes) and IDT tend to focus on electric energy needs[39], without considering the full range of energy requirements of such institutions in their planning. The latter could be achieved by joint planning and implementation by the electricity supply implementing organisation, the relevant Departments of Health, Education or Works, and possibly petroleum companies.

7 CONCLUSIONS: MORE EFFECTIVE USE OF RESOURCES IN ELECTRIFICATION PROGRAMMES

7.1 Evaluation criteria

Amongst the criteria considered important in evaluating how resources may be more effectively applied in the different electrification programmes, are the following:

- ability to supply specific appliances linked with services identified as important
- ability to be upgraded to cater for growth over time
- sustainability regarding capacity and resources to provide adequate operation and maintenance support
- the cost-effectiveness of different supply options considering the total energy needs of users
- the reliability of the supply option

The sections below use the above criteria to evaluate the clinic, school, SMME and household electrification programmes.

7.2 Health

The IDT clinic electrification programme addresses rural health care priorities reasonably well, and all the rural health care service priorities are catered for in the PV, grid and genset-plus options provided. These service priorities are: vaccine refrigeration, 2-way radio, indoor and outdoor lighting, staff lighting and TV plug point, and a medical examination light. The primary focus of rural health care is through rural health care centres such as clinics (Ross et al, 1997), and indications are that future efforts in this field will upgrade increasing numbers of clinics to offer 24-hour services and will increase the clinic capacity to cover adequate neo-natal care and other services. The ability of the power supply to accommodate such upgrading may thus be important. On these grounds grid electricity is more appropriate than PV or genset systems, although the latter has the advantage that it is relatively easily transportable should grid power become available. Currently grid connected clinics are provided with 60A singe-phase supplies. While this may be excessive for medium and small clinics in the short-term, it is not certain that lower capacity supplies (for example 20A) would not constrain electricity use in many clinics, particularly the larger ones. Further investigation is necessary to clarify this. In addition, savings by installing lower capacity supplies are generally not great for once-off connections[40], and given that labour and transport to upgrade supplies in remote areas may be substantial, it may be sensible to provide a higher supply capacity even if it will not be fully utilised in the short-term.

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39 Although the IDT is moving towards considering other energy needs at clinics as well.

40 although for a community, where each low-capacity connection realises a saving, the cost reduction can accumulate to make a more substantial difference

All of the technologies used in the IDT programme appear to be technically sound, although no detailed independent evaluation of the programme has yet taken place. Amongst the main criteria used in technology selection in the IDT programme is system capital cost and LCC. The IDT supply option selection criteria are broadly as follows:

- grid connection for clinics within 1km of the grid
- genset-plus systems clinics between 1 and 5km from the grid
- PV for clinics over 5km from the grid

The genset-plus system is intended as an interim solution for areas where grid extension is anticipated in the short to medium-term. Given that there is still often uncertainty in grid extension plans, and that the genset systems appear to be meeting clinic needs adequately, this can be considered an appropriate strategy, although who is responsible for relocating such systems should grid be extended to the area, and how effectively this will be done is still uncertain.

The IDT clinic programme has so far not ensured that a sustainable maintenance programme for their systems exists beyond the 1-year guarantee provided by the PV system installers. While they have allocated funds for maintenance for the next 10 years, systems by which these funds are utilised have not been institutionalised. The sustainability of the IDT programme will thus remain in question until this issue is addressed.

If LCCs of PV, grid and genset-plus options for providing electricity to clinics are compared, and costs of meeting thermal and other services are included where they are not provided by the electricity option, indications are that grid extension is likely to be an economically sound choice for between 1.5 and 2km extension distances. Given that grid electricity is the most versatile in its ability to meet future upgrade needs, it therefore appears to make sense that the IDT clinic electrification programme extends its 1km cut-off criterion for grid extension. However, capital and LCC costs for extensions over 1km tend to be more than those of PV systems, and substantially more than those for a genset-plus system (not considering other energy use costs). The IDT programme, which is partly target-driven (i.e. there is some pressure to electrify significant numbers of clinics) and which operates off a finite budget tends to place added weight on capital costs particularly, and this is probably a key motivation for setting the abovementioned selection criteria.

Given the above, and the fact that grid extension will be able to accommodate rural health centre upgrading in a way that the other supply options will not, there may be a case for extending the grid extension cut-off to 2 or even 3km.

It needs to be stressed that the provision of an adequate electricity supply is merely one input into facilitating improved rural health care, and is typically not the most important input. For example, regarding the cold chain, Ross et al (1997) point out that the vaccine programme is '*most fragile at the points of human interaction rather than solely in the technical implementation of the cold chain*', and regarding improving staff facilities via electricity provision, they say that '*it would not be wise to assume that electrification per se will ameliorate the working and living conditions that rural health workers will have to deal with*' (although this needs to be tempered with other evidence that suggests that electricity is indeed very important to clinic staff). This stresses the importance of any electrification programme linking with a more integrated approach to health care, and thus the importance of proper institutional coordination.

Households

The potential for electricity to be linked with health benefits in the household revolve mainly around the provision of refrigeration, lighting, cooking and media services. PV systems can meet some of these needs only, and thus potential benefits associated with the use of electricity for cooking and corresponding reductions in indoor air pollution, for example, cannot be realised via the use of such systems. This is also the case for low-capacity grid connections, although upgrading to a higher capacity supply should the need arise is usually far easier with grid than with a PV system. In practice, however, many households do not cook with electricity, nor use it for refrigeration, and thus the benefit of PV systems is often in effect comparable with grid supply, at least in the short term.

Grid supplies are usually more easily upgraded than other supply options and therefore can most easily cater for increased demands for electricity over the longer-term, with some concomitant increases in benefits. Genset systems are unlikely to be appropriate energy supply sources for households as typical household demand profiles do not suit genset operation, although genset-plus systems could be more appropriate.

It needs to be noted that the provision of an appropriate power supply does in no way directly result in significant benefits, as some appliances may be unaffordable by households (such as refrigerators), and some appliances may only be partially utilised (such as hotplates), thus limiting their benefit. To avoid paraffin poisoning, for example, the household would need to switch completely from paraffin use for cooking or lighting, and thus partial use of other alternatives would probably have little impact here. An appropriate approach to ameliorating health problems linked to energy use in households would therefore need to look beyond electricity to a suitable mix of energy sources and appliances.

Water pumping

A critically important component of rural health care is the provision of safe water, and electricity can contribute here by providing energy for water pumping. Grid electricity is likely to be the most appropriate power source for this application if available, although PV pumping for smaller water demands and diesel pumping for larger water demands are also both appropriate pumping power sources.[41]

7.3 Education

The Eskom schools electrification programme in general appears to meet at least the short-term education service priorities - indoor and outdoor lighting and TV/VCR - although no outdoor lighting is provided where schools are supplied by PV systems. Outside lights can be a factor in making schools more accessible at night, particularly for women, and so this may be an important omission. While Eskom provides an OHP to schools, no evidence was found to indicate that this is in fact a priority. Education is an important national focus, and plans are being developed to provide greater access to education in all parts of the country. This means upgrading of rural educational facilities over time, and thus it can be important that supply options to schools are easily upgradeable. Grid supply is more easily upgraded than PV supply, which indicates that it should possibly be given preference over PV even in circumstances where it is more expensive in the short-term.

Currently Eskom extends the grid to schools within 3km of the existing (or planned) grid, and beyond this distance a PV system is installed. For a 3km extension, grid capital and LCC costs are substantially more than for a PV system (although c/kWh costs are likely to be lower due to the higher consumption typically experienced on grid systems). This indicates that Eskom may to some extent have taken a broader view than merely comparing capital costs or LCC in determining supply technology criteria. However, a more detailed economic analysis covering all energy sources used by schools is necessary to determine an appropriate extension cut-off distance. Such a study has not been done in this report due to lack of information, and thus the current indications are that the selection criterion is appropriate. Eskom is partially target driven, and the schools electrification programme operates of a limited annual budget, so capital costs are therefore clearly an important factor in setting the selection criteria.

Currently, Eskom provides a standard 60A single-phase supply to the majority of schools it connects to the grid. This is likely to be excessive for most medium and small rural schools, where a 20A or even an 8A supply would be adequate at least in the short-term, although the labour costs to upgrade systems in remote locations may justify the use of a higher supply capacity which will be adequate over the longer-term.

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41 the Energy and Development Research Centre is about to conduct more in-depth studies on electrification and water pumping, and the Department of Water Affairs and Forestry has recently embarked on a project to determine appropriate energy sources for different community water pumping needs.

While the Eskom programme appears to be meeting stated national education priorities relatively well, Gordon (1997) indicates that there is some concern over the extent to which provincial and regional authorities see the programme as being effective. Functions of different schools are likely to be sufficiently varied in many cases, even over the long-term, to merit considering different supply 'packages'. Gordon sees it as important that the programme consults more locally to ensure that individual schools needs are being taken into account, or the programme may be seen as a waste of money. She also indicates a greater need for informing users on the effective use of electricity, and stresses the need for improved coordination amongst service providers and education authorities. She quotes '*there is a real danger that the significant infrastructural development currently taking place in South Africa might end up being of limited value to the education and training system, unless structured relationships are established between the Department of Education and major physical infrastructure providers such as Telkom and Eskom*' (Department of Education, 1977, Technology Enhanced Learning Investigation Report, in Gordon, 1997)

Questions around the appropriateness of the Eskom schools programme add an urgency to the need for a detailed evaluation of its effectiveness, particularly given the substantial resources committed to this programme.

A further concern regarding the Eskom off-grid component of the programme is the lack of arrangements for ongoing support and maintenance of PV systems. As large numbers of systems are being installed around the country, the implications on the capacity and funds needed to maintain them is significant (e.g. in the Eastern Cape where more than 900 schools now have PV systems). Lack of a clear mechanism to ensure that the necessary capacity and other resources exist within the Department of Education, who become responsible for the systems, raises questions concerning the sustainability of the programme.

It needs to be remembered that electricity is usually of secondary importance in rural education and any equipment only becomes effective when appropriate education material is available, where the capacity exists to utilise the technologies effectively, and where the services provided by the technology can be integrated into education adequately by teachers. Gordon (1997) cites studies which stress how '*technology is only one part of a complex system of processes and relationships that make up the education and training system*', and summarises: '*where schools operate with few basic facilities, too few classrooms, and no resources to administer the service, the impact of electricity on teaching and learning is likely to be minimal*'.

Households

Areas where electricity supply can impact on education in the household are linked with provision of lighting for study, access to educational TV and radio, and 'easing the domestic burden' via the use of electrical cooking and other appliances. While larger capacity grid supplies can meet all of these service needs, PV and 2.5A grid supply will meet all except cooking needs, and thus are also expected to result in clear education benefits.

As with the links between household electricity supply and health benefits, it must again be noted that suitable capacity supply does not imply education benefits will result. Access to relevant appliances and degree of appliance use, as well as suitability of educational material in the case of TV, are all important factors for any benefits to be realized.

7.4 SMME

As the SMME sector is overwhelmingly survivalist in rural areas, and many rural small businesses operate from households, SMME electrification is closely linked with household electrification. PV electricity supply is likely to be able to meet basic energy needs of some small businesses, with 2.5A, 8A and 20A grid supplies being able to meet needs of increasingly larger businesses. PV and 2.5A grid supplies will not be adequate for those requiring anything other than lighting, limited refrigeration, and power for small electric motor-driven devices such as sewing machines. Grid power is relatively easily upgradeable in most cases, and thus it can cater for business growth in a way that PV systems may not easily be able to. Without financing, PV systems are likely to be unaffordable to many small businesses, while grid connections are usually financed through the tariff. Although gensets may be able to meet energy requirements of many businesses, they are often inappropriate because of the need for continual fuel supply, regular maintenance and occasional repair, and their fixed supply capacity can also limit business growth. Different supply options therefore have their limitations which render them appropriate in different conditions, although grid connection is in general likely to be the most convenient, cost effective and versatile option where extension distances are not too great.

The Eskom SMME department considers the specific business needs when advising on supply capacity required. Typically, 20A or 60A single-phase supplies are provided, indicating that businesses supplied are substantial users of power or that Eskom provides substantial overcapacity to many of them. It is noteworthy that Eskom's programme does not extend to any significant degree into areas where grid extension is not planned. Many enterprises in rural areas will therefore have difficulty accessing support regarding appropriate electricity or energy supplies for their needs, and this will need to be addressed given the importance of SMMEs in national development plans.

As has been noted in both the education and health sections preceding this one, the importance of electricity to SMMEs is usually secondary, and benefits of electricity are dependent on a range of other factors being in place. Rogerson (1997) stresses that '*rural electrification must be accompanied by complimentary inputs such as extension of rural credit and greater access to markets*' if it is to have a positive impact.

7.5 Maximising benefits via integrated planning and implementation

All of the sectoral studies covered in this report have stressed limitations on the sectoral electrification initiatives due to ineffective coordination between implementers and relevant government departments or other institutions involved with the sectors. Neither the Department of Health nor the Department of Education are considered to have been adequately involved in planning and implementing of the clinics and schools electrification programmes respectively, nor is Eskom coordinating with other key organisations involved in supporting SMMEs in their SMME programme. All of the studies have also stressed that electrification needs to be part of a coordinated service provision implementation plan if benefits are to be maximised or even realised.

With household electrification also, a link between the use of certain appliances and health and educational benefits exists, and it may therefore be advisable to increase efforts to facilitate access to certain appliances from a national economic point of view[42].

Not only is their inadequate integration between the electricity sub-sector and the health, education and SMME sectors, but coordination is lacking within the energy sector. Energy needs of schools and clinics, for example, are not considered as a whole, but the tendency is to focus on electricity provision, which can lead to inappropriate electricity supply technology selection criteria which do not optimise total energy LCC for the relevant institution. It is also necessary for electrification technology selection criteria to consider the electricity needs of other electrification programmes (for example clinic electrification planning should be integrated with that of the schools electrification programme), as well as to integrate the needs of other businesses and communities in the areas in question. The need for a more integrated approach is thus clear, both between the sectors, and within the energy sector.

42 although it is realised that links between appliance accessibility and changes in use characteristics are not straightforward.

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APPENDIX A

APPLIANCE USE INFORMATION & ASSUMPTIONS

The following values have been used in the report:

Service	Appliance	Application	Capital cost (R)	Demand (Watts)	Use time (hrs/day)	Daily use (kWh)	Other assumptions
Cooking	Hotplate (2-plate)	domestic	100	2000	2	4	
	Stove & oven	domestic		8000	0.5	4	
Refrigeration	Domestic AC refrig (200	domestic	3500	300	10	3	
	Domestic AC (small)	domestic	1500	100	10	1	used by small shops also
	Domestic DC (225l)	domestic		50	10	0.5	
	Vaccine (DC)	clinic	6000	60	7	0.42	
	Display fridge	commercial		600	10	6	
	Freezer	commercial		800	10	8	
Vater pumping	Circulating			80	4	0.32	
	Medium (1/3hp)	irrigation		900	1	0.9	
	Large	village supply				0	
.ighting	Hi-eff fluorescent	indoor/outdoor	50	15	4	0.06	
	Incandescent	indoor/outdoor		60	4	0.24	
	Normal fluorescent	indoor		30	4	0.12	
V & video	B&W (AC)	educational/domes		20	4	0.08	
	Colour (AC)	educational/domes		80	4	0.32	
	B&W (DC)	educational/domes		12	4	0.048	
	Colour (DC)	educational/domes		55	4	0.22	
	VCR	educational/domes	1500	30	4	0.12	
	TV & VCR combo	educational/domes	3000	110	4	0.44	
Radio	Radio (portable)	general		3	8	0.024	
Hi Fi	Hi-Fi (20W)	domestic		20	2	0.04	
Space heating	2-bar heater	domestic		2000	2	4	
Space cooling	Fan	general		50	2	0.1	
	Airconditioner	workplace		850	4	3.4	
Comms	Radio 2-way	clinic		100	0.25	0.025	uses little on standby, ~100W on br
Medical services	Incubator (basic 'tray')	clinic		200	10	2	
	Steriliser	clinic		1000	1	1	
	Suction pump	clinic		50	0.5	0.025	
eaching aid	OHP (AC)	school		300	4	1.2	
	OHP (DC)	school		150	4	0.6	
eaching	Lab power point	school		200	3	0.6	
omputer	Computer - basic	office/school		80	8	0.64	
	Computer - (pentium)	office/school		200	8	1.6	
	Printer - dot matrix	office/school		40	1	0.04	use little power on standby
	Printer - laser	office/school		800	1	0.8	use little power on standby
ffice equip	fax	office/school		60	1	0.06	use little power on standby
	photocopier	office/school		1000	2	2	use ~50W on standby
ash handling	Cash register	shop		15	8	0.12	
lothes manuf	sewing maching	small buss		80	4	0.32	
	knitting machine	small buss		100	4	0.4	
etalwork	grinder	workshop		300	2	0.6	
	welder	workshop		2000	2	4	
	compressor	workshop		500	2	1	
arpentry	saw	workshop		800	2	1.6	
	sander	workshop		300	1	0.3	
	lathe	workshop		700	2	1.4	
ntertainment	video games	bar/nightclub		100	3	0.3	
THER ENERGY SOURCES							
PG				kg/day			
	welder	workshop					
	cooker (stove & oven)	domestic	1200	0.7			
	fridge (200l)	domestic	1800	0.7			
	fridge (vaccine)	clinic	6000	0.25			
	heater	domestic	320	0.6			
araffin				l/day			
	fridge (200l)		2800	2			
	cooker (wick)		25				
	cooker (primus)		60				
atteries (PM9)				lifespan	batts/mt		
	radio						
r batts (66Ah)			Watts	hrs/day	Wh/day	days/cha	
	TV (DC, B&W, 10W)		10	4	40	12.5	500Wh/charge assumed
	TV (DC, Colour, 55W)		55	4	220	2.3	"
	lights (15W)		15	4	60	8.3	"

urces:

PS Design Manual, 1992, EDRC, UCT

rris, GM, 1990. Unpublished compilation of appliance demand and energy use figures from various sources. EDG.

ormation from various suppliers

served prices and power use

APPENDIX B

LIFE CYCLE COSTING ASSUMPTIONS

General

Discount rate = 10% real
Lifetime = 20 years
VAT included in all costs
All costs in Present Value

Installation includes	Equipment hardware cost
	Connection fees (in the case of grid extension)
	Installation costs for system
	Wiring costs
	Transport costs
	Consultants fees
	Pre-installation surveying/data collection
	Some appliance costs

Photovoltaics

Component replacements: R900 every year for 2kWh/day system
Maintenance per year: R2000 every year for 2kWh/day system
Appliance costs included: vaccine fridge, lights

Grid extension

Eskom Landrate tariff applicable
All operation and maintenance costs included in the tariff.
Grid extension cost R 45 000 per km
Appliance costs included: lights

Diesel gensets

Genset has major overhaul or is replaced every 8 years. Cost=R 13 000
Batteries are replaced every 3 years. Cost=R 4 000
Maintenance cost per year=R 2 000 (servicing)
Operation cost per year: R 2 880 for fuel
R 180 for LPG for vaccine fridge
Appliance costs included: LPG vaccine fridge, lights