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**ELECTRIFICATION TECHNOLOGY AND PROCESSES TO
MEET ECONOMIC AND SOCIAL OBJECTIVES IN
SOUTHERN AFRICA**

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Acknowledgements

This thesis investigates some of the problems of electrification in developing countries. It offers a new framework in which to analyse electrification programmes and projects. The experience on which the concepts have developed built up slowly over more than 30 years. During this period, I have participated in the planning and implementation of many projects, and later in the evaluation of projects and programmes. I have had many opportunities to share ideas with my colleagues and a wide range of individuals, from artisans to managing directors, and I have benefited from all of them. My thanks are due to a few organisations and people in particular:

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For all this help there is no debt to repay, except to help others in their turn.

Charles Trevor Gaunt
Cape Town
May 2003

Declaration

I have identified all work by others in this thesis, consulting original references unless stated. All other work presented in this thesis is my own work.

All photographs are my own.

The number of words in the main text of the thesis does not exceed 80'000.

C T Gaunt

From the Deputy Minister of Minerals and Energy:

"The (South African) government is committed to providing as many people as possible with electricity at the fastest sustainable pace" [Shabangu, 1997] and

"It is evident that successful household electrification has largely happened in the urban areas and a few of the more densely populated rural areas where the cost per service point is comparatively low. Consequently most rural areas today still lag far behind, while experience shows that the economics of electricity supply to those customers become progressively more adverse as more remote areas are targeted. The net result is that service delivery in the rural areas is unrealistically low." [Shabangu, 1999]

Despite the adverse economics, the electricity supply utilities, including Eskom, exceeded their electrification targets:

"Since the inception of Eskom's electrification programme in 1991, well over two million homes were electrified, of which 1 750 000 were in terms of the RDP² compact entered into with government in 1994. The intention was to realise the RDP commitment by the end of the year 2000. However, the compact was achieved at the end of 1999 – a year ahead of schedule. Despite having met the compact, we went on to electrify a further 256 023 homes, including farm worker homes, in the year 2000." [Gcabashe, 2000]

And in 2001 the Minister of Minerals and Energy stated in the parliamentary budget speech:

"The annual budget of R1.2 billion from the fiscus needs to be maintained in order to achieve universal access. It is for this reason that the allocation of R600 million for electrification needs to be maintained at the level of R1.2 billion in the future." [Mlambo-Ngcuka, 2001]

But according to the National Electricity Regulator (NER):

"In evaluating the last few years of the electrification programme, it became apparent that the current system of electrification has focused very much on the number of connections made over a period of time - a target driven process. ... The new challenge in electrification for South Africa in the next couple of years is to address the effective electrification of rural areas in a sustainable manner. The NER has responded to this challenge by allocating 45% of all the electrification allocations to municipalities for the year 2001 to projects in rural areas ..." [Mkhwanazi, 2001, and re-stated in 2002].

2 RDP = Reconstruction and Development Programme

By contrast, the published information [NER 2002b, Tables 6 and 8] indicates that Eskom, responsible for most of the rural areas of the country, must have allocated only 40% to rural electrification, as shown in Table 1.1.

Table 1.1: Capital expenditure on rural electrification in South Africa in 2001

	Total [Rm]	Rural electrification [Rm]	Rural [%]
By Eskom and municipalities	909,6	380,8	42
Capital allocation to municipalities	330,9	148,9	45
Indicating: Eskom	578,7	231,9	40

Derived figures in italics

In the meantime, the National Research Foundation reports:

"Over a third of the population is still not connected to Eskom's power grid and the cost of doing so seems prohibitive. Renewable energies, particularly solar power, offer viable, sustainable solutions." [NRF, 2002]

Finally, it is clear that the requirement for electrification subsidies is still being calculated:

"The subsidies that the REDs³ will require to manage their estimated electrification obligations, particularly in remote rural communities, while remaining financially viable, are being determined in close liaison between the NER, NECC and NEP. Still within the country's agenda for socio-economic upliftment, the NER has engaged with Government on the question of the economic implications and implementation of a Basic Electricity Support Tariff (BEST)." [Mkhwanazi, 2002]

The meeting of the targets for new connections, as achieved in the National Electrification Programme, was clearly 'successful electrification' at the level of project construction. However, the participation of managers, contractors and designers possibly not always familiar with the overall policy could result in individual decisions being taken out of context and, possibly, conflicting with objectives of viability and economic development. Simple project goals introduced the risk that other objectives and less obvious constraints might be neglected.

A review of electrification progress in sub-Saharan Africa, considering household connections, reported that *"an ambitious target to increase access"* to electricity, requiring *"5-fold and 7-fold increases in the annual rate of new urban and rural connections respectively"*, will still leave the region with more people without electricity in 2025 than today [Leach, 1999]. However, electrification considered as

³ It has been proposed that the Electricity Distribution Industry in South Africa be restructured into six Regional Electricity Distributors or REDs.

the provision of access of households to electricity, does not always have the same meaning everywhere. In Zambia, for example, rural electrification *"can have different meanings at different stages of the developing process"* and the *"objectives of rural development are two-fold: to improve the living standards of the low-income rural population through economic growth, and to make their development process self-sustaining in the long term"* [Mbewe, 1992]. In Zimbabwe, the Expanded Rural Electrification Programme is aimed at *"nearly 10'000"* community institutions and businesses in villages, rather than households [ZESA, 2001].

Electrification, then, is a broad term meaning different things to different people, according to their perspectives of their activities and responsibilities. It is also quickly apparent that the technologies⁴, standards, processes and results of electrification programmes and projects differ widely. However, it is not clear whether the different solutions reflect the differences in conditions, the environment, or the policy targets.

For example, electrification programmes in different countries variously adopt three-phase or single-phase distribution technologies at several different voltages, with different specifications for the system components, and making different assumptions about the loads to be supplied, seemingly without detailed or comparative consideration of the context or objectives. In some cases the specifications appear to be more closely related to the financial donor than to the physical circumstances of a project.

Engineering planners, designers and operators seek optimum solutions for electrification. Sometimes only sub-systems are optimised, such as in selecting conductors for low voltage feeders, or seeking minimum capital cost solutions instead of considering lifetime costs. As a result, projects may be planned, designed and implemented without optimisation of the overall programme. Part of the problem is the complexity of working with many components in many different combinations, so that distribution networks become more complex than transmission systems. Possibly, distribution systems may be too complex for optimisation except within limited, sometimes simplistic, objectives.

This research investigates some engineering planning and design decisions for electrification, and seeks solutions to the problem of optimisation in the context of multiple objectives. However, it should already be clear that such a study requires consideration of the broader (non-electrical, non-engineering) context within which electrification takes place. At the same time, the technological aspects affect policy,

⁴ A distinction is made in this thesis between *technical* in the sense of a skill within finance, engineering or any discipline, and *technology*, which is used only in the sense of engineering.

so the research could be useful to non-engineering participants in electrification and energy policy.

1.2 Electrification in Southern Africa

Over 3 million new domestic customers (households) in South Africa were connected during the past decade. This significant electrification programme raised the proportion of households with access to electricity from 36% in 1991 to 69% in 2001. Prior to 1991, South Africa was already more electrified than any of the other countries in Southern Africa, where electrification has been implemented at a much lower intensity. As a result, the level of electrification in South Africa is now very high compared with other countries in Southern Africa, as illustrated in Table 1.2⁵. However there are still many households without access to electricity and politicians have stated goals of achieving universal access by 2012.

Table 1.2: Household electrification in Southern Africa in 1999

Country	Population [millions]	Urbanisation [% of total]	% Households electrified	
			Urban	Rural
Botswana	1.6	50	26	2
Lesotho	2.1	27	14	4
Malawi	10.8	24	11	<1
Mozambique	17.3	39	17	<1
Namibia	1.7	30	26	5
South Africa	42.1	52	80	46
Swaziland	1.0	na	42	2
Tanzania	32.9	32	13	1
Zambia	9.9	40	18	1
Zimbabwe	11.9	35	65	<1

Sources: Population and urbanisation data from World Bank [2001]; South African electrification data from NER [2000]; remainder from Karekezi [1999]

Some of the history of electricity supply in Southern Africa relevant to this study is described in Chapter 2. However, the differences between countries are not merely a matter of history. As well as having some of the lowest electrification development in the world, Africa is also characterised by poverty, low levels of community-scale commercial development, and large areas of low-density rural populations. The impact of these characteristics on electrification needs to be considered.

5 There may be significant errors in some of the figures quoted in the table. For example, Kayo [2002] quotes ZESA figures of urban 80% and rural 18% for 1999, while Dube [2001] gives rural electrification in Zimbabwe as about 5% and ESMAP [2000] states that even including worker housing on commercial farms and mines access to the electricity grid is less than 5% for rural Zimbabweans. Karekezi and Kimani [2002] indicate electrification in Zambia as urban 25% and rural 2% in 1996. These other estimates of electrification may not refer to households nor be defined consistently.

Recent South African experiences have the potential to inform decisions on the balance of electrification in South Africa and electrification programmes in other African countries. Approximately 100 million of the 131 million people in Southern Africa have no access to electricity⁶. Although electrification is relevant to developing countries throughout the world, supported by organisations and individuals in developed countries, this study adopts a regional scope, considering electrification in Southern Africa, including South Africa. ✕

The research should provide answers to the following types of questions leading to better optimisation of electrification in the region:

- What can African countries embarking on new or expanding electrification programmes expect to derive from the apparent confusion of previous programmes?
- What is the purpose of electrification?
- Is electrification viable? and
- How can the viability of electrification be improved?

1.3 Hypothesis and research methodology

The basic hypothesis that this research addresses is:

Classification of electrification as being for economic, socio-economic or social (for poverty alleviation) objectives provides a concept system which allows for better decision-making and allocation of resources, making the attainment of the objective of electrification more likely.

These three different classes of electrification are defined briefly below, according to the reasons for undertaking the programmes:

- Economic development is where the users meet the costs of electricity supply in full, and the electrical energy supplied contributes to productive output. The hypothesis allows that viability may not be the only or primary objective of electrification.
- Socio-economic development, in which the financial costs are not completely paid by the customers and subsidies are needed, is justified by the broader economic benefits derived from developing electricity supplies.

⁶ Accurate numbers are difficult to assess, because the percentage of the population without access to electricity is not the same as the percentage of households not electrified.

Essentially, effective electricity distribution, including electrification, requires an understanding of the environment, problems and key factors for success, both in the management of the utilities and among those formulating the policies that guide the operation of those utilities.

The nature and scale of electrification are such that the main hypothesis of this research cannot be investigated by laboratory or simulation experiments or proved by mathematical analysis or considering a case study of a single project. Instead, a case study approach using the experience of the whole programmes of many projects is used. The complex overall problem is simplified by defining sub-systems and constituent problems. The negative hypothesis is considered where a particular example does not contribute to confirming the hypothesis of the benefits of better understanding. In other words, some cases show that a lack of understanding of the purposes of the electrification development explains the failures.

In a sense, South Africa during the past 15 years has been an intensive site for research of electrification, with unparalleled opportunities to participate in the preparation, conduct, monitoring and evaluation of a complex and expensive experiment. The past electrification can be considered as a billion dollar experiment in a programme that will be extended.

Africa is different from other regions of the world in many respects, but in other ways quite similar. Despite defining the study region as Southern Africa, some of the concepts and evidence considered - and the conclusions - may not be restricted to Africa alone, as the investigation also draws on international literature about electrification and development. X

The apparent problems and the proposed classification of electrification as being for economic, socio-economic or social objectives lead to the following questions:

- What is electrification, and how does the definition relate to grid and non-grid technologies and identify target customer sectors?
- Who are the stakeholders in electrification, and how are their objectives incorporated into the purpose for which electrification is implemented?
- How are decisions taken, targets set and programmes planned and evaluated? How do decision-makers compare the benefits of electrification with the costs (in both short and long term)?
- What are the characteristic economics of electrification - capital, operations, revenue/tariffs, and viability?
- What changes have occurred in the technology of electrification? What drives technological change and how do the changes affect an

electricity distribution grew, and yet, despite the apparent maturity of the industry, many recent local contributions to understanding electrification have been made:

- Workshops, seminars and conferences have brought together experts in distribution and electrification in the region to share information and ideas.
- Staff and students at several universities have carried out research leading directly to applications in the electrification programme [Hofmänner, 1999; Dwolatsky, 2001].

These contributions have described, supported and sometimes led to basic changes in the emphasis of electrification from a techno-economic activity to one with socio-economic and, recently, social characteristics.

This research also draws on personal experience gained from participating in:

- establishing a new electricity utility
- various aspects of technology research relevant to electricity distribution and electrification
- development of national electrification proposals
- the National Electrification Forum's report on electrification technology
- utility, national and international technology standardisation
- a wide variety of electrification projects as a consulting engineer for several electricity utilities and development agencies
- the recent evaluation of the South African National Electrification Programme, and
- recent and current research into options for a basic electricity support tariff.

This experience provides a local context in which to review the extensive international literature, including many publications by the World Bank and other development agencies. The intent is to separate the underlying themes and values of electrification from the complexity of the overall problem.

Most prior research has addressed particular aspects of electrification, such as policy, technology, financing or the industry structure. These will be considered. However, given the complexity of electrification and the different circumstances under which it is implemented, it is not surprising that questions addressed from only one direction remain largely unanswered or in open debate. This thesis attempts to reach an understanding of the relationships between the several aspects of electrification.

1.5 Novel elements of this research

The nature of this research is such that it incorporates several novel aspects, requiring particularly careful consideration as the analysis develops. For example,

- The classification of electrification as economic, socio-economic or social appears to be new.
 - The approach considers economic electrification as a process of supplying electricity to customers that can afford the costs of the supply in the productive activity for which it is intended.
 - Socio-economic electrification provides electricity to customers at costs subsidised by others, on the basis that the introduction of electricity to these customers may not be financially viable, but makes a contribution to economic development.
 - Social electrification contributes to poverty alleviation. Self-targeting subsidies are proposed as an approach to meeting poverty alleviation objectives.
- The evaluation and assessment of existing projects and programmes is made in the context of the different objectives of electrification.
- The analysis draws on the experience of large-scale electrification undertaken within an African context and culture, only some of which has been formally evaluated and that only recently.
- The thesis proposes some new approaches to electrification - particularly in respect of international participation and the role of aid - which conflict with the existing practice based on present concepts of electrification. ✕

1.6 Relevance of this research

Electrical engineers and electricity supply utilities are responsible for planning, designing, implementing and operating large, capital-intensive, electricity networks that affect most productive facilities in the country and the quality of life of the inhabitants. Most of the training and work habits of these engineers are based on a problem-solving approach using technological principles that have matured over the hundred-year life of the electricity industry. However, in many cases, the people involved in the problem solving and the financial and political activities that support the investments have little understanding of the overall objectives being pursued because, from their point of view, the complex system is simplified into discrete tasks. Since problem solving is always directed towards reaching objectives, each task is given an objective, and it is assumed that the sum of reaching all the sub-objectives will attain the overall objective. However, experience with electrification shows that this is not always the case. There are many reports that the objectives of projects and programmes have not met expectations.

This research investigates whether the evidence supports a hypothesis that a greater understanding of the overall situation and better definition of the sub-objectives of each task will improve the decision-making and problem solving inherent in the planning and implementation of electrification. The core technology of electrification is electrical engineering, but the objective of electrification is economic and social. Therefore the research has to span the intersection of electrical technology and the economic and social outcomes of its application. X

Some research and writing is directed to promoting a product or service, such as a particular technology or financing mechanism. Characteristically, that work is often by authors from the organisation supplying the product or service, usually with a simplification of the analysis by addressing limited parts of the problem, and mostly making recommendations in line with the aims of the organisation represented. Such recommendations possibly represent a sub-optimal solution, as the scope of the analysis was limited.⁷ In contrast, and perhaps unusually, this research is not directed to making recommendations for any particular group (utility, government, etc) but for the wide community of all those involved in electrification, and attempts to present objectively the results and analysis of a complex problem in an internally coherent structure, without commercial or political alignment. X

The research is based on experience of electrification in Southern Africa, arising from which it is possible to make findings regarding several aspects of electrification programmes including:

- programme financing and aid
- management, goal setting, control and evaluation
- institutional structures
- electrification technology.

The particularity of the experience means that the concepts may not in fact be suitable for general (worldwide) application, but there are many aspects of electrification in Southern Africa that are similar to conditions elsewhere, indicating that the research may have wider application. A better understanding of these aspects could assist many countries to reach a global optimum instead of local sub-optima in their electrification programmes.

⁷ Such research is not necessarily wrong, and the recommendations are probably valid within the context of the studies. However, the simplification may limit the applicability of the findings, and this may not be evident in the recommendations. Obviously my statements do not apply to all research into electrification.

1.7 Structure of the thesis

The structure of this thesis is determined by the objectives of the research, its relevance to electrification programmes, and the processes needed to test the hypothesis. The various chapters are described briefly below, to put the work in context as each section of the research is being developed.

Chapter 2 reviews the history of electrification in South Africa and the National Electrification Programme. Chapter 3 reviews some of the extensive literature on electrification in the context of the proposed hypothesis and the broad description of the Southern African experience.

Chapter 4 examines the electrification of Southern Africa (in response to a definition of electrification as a particular approach to problem solving) to identify several aspects of technology development since 1980.

The description of technologies provides information, but without a basis for making decisions, so Chapter 5 examines some of the ethical issues relevant to electrification, particularly in Africa. Chapter 6 examines questions of social influence and economic impact, and the concept of a special tariff for poverty alleviation. Chapter 7 reviews institutional aspects of electrification. Chapter 8 considers project planning and evaluation.

Chapter 9 summarises the findings of the research, evaluates the hypothesis and comments on the application to electrification in the rest of Africa.

1.8 Onword⁸

The huge cost of electricity distribution justifies research into improving the performance of electrification programmes and their operation. Electrification is not defined in the same way everywhere. It is characterised by complexity and possibly by the adoption of sub-optimal solutions to the various problems. The substantial electrification activities in Southern Africa provide a special opportunity for investigation. It is proposed that better decision-making and resource allocation will result from an improved understanding of the economic, socio-economic or social (poverty alleviation) objectives of electrification, and better attainment of the objectives for which electrification is implemented.

⁸ The onword reflects the progress in the chapter, without trying to summarise it, and indicates the direction for the next chapter. The word is taken from Busan's Mind Mapping.

Several questions have been identified as requiring research, including technological, financial, institutional and ethical aspects, and a structure for analysing these has been outlined.

The next chapter describes the electrification in Southern Africa, within the framework of the proposed concept of economic, socio-economic and social electrification. The intention is to provide a practical base for a subsequent review of the findings of other researchers in the field of electrification and development.

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Chapter 2

History of Electrification in South Africa

2.1 Introduction

About a hundred years ago the young electricity departments in some municipalities in South Africa were already providing electricity to their communities, as a public service but also to raise revenues to fund other activities. They had recognised the potential for business in this new technology. At the same time, private electricity suppliers were building their markets, with mines and industry being key customers.

There were many problems. Much of the electrical equipment had to come from far away and delivery times were long. The new technologies of electrical materials, network planning, protection and tariff metering required new skills and there was not a lot of local experience. The country was recovering from internal conflict and its effects on the economy, but the exploitation of natural resources offered promising development. Government was undergoing change; old allegiances were no longer appropriate and further changes were to come in the structure of the electricity supply industry.

It is said that history repeats itself. In many ways the situation in South Africa now is similar to that nearly a hundred years ago. Electricity utilities are making new alliances, facing reorganisation, coping with advanced technologies with too few skilled people, offering valued services to their customers and still making a business of it [Gaunt, 2002b].

The difference lies in the achievements during those one hundred years. Table 2.1, assembled from many sources, illustrates some milestones of electricity supply in South Africa (shaded) in the context of world developments. This chapter considers the growth of electricity distribution from the early days of private companies to the nationalisation of the industry and the restructuring of Eskom. Electrification just 20 years ago is then contrasted with the approaches that developed during the 1990s. The National Electrification Programme is described, and proposals for restructuring the electricity supply industry and new social electricity tariffs are introduced. The

principal objective of the chapter is to develop sufficient understanding of electricity distribution in South Africa to provide a context for the subsequent literature survey and an analysis of economic, socio-economic and social electrification.

Table 2.1: Electricity supply in South Africa in the context of world developments

Year	Generation	Utilisation	
1831	Michael Faraday (UK) discovered link between electricity and magnetism		
1832	Pixii (F) Dynamo to convert mechanical power into electricity		
1835		Davenport (US) Electric motor	
1866-1873	Varley, Wheatstone (UK), Siemens (Germany), Gramme (Belgium): Practical dynamos and motors		
1876		Brush (UK): Electric arc lamp	
1877		Table Bay docks in Cape Town lit with arc lamps	
1879		Swan (UK) and Edison (US): Electric carbon-filament lamp	
1881	Hydroelectric power station in Goldaming UK supplies customers with lighting		
1882	Edison's first power station in London (January) rated 60 kW and New York (September) Electric lighting for Parliament in Cape Town (May) and public lighting in Kimberly (September)		
	Generation	Distribution	Utilisation
1883-5	Laval (Sweden): Impulse steam turbine (1883) Parsons (UK): Reaction steam turbine (1884)	Gaillard and Gibbs (UK, 1883), Stanley (US, 1885): Practical transformer	Tesla (US): Induction motor (1885)
1889		4 kV ac, 21 km power line (US)	
1891	Electricity distribution in Johannesburg from Siemens and Halske's power station 12 kV 3-ph 179 km (Germany)		
1892			Crompton (UK): Electric heater
1902	Danielson (US): Synchronous machine		
1903	Steam turbine-driven three-phase synchronous generator First turbo-generator in SA installed by de Beers		
1906	Victoria Falls and Transvaal Power Company formed		
1923	Escom formed		
1927			Baird (UK) Television
1934		287 kV 430 km line to Los Angeles	
1940s		HVDC ± 200 kV Berlin	
1947			Bardeen, Brattain (US) Transistor
1948	Escom takes over assets of VFP, incorporating them as Rand and OFS Undertaking		
1957	First nuclear power station 90 MW		
1974		HVDC ± 533 kV Cahora Bassa to South Africa	
1980	Koeberg nuclear power station starts operation		Personal computers
1987	Escom restructured as Eskom.		
1994 - 1999		National Electrification Programme in SA	

2.2 From electric light to the end of the VFP (1882-1948)

The importance of electricity supply was recognised early. The first uses were for public lighting, lighting in shops and houses, municipal water pumping and industry [Botting, 1926]. The fastest growth in South Africa was in gold mining, where electricity replaced steam, compressed air and manual labour to significantly reduce the costs. The municipalities created their own electricity supply departments, shown in Table 2.2, but private companies supplied the gold mines under concession licences from the government.

Table 2.2: First municipal electricity undertakings in South Africa

Municipality	Year opened	Energy sold in 1924 [GWh]
Johannesburg	1891	44 200
Pretoria	1892	10 172
Cape Town	1895	27 873
Pietermaritzburg	1896	3 502
Durban	1897	41 872
East London	1899	4 123
Bloemfontein	1900	4 366

Source: Botting, 1926

In 1907 the Victoria Falls and Transvaal Power Company (VFP) took over two smaller power companies and established a network that eventually supplied most of the gold mines. By the end of 1914, the VFP was one of the biggest electricity companies in the world, supplying a maximum sustained (1-hour) load of 100 MW at daily load factors of nearly 80% [Price, 1915], which was significantly larger than the Johannesburg municipal electricity undertaking that had a peak load of only 11 MW [Price 1916]. Many of the municipalities, including Johannesburg [Sankey, in discussion of Gillott, 1923], were pessimistic about the potential for domestic consumption except for lighting, but others such as Durban were “most active in developing the domestic load” [Botting, 1926].

After the South African War and First World War, the domination of industry on the goldfields by non-British interests was balanced by forming new alignments. One of the industries was the power industry, initially mostly supplied by AEG and Siemens & Halske of Germany. Political considerations lay behind investigations by British commissions, leading to the passing of the Power Act in 1910, and providing for the take over of the assets of the VFP by 1948. The consulting engineers Merz and McLellan were appointed to study the electrification of the railways in 1917 and the general supply of power in South Africa in 1919. They recommended the establishment of the Electricity Supply Commission (Escom), effectively in competition with the VFP, to supply the traction needs of the railways and to promote industrialisation through the efficient supply of electricity at cost. Municipalities

retained the rights of supply within their areas and with the approval of the Provincial Administrator, but Escom had the right to make recommendations to the Administrator regarding any municipal proposal [Christie, 1984].

The VFP had established many of the standards of the electricity supply in South Africa, including 10, 20, 40 and 80 kV transmission and distribution with central system control, power factor correction, unit protection, demand and consumption tariff metering, and lightning arresters to cope with the serious lightning in the region [Price, 1916]. The company and Bernard Price, its General Manager, also contributed financially to the research by Schonland and others into lightning, radar and the use of electricity in mines. [Austin, 2001]

The termination of the licence for the operation of the VFP in 1948 and the takeover of its assets by Escom effectively brought to an end the substantial and profitable private sector participation in electricity supply in South Africa.

2.3 The growth of Escom (1948-1987)

Power station construction was deferred by the VFP because of uncertainty during the years prior to its takeover, and the industrial and mining expansion after the Second World War led to power shortages and rationing of electricity from 1950. Escom therefore had urgently to build several new power stations to meet the quickly increasing demand for power.

The mining companies opened new mines with entirely electrified new towns, such as Welkom [Gillett, 1951], and domestic consumption in all urban areas increased rapidly with the introduction of new appliances [Kane, 1956]. Even some Black townships were fully electrified, including Daveyton in Benoni, Vosloorus in Boksburg, Mamelodi in Pretoria and Dobsonville in Roodepoort, such that 28% of African township houses were electrified in 1974 [Christie, 1984].

Meanwhile, political support for the government from the farming community increased the pressure on Escom to extend supplies for rural electrification, especially after the oil price rises of the 1970s. Escom reported "*... small rural consumers found their diesel generators to be uneconomical and Escom was inundated with applications to supply them with electricity. Escom felt this matter should enjoy priority although the programme is labour and materials-intensive. As a result there are construction delays of up to 48 months in extreme cases.*" [Escom, 1983]. However, the number of new rural connections that year was only 4400, exceptionally small compared with later achievements.

Following a recommendation in 1962 from a Commission of Enquiry into the relations between central and local government, no further municipal power station construction was approved by the Provincial Administrators and, except for operating their existing power stations, municipal undertakings were restricted to retail distribution [Christie, 1984]. Rapid growth in energy consumption continued (Figure 2-1) and, despite Escom building increasingly larger power stations and a 400 kV transmission grid linking all four provinces (Transvaal, Orange Free State, Cape and Natal), there were further shortages of electricity in 1978/79, a surge of power station construction, and large price increases to fund power station construction, leading to a government enquiry [De Villiers, 1984].

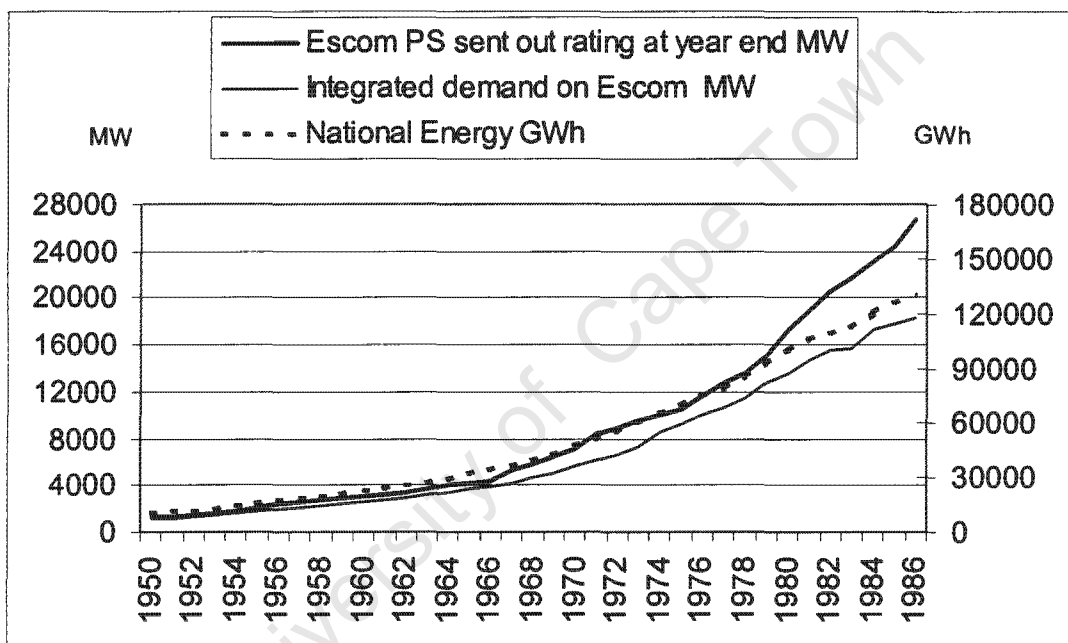


Figure 2-1: Energy consumption and power, South Africa, 1950-86
(Source: Escom Annual Reports)

The power shortages and the enquiry were to have significant impact on electricity supply in South Africa. Together with external influences, they led to the following in the late 1980s:

- reduction in the rate of growth of electricity consumption and demand
- power station over-capacity to the extent that some power stations were mothballed and construction commitments had to be deferred
- the restructuring of Escom by a new Electricity Act and Eskom Act in 1987
- excess Eskom staff released from power station construction and operation.

Meanwhile, separate electricity utilities had been established in three of the "homelands": Tescor in Transkei [Gaunt, 1980], BECOR in Bophuthatswana and

VEC in Venda. Together with the Provincial Administration Boards, later called Development Boards, and Town Councils having authority in Black townships, the traditional municipal electricity undertakings and Escom, the electricity distribution industry was diverse to the extent of being fragmented. Escom was withdrawing from urban retailing, selling its distribution systems to new municipal undertakings like Midrand, Goodwood and Bellville, but taking over the rural networks of some municipalities such as Duivelskloof. Among many other problems, including shortages of suitable staff and tariff discrepancies between adjacent utilities, there were problems with differences in standards for the distribution systems (see case study 1).

Case study 1: Design requirements affect distribution system costs

A firm of consulting engineers designed the electricity distribution for a residential area for a particular government department, to the approval of their electrical engineers. The township lay within the jurisdiction of another government department; they wanted changes and the system was re-designed to meet the new requirements. Both systems were based on low voltage aerial bundled conductor cables and the township layout did not change, but the networks differed in the design parameters and the system accessories. The contractor priced both systems on a bill of quantities basis, and the re-designed system cost 45% more than the original. The more expensive system was installed.

Source: Gaunt, 1988

Analysis

- (1) The capital cost of distribution is very sensitive to the design standards, even if the layout of the customers does not change.
- (2) Different organisations, even in the public sector, have different standards for the design of electricity distribution systems.

Christie [1984] maintained that the electricity supply industry in South Africa was developed and operated to provide public supplies of cheap power for the “*capitalist state and property-owners*” to improve productivity and profitability and “*denying the benefits of its power to the bulk of the population*”. Whether or not his political viewpoint is valid, it is clear that electricity supply changed during the period 1948 to 1987 from being entirely for economic reasons to include socio-economic objectives, particularly in the rural areas. At the same time, people outside the political structures were identifying problems associated with the existing policies:

“South Africa with its diverse cultures has a great number of people who have not been raised in a technical environment. This makes it extremely difficult to educate people in high technology over a short period of time. If the population is barely-literate, unskilled and burdened with cultural attitudes that are incompatible with a technological society, the development will be very slow.” [Ralph, 1987]

In response to the country's changing internal conditions and environment, South Africa was on the threshold of further major changes in both politics and electricity supply.

2.4 National Electrification (1988-present)

Political unrest in the 1970s and 1980s drew attention to the unequal living conditions of the different race groups in South Africa. As a result of political and economic discrimination most Black people lived in areas where access to electricity was limited or non-existent. A large project had been implemented in the early 1980s to electrify Soweto, and this provided an opportunity to demonstrate opposition to the government by not paying for electricity. Rioting, violence and civil disobedience in respect of all municipal services created tense conditions and were supported by international sanctions against South Africa's legislatively structured racial discrimination or apartheid.

Economically, large industries and sophisticated businesses made South Africa a developed country. At the same time it had typical characteristics of a developing country, with much of the economic activity still in primary production, mining and agriculture, and a substantial proportion of the population living in the subsistence economy, being unemployed or underemployed. Poverty existed beside the substantial economic activity. So, South Africa was advanced compared with the other countries in Southern Africa, but still a developing country compared with the transition countries of the East.

Part of the response to sanctions was to provide subsidies to all units of local production, including agriculture, to support national self-sufficiency:

"Electrification in South Africa during the 1980s addressed the needs of commercial farmers, providing network connections to support agriculture and agricultural industry. Network extension was effectively subsidised by other electricity customers. As a result, most economic units were electrified by 1990." [Gaunt, 2002a]

The need for "corrective action" by supplying electricity to those for whom it had not been available was evident: "... a social 'right of access to energy' will develop ... because electricity will support an improvement in the quality of life. It is therefore important to find ways of supplying at least some of the benefits of electricity at prices which are sub-economic by present standards" [Gaunt, 1988]. The development of new major townships, such as Khayalitsha near Cape Town and Motherwell near Port Elizabeth, to cope with massive urban influx in the early 1980s,

had proceeded on the basis that most residents would use other sources of energy (see case study 2). The conditions stimulated the search for new approaches.

Case study 2: Electrification of Khayalitsha

Khayalitsha was established as a new town outside Cape Town in 1983, to create living space for the thousands of people arriving weekly from rural areas, mostly in the Eastern Cape, after the effective collapse of the pass laws system restricting the right of people to live outside their "homelands". An area of about 25 km² was set aside for residential development to accommodate 45'000 households. The initial intention was to provide core housing that could be extended, fully serviced with water, sewerage and electricity. However, the demand quickly forced reassessment of the standards, leading to the adoption of smaller stands serviced with water and sewerage only. Electricity was supplied to businesses, high mast area lighting, and institutions like schools and community centres, but fees were too high for household connections.

Khayalitsha was established on the Cape Flats, a sandy area stabilised decades earlier by the planting of Port Jackson, an alien plant very useful for fuelwood. When challenged about the need to provide electricity, officials stated, "there is more than enough fuelwood here", and indeed that was the main source of energy for several years, supplemented with paraffin, bottled gas and candles. However, provision was made for future electrification in the planning of the main supply system and the reservation of servitudes for future overhead lines.

The uncertainty of future electrification created an opportunity to minimise the cost of the backbone infrastructure by planning several smaller 66/11 kV substations instead of the main "city" substations initially proposed, and "temporary" woodpole lines still in use nearly 20 years later. This flexible, though less robust, system deferred capital expenditure and achieved substantial savings.

By 1992 Khayalitsha had over 68'000 households, of which about 10'000 were connected. Eskom, as part of its Electricity-for-All programme, negotiated with the local and provincial authorities to obtain the rights of supply and, in 1994, established Phambile Nombane, a joint venture company with East Midlands Electricity (subsequently withdrew) and Electricité de France, to implement household electrification and operate the distribution system. Between 1994 and 1999 PN electrified a further 34'000 households. Further households have been electrified since 2000, excluding squatter households in areas unsuitable for housing (flood plains, reserved space, etc). The extensive tracts of fuelwood have been totally cleared, as has most of the growth within walking distance. See Figure 6-1.

Source: Own experience

Analysis

- (1) Khayalitsha illustrates the rapid change in electrification in South Africa, from supplying only economic units and community centres to connecting all households, even those who could not afford connections under the initial tariff structures.
- (2) The provision for complete electrification and the phasing of investment to reduce costs was relatively unusual for that type of development at the time.
- (3) The clearance of the fuelwood illustrates the limitations of sustainable biomass in areas with urban concentration, and the potential for environmental effects in rural electrification.

Some development theory holds that developing countries should be able to leapfrog development, omitting stages of technological and institutional evolution, and learning from the experience of other countries. However, an alternative concept is that development arises from the process of change, and that it is not possible to reach the end state without progressing through the intermediate stages, even if the progress can be accelerated.

As South Africa was politically and economically different from other developing countries, it is not obvious that direct comparisons could or should be made with their electrification processes. In spite of this limitation, the household electrification programme in South Africa can be thought of as inspired by comparisons with electrification achievements in other countries, leading to proposals to accelerate development in South Africa. In this sense, the South African experience supports the leapfrog theory.

Dingley [1988] visited six countries during 1988 to investigate their electrification programmes. Among other things, he found that the rate of electrification in all the countries studied *“show a remarkably consistent value of between 10 and 13 new connections annually per 1000 of population in the supply area”*. On this basis he concluded that an electrification rate of at least 350'000 connections per year could be achieved in South Africa. At the time, the proposal appeared ambitious, but the achievement was even higher, as indicated by the data from the National Electrification Programme in South Africa, added to Dingley's figures in Table 2.3.

Table 2.3: Electrification rates in various countries

Country	Utility	Period	Consumers connected annually (1000s)	Annual connections /1000 population
Brazil	CEMIG	1983-87	172	11
Brazil	COPEL	1982-86	93	12
Costa Rica	All	1982-86	28	11
USA	Rural co-ops	1976-86	305	12
Hong Kong	CLP	1978-87	55	13
Thailand	PEA	1982-86	455	10
Greece	PPC	1986	121	12
South Africa	All	1994-1999	450	11

The problem facing the supply authorities was that *“the large scale construction of electricity distribution systems for domestic consumers in South Africa will probably cost more than the country can afford if conventional systems are adopted”* [Gaunt, 1989]. Innovative design and new standards were needed to meet the multiple objectives of the many interest groups involved in electricity supply.

A business study sponsored by Nedcor-Mutual in 1990, independent of the political structures, considered various ways of improving the social conditions in South Africa and stimulating economic development [Tucker and Scott, 1992]. Among other possibilities, the scenario studies identified the scope for and potential benefits of a large electrification programme. Several people supported and developed the concept for their benefit or the survival of their organisations.

At the same time, the possibilities of national electrification and tariff rationalisation were promoted to municipal engineers [Gaunt, 1991b], and the Energy and Development Research Centre at the University of Cape Town prepared and distributed several reports on electrification (1985-1992) that contributed to the target setting for the electrification programmes adopted in 1991 and 1994.

Arising from the awareness of the possibilities, an Electricity-for-All initiative was adopted by some municipalities and Eskom. In 1991, the government released Nelson Mandela and unbanned most of the opposition political parties. The electricity industry, business, communities, and local and central government had many meetings about electricity supply industry structure, tariffs and electrification⁹ during the period of negotiation of the new political structures for the country. The Electricity-for-All programme was given widespread support during the emerging political normalisation and the new government adopted it as the National Electrification Programme (NEP) in 1994.

2.4.1 Numbers connected

The numbers of connections achieved in the Electricity-for-All programme are shown in Table 2.4 and the connection targets adopted for the National Electrification Programme and subsequently achieved are shown in Table 2.5. The urban areas served by the municipalities were already substantially electrified, with approximately 1.8 million domestic customers. As Eskom only had 111'696 domestic customers in 1990 [Eskom, 1991], it was responsible for the greater share of new electrification.

Table 2.4: Yearly connections of Electricity-for-All programme

	1991	1992	1993	1994
Eskom	31 035	145 522	208 801	254 383
Local government and other	51 435	74 335	107 034	164 635
Total	82 470	219 857	315 835	418 918

[NER, 1996b]

9 Conference on the electrification of developing communities, SAIEE, November 1991; ANC National Meeting on Electrification, February 1992; National Electrification Forum (NELF), 1992-1994.

Table 2.5: Connection targets of the NEP in 1994, and achievements

	1994	1995	1996	1997	1998	1999	Total
Eskom	250 000	300 000	300 000	300 000	300 000	300 000	1 750 000
Other	100 000	100 000	150 000	150 000	150 000	150 000	800 000
Total target	350 000	400 000	450 000	450 000	450 000	450 000	2 550 000
Achieved	418 918	478 767	453 995	499 391	427 426	443 290	2 669 345

[Eskom Annual Report, 1995; achievements from NER reports, 1996-2001]

The municipalities significantly exceeded their target and Eskom achieved slightly less than its target. In addition, nearly 70'000 farmworker connections were made, and if those made under the Eskom financial incentive scheme are added to the Eskom figure it can be said that Eskom also exceeded its target¹⁰. The overall extent of electrification was increased from about 36% of households in 1990 to 67% in 2000.

Some have envisaged complete electrification by 2012: *"Government committed itself to funding both grid and non-grid connections at the average rate of R3000 per connection for 300'000 connections per year from 2001 to 2005, and 250'000 connections per year from 2006 to 2010. However, recent budgetary allocations indicate that these targets will not be met."* [FFC, 2002].

On completion of the commitment to electrification at the end of 1999, the actual and target connections implemented by Eskom has steadily reduced. As a result, with growing population, urbanisation and the construction of new houses, the percentage electrification in some urban areas and nationally has apparently gone backwards since the highest percentage national electrification in 1999.

2.4.2 Costs of connection

It had been recognised at an early stage that the electrification targets would be difficult to achieve:

"The targets will become increasingly difficult to achieve as the electrification progresses since construction will move more and more into the rural areas that are more distant from the electricity grid and where the density of dwellings is lower." and "the cost per connection varies considerably depending on the location where the connections are made and the deployment of distributor staff and equipment and the cost of finance." [NER, 1996b]

10 Customers added by Eskom taking over other utilities are not counted as new connections.

The expectation that costs of household connections would be higher in rural areas than in urban ones is reasonable from a comparison of their visual appearance, as illustrated in Figures 2-2 and 2-3.



Figure 2-2: Rural households



Figure 2-3: Urban households

The average costs per connection by province and urban/rural in 1995 and 2001 are shown in Table 2.6.

Table 2.6: Average cost per connection, 1995 and 2001

Province	Cost/connection [Rand current 1995]		Cost/connection [Rand current 2001]	
	Rural	Urban	Rural	Urban
Eastern Cape	4397	2082	2644	2695
Free State	4088	1194	2018	2624
Gauteng	na	2475	na	2626
KwaZulu/Natal	5055	2642	2533	2639
Limpopo (was N Prov)	3010	2146	2783	2777
Mpumalanga	2653	1681	2632	2644
North West	3063	2712	2740	2746
Northern Cape	4437	1301	1447	2701
Western Cape	1474	na	3453	2655
National average	3568	2170	2622	2674

Source: Derived from NER [1996a and 1996b, 2002a and 2002b]

It is clear that the costs of rural connections have been brought down considerably, especially taking into account the approximately 35% inflation over the period. The costs for urban electrification appear to have evened out, but this is largely due to an underlying figure ascribed to the municipal urban connections of R2600 for all provinces. (The figure is not disclosed but can be calculated from the reports.) Nevertheless, the national average cost of urban electrification appears to have increased by about 15% in current terms but decreased by 20% after allowing for inflation (more details are given in chapter 4). At the same time, the average cost of rural electrification decreased by 40% in current terms and a massive 70% after inflation.

2.4.3 National system demand after electrification

The excess generating capacity that gave rise to the opportunity of electrification without creating electricity shortages was such that the reserve margin is still very wide. The maximum demand on the transmission system in 1995 was 25 GW on the winter peak day [NER 1996a]. Without building new power stations, the estimated national peak demand in 2000 was 30.9 GW with 41.6 GW of active licensed capacity and a further 10% not in operation [NER, 2001c].

2.5 Electricity supply industry structure

The Electricity-for-All and National Electrification Programmes were implemented initially with design and construction undertaken by a mixture of external consulting engineers and contractors and the in-house municipal and Eskom resources.

Eskom introduced public-private partnerships (TED, Kwanolec and PN), but later Eskom took over TED, and both Kwanolec and PN changed their form. Eskom also took over the former homelands' electricity utilities, Tesco, Becor and VEC, that had become redundant in the new political structure and whose rural electrification programmes had been severely constrained by their limited access to financial resources. As a result, the number of Eskom customers grew more quickly than simply by the new connections.

The present structure of the industry is illustrated in Table 2.7. According to the NER there were 376 licensed distributors in 2000¹¹, and many of these are very small utilities. Eskom was predominantly a bulk supplier, but now has a large number of domestic customers. The average domestic and commercial customers of municipalities consume more energy than the equivalent Eskom customers. In 1998 Eskom's domestic customers used 210 kWh/month on average, compared with 734 kWh/month for the domestic customers supplied by municipalities¹². In most other categories Eskom's customers are significantly larger energy consumers than in the municipalities.

Table 2.7: Structure of electricity distribution industry by sector (for 1998)

Category	No of customers		MWh/customer/year		Total energy	Av sales price
	Eskom	Municipal	Eskom	Municipal	TWh/year	c/kWh
Domestic	2376069	3011503	2.5	8.8	32.5	23.94
Agriculture	148369	20907	25.1	27.3	4.3	26.02
Mining	750	17287	42193.1	25.1	32.1	12.27
Manufact'ing	10354	47142	5152.3	624.7	82.8	12.80
Commercial	27273	171571	29.4	67.8	12.4	23.42
Transport	40	414	85972.5	1809.0	4.2	15.11
General	62	12396	4906.9	211.2	2.9	13.43

Source : NER, 1999b

Since the first proposals for national electrification were made there have been many suggestions for restructuring the electricity distribution industry and these are considered in chapter 7.

¹¹ The NER [2001c] states there were 376 licensees but lists 385, including industries with housing, but only 29% of all licensees submitted statistical returns in 2000. The demarcation of local authorities since 1994 reduced 843 former local authorities to 241 Metros and municipalities by the end of 2000 [van der Merwe, 2000].

¹² The NER's figures for municipalities need to be treated with caution because inspection of the tables in NER 2001c indicates that for some, such as Rustenburg, all consumption is assigned to the domestic sector, introducing significant error. For the year 2000, average monthly domestic consumption for Eskom was 216 kWh and for municipalities about 625 kWh (after some corrections).

2.6 Evaluations of the electrification programme

Many researchers with different perspectives have assessed the electrification programme, including internal studies by some utilities.

Between 1996 and 1998 the Energy for Development Research Centre (EDRC) at the University of Cape Town carried out broad research on the role of electricity in the provision of energy to rural areas in South Africa. 45 research reports and papers were prepared on a variety of topics including energy demand, grid and non-grid electrification, community participation and social impact [EDRC, 1998].

The Development Bank of Southern Africa and the EDRC made a significant assessment of electrification for the Department of Minerals and Energy in 2001 [Borchers et al, 2001 and DME, 2001]. The evaluation was constructed around the logical framework (logframe) adopted by the European Commission for project design and analysis. Although intended as a planning tool, it is useful for evaluations because *"When used properly the logframe helps to make the logical relationships between activities, results, purpose and objectives more transparent"* [European Commission, 1999]. In many electrification programmes the linkages are assumed to exist, but are not given explicit attention. The details of logframes are usually presented in tables but the basic concept is illustrated in Figure 2-4. Logframes had not been used in planning the National Electrification Programme, so they had to be developed retrospectively for the evaluation.

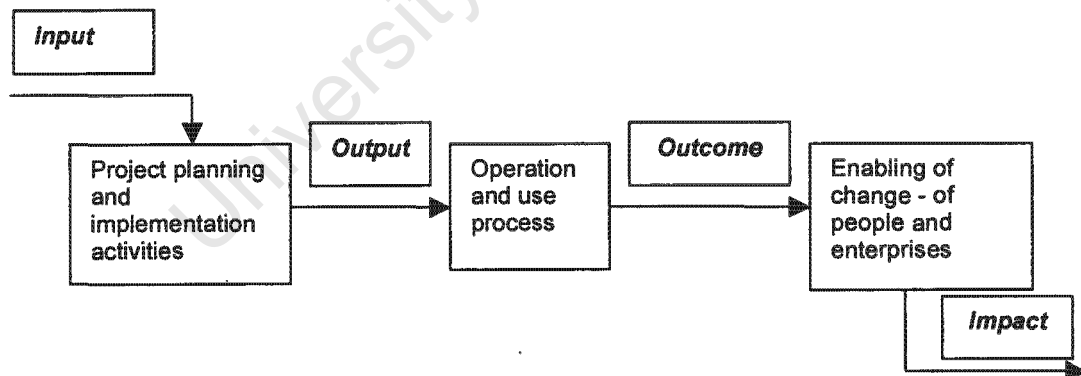


Figure 2-4: Logframe approach to project analysis

The findings of the evaluation of the South African National Electrification Programme have been summarised as follows [Gaunt, 2002b]:

- Electrification in low-income areas is not financially viable. Economic analysis indicates the investment is marginal, but probably understates welfare and multiplier benefits.
- Electrification has significant social impact, but the benefits are constrained by lack of access to the network, lack of appropriate appliances for those connected and a poor understanding of tariffs.
- The effectiveness of an institution's performance in electrification is independent of the institutional structure, and the achievements indicate strength in diversity.
- A wide range of technological alternatives exists to reduce the investment and operating costs of electrification. The alternatives have significant implications for both grid and non-grid electrification. However, innovative technologies and processes will be introduced by utilities only when forced by financial restrictions.
- Achieving the desired impacts of electrification requires a broad approach to setting targets in terms of benefits, with implications for management, evaluation and regulation.

Evaluation of the NEP provided an opportunity to compare projects implemented concurrently by different utilities. The scope was unusually broad for most project assessments, including technology, institutions, costs, and social impact. The use of the logframe approach was one of the first applications of this methodology in Southern Africa. It provided a framework to assess the electrification programme in terms of the overall objectives of electrification, instead of merely the stated goals expressed as a number of connections. As a result, it introduced a different and useful perspective to assessment.

2.7 Proposals for a “poverty” tariff

Poor households in Africa are really poor. Absolute poverty as defined by insufficient nutrition is widespread, and is not the same as the poverty line, defined as the upper bound of the two lowest quintiles (40%) by household income. As a result of their poverty, poor people cannot afford much electricity, even if the electrification connection is provided very cheaply or free. In many cases a subsidy on consumption is needed to achieve a benefit from the investment in electrification networks.

The University of Cape Town was appointed by Eskom and the Department of Minerals and Energy in October 2001 to carry out research into a proposed tariff to subsidise the electricity consumption of poor customers. Technological, social,

financial, economic, environmental, health and institutional factors were researched, and key issues identified.

Some of the findings of the tariff research report [UCT, 2002] were summarised as:

"Research into poverty alleviation and tariffs cannot be carried out effectively without a good knowledge of the load parameters. A national load research programme, collecting urban and rural household load data for about ten years, provided a comprehensive model of loads against which to test various tariff alternatives and the impact on feeder overloading and generation capacity.

Tariffs for consumption subsidies can be targeted to the poor, or applied as a broad-based (available to all connected households), increasing block rate tariff. Targeted tariffs are not as effective in reaching all the households, but have lower leakage of benefits to those outside the target group - the non-poor.

Most of the poorest people in the country are in rural areas and many are not yet electrified. A broad-based subsidy tariff will require significant financial transfers from utilities with a low proportion of poor households, in a national sense, to the utilities serving the rural customers.

A targeted tariff should limit the demand of customers to 8 or 10 A and the first block of energy should be supplied at a heavily subsidised rate. Further energy purchases during the month will be at the same rate as for other households. Most metering and vending systems are capable of implementing such a tariff." Gaunt [2002b]

The research led to the recommendation that, *"if it is to be adopted for poverty alleviation, a special tariff will have to be a self-targeted tariff, with customers electing to have it. For utilities not already offering a range of household or domestic tariffs, the basic electricity support tariff will require a change in the concept of providing services to customers."* Gaunt [2002b]

Fixed cost load-limited supplies must have a high enough tariff to protect a utility from customers capable of consuming substantial energy, that is, having a high load factor, and a severe current limit, such as 2.5 A, prevents customers from using many normal appliances. The cost to customers of upgrading from a flat-rate supply to conventional supplies is usually very high, so the severe limit constitutes a poverty trap. Although the cost of prepayment metering is higher than a simple load-limiting device, the consequences of implementing a policy with a poverty trap are more significant. The proposed self-targeted tariff, with prepayment metering and a less severe load limit, avoids the poverty trap of unmetered load-limited supplies.

2.8 Research questions answered

This introduction to electrification in South Africa already provides preliminary answers to questions posed in chapter 1.

What is electrification, and how does the definition relate to grid and non-grid technologies and identify target customer sectors?

Electrification must be defined broadly, including supplies to economic, productive units as well as to the households of ordinary people who need access to modern energy for the impact it can have on their lives.

Initially, the emphasis of electrification in South Africa was on meeting economic needs, that is, the energy needs of customers in mining, industry and commerce that could pay the full cost of making the supply available. In the 1970s and 1980s the electricity networks were extended to rural towns, farms and community centres, in many cases providing the benefits of electricity access to customers contributing to economic development, but at tariffs below the costs of supply and subsidised by other customers. Intensive household electrification only occurred with the Electricity-for-All programme in 1991 and the National Electrification Programme in 1994. These programmes supplied electricity to small household customers using it for lighting, media access and limited cooking, at tariffs that are mostly not financially viable for the supply utilities and have been shown by broader economic analysis to be marginal or below normally acceptable rates of return.

Municipal electricity undertakings, Eskom (and its predecessor, Escom) and private companies have implemented electrification in urban and rural areas.

Non-grid technologies have not yet been examined.

Such a broad definition of electrification results in it having many different characteristics. What applies in some places may not apply in others. Different underlying objectives are likely to result in different approaches to electrification.

Who are the stakeholders in electrification, and how are their objectives incorporated into the purpose for which electrification is implemented?

The stakeholders include the utilities and customers, the government in its role of establishing the framework within which the others operate, and groups of politicians, businesses, financiers and others wanting to influence the course of electrification so that it meets their various objectives. The diversity of stakeholders results in conflict between some objectives, and the need to assess proposals according to their origin.

What are the characteristic economics of electrification - capital, operations, revenue/tariffs, and viability?

The capital cost of electrification depends on the technologies adopted and the loads to be supplied. Operating and maintenance costs depend on the extent and complexity of the networks. Revenue depends on tariffs approved by regulatory authorities, but need to be simple for understanding, and reflect costs so that they send appropriate economic signals. The viability of electrification depends on the cost control of implementation and network management, and the capacity of the customers to use electricity. An evaluation of the National Electrification Programme indicated that the household electrification undertaken since 1990 was not financially viable. The possibilities arise that the electrification programme was unsuccessful or that electrification was undertaken for purposes other than the economic development used as the basis for the evaluation.

What changes have occurred in the technology of electrification? What drives technological change and how do the changes affect an electrification programme - including methods, implementation process, components, planning, and standards?

Substantial changes in the construction of the electrification projects are evident from the significant reduction in capital costs, to the extent that rural electrification is no longer more expensive than urban electrification, and the changes in standards. More detailed analysis of these changes is undertaken in the following chapters.

The rest of the research questions remain unanswered at this stage.

2.9 Onword

Electrification in South Africa started for economic reasons, to reduce the costs of the mining industry, other industries and the railways. The convenience of electricity for lighting induced the municipalities to adopt it for public and private supplies, and the government recognised the importance of controlling and owning this economic function.

The social aspects of electrification were evident early, at about the same time that developed countries were implementing household electrification for social and socio-economic or socio-political reasons. However, the authorities in South Africa did not have or allocate the resources for such widespread programmes. The most significant socio-economic electrification in South Africa took place during the 1970s and 1980s when, spurred by political pressures, Escom (as it was then) extended

subsidised supplies to the farms in rural areas. Even then, many farms were too far from the grid to be able to afford the supplies at the high costs associated with the technologies and tariffs then in use.

The establishment of several new townships near the cities during the 1980s, associated with the influx of people from the rural areas, emphasised the issue of whether electricity should and could be supplied to poor families. In many cases where electricity was available, the viability of the distribution was challenged by expensive technical standards, uneconomic tariffs and bad debt.

A business strategy process in the late 1980s identified the possibility of deriving significant socio-economic benefit from a national electrification programme. The programme was adopted in 1990/1, mostly as "Electricity-for-All" and became a focus for discussion of alternative government as South Africa started going through political change from apartheid to a broadly democratic government. Parallel with the implementation of the electrification, policies were defined by the National Electrification Forum and in 1994 adopted by the new government as the National Electrification Programme.

It became evident that many people were too poor to benefit substantially from access to electricity, and the voter appeal of promising free services was recognised. Proposals for "poverty" tariffs and promises of free electricity identified another reason for electrification, one that does not have socio-economic, but purely social objectives. There are two aspects: poverty alleviation and political support.

Three different objectives can easily be identified for the electrification in South Africa: initially economic, later socio-economic and recently social. Basic theory indicates that the "solutions" for different objectives are usually different, so this thesis explores the solutions to the electrification programmes in these three phases, and the differences that did, should or might support them. However, before looking at the electrification programmes in South Africa in greater detail, it is useful to review other theories and reports in the international literature regarding electrification and development.

In particular, it should be useful to identify approaches to defining the purpose of electrification, processes of electrification, and the assessment of the impact of electrification.

Chapter 3

Published information on electrification for development

3.1 Introduction

Chapter 1 identified several questions related to the hypothesis that classification of the objectives of electrification would improve the understanding of and approach to the policy formulation and problem solving. Although it provided some clarification and preliminary answers to the questions, the brief description of electricity supply in South Africa in chapter 2 left several of the questions unanswered.

There is extensive literature on electrification, the contribution of electrification to development, financial mechanisms, the role of technology, and many other related aspects. In the context of the hypothesis, this literature could provide insight to the proposed classification of the objectives of electrification as being economic, socio-economic or social, and answers to the questions posed. Therefore this survey of the literature will be directed to identifying:

- cases where researchers or practitioners have identified different purposes or objectives for electrification programmes,
 - key technologies for electrification, changes in the technology, and the process known as “technology transfer”
 - processes in the conception, implementation, operation, financing, organisation and management of electrification,
 - methods for assessing electrification programmes,
 - problems that have arisen in other electrification projects and programmes,
- all generally in accordance with the research approach illustrated in Figure 1-2.

3.2 Systems approach

The hypothesis of this research is that electrification is directed towards economic, socio-economic or social objectives. The research itself is entirely context related, because it views electrification as having a purpose, and so that the research takes a form according to that supposition of purpose. The potential limitation of the

approach is recognised, but it provides a useful framework for considering the available information.

Electrification is an inherently complex activity, involving electricity utilities with people as individuals and in organisations, and in technology, finance and economics, resources and the environment. The complexity of electrification requires that some of the techniques of the generalised systems approach be used to break down the large complex system into smaller systems amenable to analysis. The systems approach is used widely in business, engineering and computing. The diagram in Figure 1-2 is a system representation, in that it identifies the main components and connectivity relationships between them. An important characteristic of the system is that the elements affect and are affected by each other, so that a change in one causes changes elsewhere in the system. The basic aspects of the systems approach as used in this research thesis are described briefly in box 1.

Zomers [2001] uses a systems approach for the analysis of electrification, applying it to decision-making criteria and analysing the displacement of influence domains. His subsystems are environment (including societal and human aspects as well as the ecological), technology, economy, and political.

A different systems representation used in this research considers the utility sub-system operating with three other sub-systems:

- social subsystem: individuals; groups of individuals in organisations or institutions acting in a political and legal framework; groups and individuals as customers with needs and cultural, ethical and religious values.
- environmental subsystem: natural environment (ecology) and resources.
- infrastructure subsystem: physical construction, technology, finance and economic systems.

The environment of the electrification system includes all other relationships and components that only weakly influence electrification.

The model is depicted in Figure 3-1. The value of this model is that it allows the various relationships between the utility and the components of the other subsystems, and proposed changes to the system's structure and function, to be analysed separately but within the context of the whole electrification system.

Box 1: Systems approach

The systems approach simplifies complex problems by breaking them down into smaller units. The key to the systems approach is to identify and define less complex systems of components and the relationships between them, and to model, analyse, and control or modify them.

Simplification is achieved by defining the system such that:

1. the most important relationships are identifiable responses between the main components of the system,
2. the system is influenced by the environment (everything outside the system) and may have an effect on it, but the linkages are weaker than between the various parts defined as inside the system,
3. the relationships in sub-systems within components, having little impact on the other main components of the system, can be ignored,
4. the relationships outside the system (between components of the environment) can be ignored, and
5. all stimuli (events that cause something to happen) and responses of interest can be considered at the system level.

Systems are characterised by **four general properties**. The study of systems usually:

- assumes a degree of permanence - *state*
- assumes a degree of organisation - *structure*
- concentrates on what a system does or how it performs - *function*
- identifies the *relationships* between the components of the system, and between the system and the environment.

There are many ways of representing a system. These include sets defined by attributes of the components, hierarchy as in an organisation structure, precedence networks defined by sequence or time, and connectivity/relationships systems. The same complex system can be defined in different ways, according to the needs of the condition being analysed, the function or performance of the components, and the knowledge of the relationships.

As a physical example of defining the same thing in different ways, a transformer in a power supply network can be represented on an operations control diagram by a symbol indicating a unit of equipment, but, as a component in the network, it comprises conductor, magnetic core, a tank and insulation; and the insulation includes paper, fibre board, oil, air and porcelain. Alternatively, the transformer is represented for calculations by its power capacity, impedances and turns ratio.

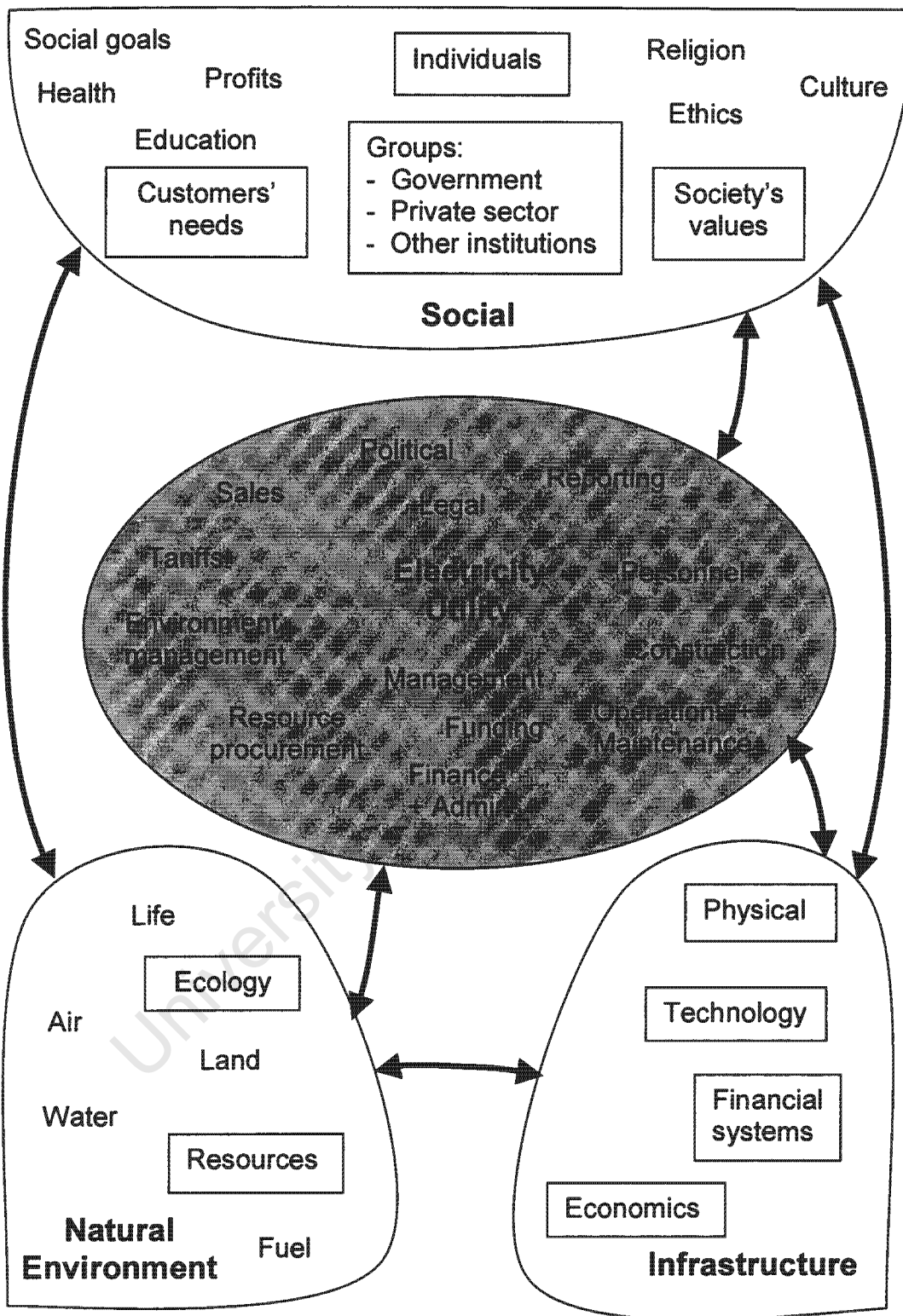


Figure 3-1: Model of electrification system.

Rectangles indicate significant sub-systems within the four main sub-systems.

3.3 Electrification not confined to rural areas

The description of electricity supply in South Africa (chapter 2) indicated that there were stages of electrification, starting privately to meet the needs of mining and industry, and initially in the urban areas. Generation was established where needs were evident, and the network developed to link the customers to the power stations. Eventually most urban areas had access to electricity, and the network started to expand towards countrywide coverage. In that sense, electrification refers to giving customers a supply of electricity, initially from isolated systems and later from an integrated network. The process was similar in most countries.

Many writers distinguish between urban and rural electrification, and much research has been directed to rural electrification, as being different from and excluding urban electrification. However, the various categories of electrification are not distinct:

"Rural electrification is generally thought of as grid electrification, and this is indeed the most common and most desired means of supply. Where load densities are low, however, diesel generators, renewable energy and hybrids of such options are more cost-effective.

Developing countries' efforts to extend electricity supplies to their populations have been impressive. During 1970-90, nearly 1.3 billion people were newly supplied with electricity from national grids, of whom 800 million were in urban areas and 500 million in rural areas" [World Bank, 1996].

Electrification, therefore, happens in developing countries and may be grid or non-grid, urban or rural. A key characteristic in this thesis is that it is electrical and not inclusive of other energy, despite some approaches to broader 'energisation'.

Zomers [2001] recently completed a wide ranging analysis of rural electrification, with particular focus on the organisation of power supply utilities. Few reports integrate theoretical aspects with wide-ranging practical experience on rural electrification to the same extent. There are many parallels between electrification in general (which is the topic of this thesis) and Zomers' study of rural electrification, and some of his findings probably have broader application.

For example, Zomers writes: *"In the past, utilities have generally conceived the electrification of rural and remote areas as a techno-economic activity. Large scale and industrial electricity supply is predominantly a technical/administrative activity, but this does not apply to rural electrification. Apart from the technical and economic issues, the rural electrification also involves such aspects as social, ethical, institutional, political and cultural."* He also states: *"... the electricity supply to rural and remote areas have mostly been treated as 'special' cases in such terms as rates*

of return, subsidies and technology.” The same factors he identifies as affecting rural electrification are important also in the electrification of households in urban areas, particularly of those that might not be justified as economic projects. Also, there are often further aspects in urban areas, including issues of urban planning and whether households have the right to occupy land, that do not impinge on rural electrification to the same extent [Floor and Massé, 2001].

Zomers assembled a table of factors comparing rural and urban electrification. The urban loads describe large industrial and commercial customers and large projects, and there are no details for areas between those defined as urban and rural. Table 3.1 is a revision of his table, based on conditions in Southern Africa and still omitting the in-between category. The existence of the ‘in-between’ illustrates the difficulty of dividing electrification into urban and rural. (The in-between densities are not “peri-urban” as defined by Floor and Massé [2001] who refer to densely populated legal and squatter communities.)

Table 3.1: Comparison of urban and rural electrification in Southern Africa

Feature	Urban	Rural
Consumer density [con/km ²]	500 - 4000. In most areas of poor and informal housing without electricity the density is typically towards the upper end of this range.	1 - 75
Economic aspects	High proportion of supplies for economic purposes (industry, commerce), except in very poor areas.	Relatively low proportion of economic supplies, mostly related to agro-industry.
Household customer loads	Poor: Demand = 3 kW, consumption = 300 kWh/month. Wealthy: 6 kW, 800 kWh/m	Mostly very poor: <1 kW and <150 kWh/m. Consumption tends to be lower in rural areas because average income/household is lower.
Social and socio-cultural aspects	Importance increases with increasing poverty. For large customers the culture is mostly techno/administrative.	Financial support and special solutions needed. Close consultation needed with recipients because of their low exposure to economic activities, formal sector and the services offered.
Technology	Many large, concentrated loads are supplied at MV, high ratio of LV to MV feeder for smaller loads, high load factor because of customer diversity.	Low ratio of LV to MV feeder, small transformers, low load factor.

Another aspect of the definition of rural electrification is that it is widely considered to be expensive. Karekezi and Kithyoma [2002] state: “*The transmission and distribution costs of extending grid electricity to dispersed homesteads is high, thus creating an ideal market for decentralised energy technologies that better match the dispersed nature of sub-Saharan Africa’s rural population.*” Schramm [1991] goes further: “*Provision of network electricity is by far the most costly form of energy*

supply in low-density rural areas, compared to other alternatives". However, the outcomes of all comparisons are very sensitive to the values used to model load factors, losses and marginal generating capacity costs. This important aspect of the cost of rural electrification and non-grid electrification will be addressed further in chapter 4 dealing with technology.

The concept of "rural electrification", therefore, is based on the premise that urban and rural areas are easily defined, determining the approaches adopted. Instead, this thesis adopts the view that electrification is a process that requires the solving of specific technological, financial and institutional problems to supply electrical energy for specific needs, possibly requiring slightly modifications according to the density and characteristics of the customers.

3.4 Purpose of electrification

"Bringing electricity to the people is, in itself, not a contribution to reducing poverty nor does it lead to rural development." [Zomers, 2001]. So why is electrification implemented?

Not all writers explicitly identify the purpose or objectives of development or projects. For example, Khatib [1997] uses broad terms: providing access to electricity to those without it *"is the greatest challenge facing developing countries in their pursuit of sustainable development"*. Other than conveying the need for sustainability of development, such statements do not differentiate between various types or starting points or the conditions or inputs needed to achieve the desired changes. In fact, Khatib's evaluation of projects is predominantly financial and economic, but does recognise *"the other four considerations in electrical power project feasibility: the sector; the market (demand); technology and engineering analysis; management and manpower"*.

The World Bank has a major role in development financing and the Bank and its officers have perceptions about the objectives they are pursuing. For example, Bergman [reported by Applewhite, 2002] explained the initiative on which he was engaged as *"to channel electrical resources into activities that have an economic return"* and refers to the handing out of light bulbs as being all well and good, *"but it doesn't generate money"*. Clearly the latter activity, intended as a contribution to the quality of life of the recipients, will not generate economic returns in the same ways as sewing machines and welding equipment, but the impact on the people may be just as significant. Thus, the objectives, whether explicitly recognised or not, dictate the type of development and electrification systems planned, financed and

supported. Without understanding the issues and consequences, it is easy to reduce the effectiveness of the development intervention.

Other writers consider electrification according to the applications; for example Karekezi and Kithyoma [2002] state that providing modern energy services to the population in rural areas is of paramount importance for household energy, energy for agriculture, and energy for small and micro-enterprises.

The hypothesis of this thesis is that electrification is implemented for economic, socio-economic or social development, and these are discussed in the following sub-sections.

3.4.1 Economic development

Most electricity utilities supply electricity to customers on the basis that the full cost will be recovered from a connection charge and the sales of energy. The customers pay the costs out of revenue derived from producing goods and services, including commercial, industrial, mining and agricultural activity. The utility may take a long-term view on the period over which the financial viability must be achieved and the potential for future customers to connect to the basic infrastructure, and it may not charge the full costs to the first customer to request supply. Utilities develop tools for the financial analysis of projects of this type.

The policy of the US Agency for International Development [USAID, 1984] clearly identified the need for rural electrification to meet economic objectives. *"USAID will ... consider rural electrification programs ... when the introduction or improvement of electricity supply will enhance agricultural production, and off-farm employment. Rural electrification programs ... must be carefully analyzed, because the opportunity costs of capital intensive projects are very high for capital scarce economies. Issues to be covered include: ... evidence of the economic benefits attributable to the electricity provided; the cost comparisons of centralized vs. decentralized systems over the life of the investment; alternative forms of investment that might be foregone"*.

Electricity supply is a fundamental requirement for most major projects, and the cost is considered as contributing to production and productivity. Other energy forms, such as coal and oil, exert competitive pressures on electricity pricing. A utility may also consider special customised pricing arrangements with large customers, such as in the aluminium and ferrochrome industries, which are electricity intensive [Eskom, 2003].

The improvement in productivity achieved by electrification, especially in agricultural processing and cottage industries, is often cited as a significant part of rural economic development. For example *"The effect of rural development plans ... is to increase the economic returns expected from rural electrification because they increase the uses to which electricity is put. A high IER for the rural electrification element indicates that it forms a very useful and productive part of the rural development plan."* [World Bank, 1975]

Where electrification cannot be justified on the financial criteria (rate of return), further criteria may be introduced to justify a project or, in other words, to make the evaluation successful. Such criteria may include environmental benefits or improvements in the broader economy, such as: *"Based on the World Bank's experience to date, rural electrification programs rarely support themselves financially. However, there are external benefits that rural populations derive from key synergies facilitated by the introduction of electricity (such as improved access to communication, education and economic opportunities, extended and more reliable health services, and improved security)"* [Sanghvi et al, 2001].

Financial viability and economic viability depend on the perspective of the analyst. Electricity utilities compare their costs with the projected revenues. However, other benefits are derived by the customers (cost-effective energy supplies) or by the country or region (better competitive position compared with reliance on other forms of energy, lower total expenditure). Economic analysis of proposed electrification is usually performed from the point of view of the country. Munasinghe [1990c] notes that many developing countries see electrification programmes as part of their economic development efforts.

However, estimating the economic returns is not easy, with the result that *"In the 1970s, support for rural electrification was enthusiastic, based on high expectations of the economic benefits it would bring. However, by the late 1980s much of the original euphoria had dissipated as countries discovered that costs had been underestimated, and utilities and governments came under severe financial pressure"* [Dutkiewicz, 1998].

Similarly, Pearce and Webb [1987] support the approach that development should be seen as an economic activity, questioning the values assigned to other benefits: *"Conventional rate-of-return criteria should play a stronger role in determining rural electrification expenditures and that some of the non-monetary benefits appear neither to be widespread nor as strong as supporters of rural electricity suggest. While rural electrification is nonetheless important in the development process, it is more usefully integrated into wider rural energy development schemes".* And

Munasinghe [1987] states *"There has been a systematic tendency to overestimate expected productivity gains in the industrial and commercial sectors during the economic appraisal of rural electrification programs."*

Ebohon [1996], on the basis of analysis of energy and growth in Tanzania and Nigeria, identified an important linkage between energy and economic development:

".. a simultaneous causal relationship between energy and economic growth for both countries, the implication being that, unless energy supply constraints are eased, economic growth and development will remain elusive to these countries. Given similar economic characteristics and profiling the same energy scenarios for other developing countries, the findings supports the view that energy plays a key role in economic development."

And further:

"the competing demands on biomass from the other sectors of the economy on one hand, and on the other, the accelerating rate of depletion has resulted in severe energy shortages. ... It is evident from this discussion that Africa cannot live with such huge energy deficits and simultaneously achieve meaningful growth and development."

Therefore, electrical energy should support development. However, confining his discussion to electrification, Schramm [1991] concluded that *"electrification by itself has not been a catalyst to economic development"* and that *"electrification should follow, rather than attempt to lead, regional economic development"*.

However, a recent World Bank Development Report [2002] states *"Small industrial enterprises demand electricity to run equipment. ... Recent research emphasises the importance of infrastructure for economic performance, especially in the long run - and its positive spillovers on private investment"*.

Generally, then, electrification is carried out for financial and economic development, even though there are difficulties in making the projections and achieving the objectives. Electrification not justified on financial or economic grounds may have to include other criteria before the project is successful in clearing the investment decision hurdles. Such projects and programmes are implemented for their socio-economic benefits.

3.4.2 Socio-economic development

Commenting on the impact of rural electrification, Zomers [2001] states: *"the impact of rural electrification could have been higher if other conditions would have been satisfied"* and *"rural electrification should be part of an integrated rural development"*

plan and not, as has often been the case in the past, a stand-alone project or programme." He thereby indicates that the value of electrification is linked to other actions and circumstances affecting the development outcome, and is not entirely economic in nature.

Electrification for socio-economic development usually considers electrification as an investment, such as for supporting employment creation, extending the scope of productive activities, or improving agricultural productivity. According to Munasinghe [1987], *"rural electrification is a tool for national socio-economic development"* and *"the integrated rural development approach has proved itself in many instances"*.

Zomers' review of the history of rural electrification in several developed and developing countries, in some cases over fifty years ago, led him to find *"that apparently economic circumstances were not a decisive factor in the wide-scale electrification of rural areas in industrialised countries. The power of lobbies and pressure groups was probably a larger determinant"*. However, he noted that the political strength of rural communities is low in many countries. He also identified that the developed countries *"had reasonably developed economies and rural infrastructures and they could afford to invest in electrification"* but *"the economies of the majority of developing countries are weak and do not allow major investments in infrastructure."*

The concept is that electrification is an investment to make a return, but that because the economics are not decisive, the justification requires non-financial aspects to be considered. In particular, electricity is expected to contribute to promoting or creating the conditions for economic development and improving the productivity of communities, especially in terms of the labour, their most abundant resource. Socio-economic development analysis incorporates the non-financial benefits and costs by assigning financial values to them, and by applying shadow prices where financial prices are felt not to reflect full economic value, and has been applied widely for about 25 years. The approach is founded on the realisation that many infrastructure projects that are not financially viable could still be justified for their broader impact on employment, education, etc. There are many papers and books on the application and evaluation of socio-economic projects, even within the narrower scope of electrification. However, Munasinghe [1987] and Schramm [1991] among others have identified the *"frequently vague and ... unrealistic"* expectations for electrification programmes: as catalysts for agricultural, industrial and commercial development; to replace more costly energy sources; to improve the quality of life and standard of living of the rural poor; to reduce urban/rural bias and stem urban migration; to improve security; and to reduce deforestation. Many of the justifications

for the Electricity-for-All programme were socio-economic in nature, though mostly not quantified.

However, the basis of socio-economic analysis, the conversion of all costs and benefits into financial terms, has two major limitations:

- There are some costs and benefits for which it is very difficult to assign monetary value, because “.. *although non-monetary benefits cannot be quantified, it does not necessarily mean that they do not represent a value in social and political terms*” [Zomers, 2001].
- The whole process of applying discounting rates has the effect that long-term benefits have no significant value, so that “*If we increase the period before the benefit is felt to twenty or thirty years, you can’t basically justify any expenditure in the current year*” [Visser and Sunter, 2002].

Indeed it is difficult to measure, either at the prediction or evaluation stages, the monetary and non-monetary benefits because of the existence of other factors (for example local skills and resources, public services and political support) needed to gain the benefits ascribed to electrification. Instead of measurement, more general needs met by electrification are identified.

3.4.3 Social development

The ADB [1999], based on a study in Bangladesh, reports “*the results clearly demonstrate the poverty alleviation effects of the rural infrastructures, specially roads and electricity*”. However, it should be noted that the poverty alleviation referred to is the Bank’s objective of “poverty reduction” measured by the increase in household income.

Dutkiewicz [1998] identifies social and political factors, but links them with economic objectives:

“Two broad categories of motivations for rural electrification programmes can be identified, social benefits and economic growth. A few governments have based their programmes on explicit political objectives such as improved rural political stability, but it is more common for the fulfilling of a combination of social and economic objectives to be used as justification.”

These references indicate that social and political factors like stability, sustainability and reducing poverty need to be considered as part of development policy, although they are neither economic nor socio-economic development.

However, it must be borne in mind that *“Projects created only for the sake of politicians to score points or for donors to locate suitable funding opportunities, are not likely to be sustainable”* [Zomers, 2001].

In an often undefined way, electricity is expected to assist the development of poor communities through the provision of basic community or public services (education, health), or reducing the quality of life disparities between rich and poor sectors of the population by meeting predominantly consumptive needs, that is for lighting, cooking, space heating and media appliances, without significantly increasing the output of that household. Munasinghe [1987] cautions *“rural electrification is generally not a good method for achieving income redistributional or social equity oriented objectives. Furthermore, care must be exercised to ensure that perverse effects do not occur, such as when electricity revenues obtained from the urban poor are utilized to subsidize the rural rich.”*

Zomers [2001] adds that any population *“attaches great importance to the domestic uses of electricity. However without any additional productive use of power, there will be no increased income generation and thus a limit to the ability to pay for the electricity. This could hamper load growth, reduce the beneficial effects, and put sustainability of the electrification scheme at risk. For this reason, some funding organisations attach requirements to the expected ratio of productive and consumptive use of electrification projects.”*

This association of the beneficial effects of electrification with productivity is very interesting in the context of the South African electrification, in which the figures clearly indicate a strong consumptive element - and the significant social role of the electrification.

Diallo [1996] argues that the *“widespread deficit of energy services in most communities in Africa may not be simply the consequence of poverty as many analysts argue, but its primary cause”*. However, consideration of the conditions in Africa shows that poverty exists even where there are abundant energy supplies (see case study 3) and that development and poverty alleviation depend on the contribution of many factors, including education, health care, and effective markets for produce, goods and services. Certainly the condition of poverty without energy, especially where fuel supplies have been exhausted by overexploitation, appears to be worse than the condition when energy is available. However, Diallo's argument that the lack of energy causes poverty does not appear to be sustained by the evidence of poverty where energy is available. Therefore, the provision of electricity (just a form of energy) cannot be sufficient to prevent poverty, but could alleviate it.

The support for energy services for social purposes is possibly confused by an underlying assumption that there is a link with economic development. For example, the purposes of SIDA's support are *"satisfying basic needs to alleviate poverty and improve living standards through efficient utilisation of local energy sources. However, the implementation of these macropolicies will have to be closely connected to the relationship between energy and economics in a transition process ..."* [Diallo, 1996].

Case study 3: Electrification at Orange Farm

Orange Farm, an urban area approximately 50 km south of Johannesburg, started in 1990 as a site and service scheme. Minimal services were installed, including scraped roads, and a water point and toilet per site. Now Orange Farm comprises a mixture of informal, low cost formal and upmarket housing. The local authority had no resources to provide electricity so it was agreed with Eskom in 1991 to use the development as a pilot project with what were, for Eskom, innovative technologies, including prepayment meters, 11 kV covered conductors on concrete poles, and LV aerial bundle conductors.

Eskom teams carried out all construction until 1996, but later, conventional contractors constructed an increasing proportion of the work. A quarter of the labour effort was obtained locally, for manual labour and sales and service staff. Some women were employed, even for the manual labour. None of the local labour progressed to employment after construction.

About 35 schools, 50 businesses and 34'000 households have electricity supply. Unemployment is very high, with most of those with employment having to travel outside the community.

Reference for additional information: Qase et al, 2001a

Analysis: Many problems were experienced in this project. Most of the MV covered conductors have been re-insulated and new lines are built using bare conductors. The failure rate of the prepayment meters has been considerably higher than expected. Some technical failures occur, but many meters fail as a result of vandalism. The non-technical losses are about 52% of the input energy attributable to domestic customers. Average monthly energy consumed in 1998 was only 72 kWh/customer, and dropped to about 30 kWh/customer the following year as a result of intensive action to reduce non-technical losses. Eskom attributes the high losses to a culture of non-payment for services. As a result of theft of electricity from the supply cables for the area lighting, vandalism and theft of cable, the limited area lighting has had to be refurbished three times.

Financial analysis shows that the project was not viable in financial or economic terms. The electrification was motivated by factors beyond just financial viability. At the centre of the programme were the government's social equity goals. However, low consumption, theft of electricity and materials, and widespread unemployment indicate that the community is still very poor, despite the increased access to electricity.

The confusion of objectives is demonstrated by contradictions in a publication of the NER [2001b]. In the foreword by the Minister of Minerals and Energy:

"Electrification of poor communities is one of the engines of the socio-economic revival. This economic revival of poor rural communities is at the core of addressing problems of endemic poverty, the creation of jobs, eradication of crime, and the creation of functional communities."

But later in the same report it is stated that:

"... it becomes apparent that the electrification programme is uneconomical and unsustainable without cross-subsidisation from other electricity users. On the other hand, it was understood from the beginning that the primary motivation for the electrification of disadvantaged communities was not to achieve economic benefits but to create a better life for all."

It could be argued that if electricity has been made available, possibly as part of a social programme of poverty alleviation, the subsequent introduction of other services might be sufficient to initiate economic development. Therefore, even a social programme could have positive economic implications in the long term. Indeed the term considered for the development appears to be a key characteristic of social development. In the short term the effects may be poverty alleviation, but in the long term, longer than the 25 years usually considered in financial and economic analysis, social effects may become economically significant.

Understanding the role of electricity in reducing poverty, or the effects of poverty on people, requires a better understanding of poverty, which is addressed in section 3.8.

3.4.4 Practical development includes all categories

Many electrification projects provide for supplies to economic units such as local industries and businesses, as well as for social services such as schools, clinics and administrative offices. In fact, this was the approach followed in the early stages of the national electrification in South Africa (schools and clinics programmes of the Independent Development Trust and Eskom) and in other African countries [Mbewe, 1992]. In South Africa the greatest part (numerically) of the programme was thereafter directed to connecting households, with an emphasis on social development. In Namibia there has also been a strong focus on connecting households, whereas in Zimbabwe the focus is still on connecting businesses [ZESA, 2001].

3.4.5 Conclusion regarding the purpose of electrification

It appears from the above that economic and socio-economic developments are sensitive to the other factors of development being available. Several researchers

indicate the importance of access to micro-credit and financing schemes, to make services “affordable”, for example the World Bank [1996] proposals for “*innovative experiments in financing, leasing and delivering systems*” to ease or defer the first costs of energy access. These are relevant to socio-economic or economic development, but not social development. In fact, micro-financing for poverty alleviation is likely to lead to increased problems with loan-sharks, so there may be strong reasons to implement poverty alleviation in the form of non-cash services instead of monetary grants. This aspect alone should influence the decision-making in respect of electrification for social development, compared with economic or socio-economic development.

Clearly terms like ‘development’ and ‘sustainability’ are broad and used by various writers to mean different things. At the same time, the different objectives of development are usually not identified, either because they are not perceived as being different or because the difference is not perceived as significant. Munasinghe [1990a] provides the closest approach to the proposed classification:

“... most developing countries are pursuing rural electrification programs as a part of their economic development efforts.

“Three broad areas of concern that will influence and shape rural electrification policy may be identified. The first area is centred around the objective of economic efficiency ... places emphasis on the productive uses of electricity in rural activities.

“A second group of goals are focussed on the satisfaction of the basic needs of citizens, providing electricity services to the poor, and improving the distribution of income and welfare.” (Note the apparent contrast with the statement by the same author [1987] quoted above.)

“The third major determinant is based on the principle of cost minimisation - to reach as many rural customers as possible, in the shortest possible time, using limited resources.”

The hypothesis of this thesis is that understanding the differences between the objectives of electrification will contribute to better decision-making and resource allocation, but the results of such an understanding is not evident in the literature. At the same time, there are many indications in the literature that good decision-making and resource allocation is context specific and depends on the nature of the proposed electrification.

The proposal that electrification can be considered as contributing specifically to economic, socio-economic or social development, and thereby affects decision-making, therefore appears to be a novel concept warranting further investigation.

3.5 Technologies for electrification

Over a hundred years ago, in his Presidential Address to the Institution of Electrical Engineers, Graves [1888] claimed *"the problem of distribution is becoming understood"*. The volume of work published since then indicates he may have been overoptimistic. There is a huge collection of textbooks, journal and conference papers, and company brochures describing the technical details of all aspects of electricity generation, transmission, distribution and utilisation. However, there are relatively few specifically on technologies for electrification. Possibly this is related to the conditions that make generation different from distribution, particularly electrification:

"Distribution companies must concern themselves with demand growth, retail markets and the concerns of hundreds of thousands or millions of customers. Also, since they are regulated, and their performance is readily measurable and apparent to customers, distribution firms are generally more concerned about country politics, unions and work force concerns. Generation firms, by contrast, tend to be more focused on technical and performance issues, wholesale markets and contract compliance." [PWC, 2001]

Similarly, the academic interest in generation and transmission has been far greater than in distribution, partly because distribution problems contain many varied elements, problems are defined more in terms of financial performance than technical, and often are less suitable for academic problem solving.

Many international organisations have focused mostly on generation and transmission. Only relatively recently has Cigré, the International Council on Large Electric Systems, given greater attention to distribution¹³ and the special needs of developing countries, before now having believed that *"Systems in developing countries do not require specific technologies; however, application of techniques may be different on account of particular conditions in these countries (climate, consumption density, maintenance of the installations, financing of investments, etc.)"* [Leroy, 1986].

The International Conference for Electricity Distribution Systems (CIRED) has members from many countries, but not yet any from sub-Saharan Africa. The conferences address mostly technological subjects, including sessions on network components; power quality and electromagnetic compatibility; system operation, control and protection; system development; dispersed generation; and management

¹³ Cigré Study Committee C6 was established in 2002 for distribution systems and dispersed generation. A working group on electrification was formed in 2003.

and utilisation of electricity. Similarly, most regional conferences in developing countries include sessions on distribution technology.

Obviously, there is a very broad range of technological options from which to choose. However, the solution of the electrification problem depends not only on the technologies but also on the costs and processes that support them. This requires an understanding of the advantages and disadvantages of the technologies in context, and not just an awareness of the technologies themselves. ← LR

Referring to a 1999 study by Covarrubias, the World Bank [2000] identified one of the factors influencing project outcomes and programme performance as “*Low technical capacity, especially a limited human resource base*”. Without suitable people to plan, implement, operate and maintain the distribution systems, no technologies are likely to be better than any others. Therefore a significant part of the technological dimension of electrification is the capacity of the utilities’ personnel to learn about, adapt and apply the technologies that suit their needs; that is for technology transfer and adaptation, standardisation and research and development.

3.5.1 Technology transfer

“Throughout history, technology has been a powerful tool for human development and poverty reduction.” However, “The market is a powerful engine of technological progress - but it is not powerful enough to create and diffuse the technologies needed to eradicate poverty [UNDP, 2001]. Therefore, approaches are needed to diffuse the technologies beyond the level achieved by the markets.

The requirement for technology transfer is built into the specifications of many internationally supported studies and projects. Technology transfer is a process of ensuring that an institution procuring new equipment, software packages or any other high technology products acquires the knowledge needed to use them.

Referring to technology transfer in relation to equipment, but equally valid in respect of techniques, Vei and Haren [1986] identified the following aspects as important:

- recipients chosen for training should be from among those to be responsible for operation and maintenance after delivery
- integration into supplier’s project team
- supplier to make full use of the recipient personnel to ensure they acquire the expertise
- basic training received must be built upon and extended to a wider group.

However, others have criticised the assumptions that technology can be transferred so easily, proposing that the actual technology being acquired needs to be

considered more carefully. *"The ideas which led to the transfer of technology, even granted the benefit of the doubt as to their final purpose, and to the action of major international financial groups have proved to be wrong. The facts have shown that this transfer and action could not be a long-term solution to problems of development. ... To take one example, though quite typical: is it right to lend capital to poor countries and that the reimbursement conditions imposed be very similar to those which apply in the industrialised countries. This is nonsensical for if these countries were capable of such performance, they would not be developing countries."* And recipients of assistance in developing countries must *"... adjust to their own needs the techniques and methods made available to them by industrialised countries as those techniques and methods were not originally designed for this purpose"* [Paul-Apandina, 1985].

Following this argument, the basic unsuitability of a proposed technology becomes problematic. For example, Pandey [1997] described a micro-hydro project of capacity up to 100 kW as adequate for 1000 households, premised on *"obtaining a grid connection to sell excess energy"*. In reality, once the grid connection is provided, power delivery of 100 kW would generally be so inexpensive that the cost of a hydro station would be unviable unless energy availability is severely constrained and excess energy from the scheme has relatively high value. Such technological "solutions" applicable only in restricted circumstances hinder technology transfer.

The need to ensure that technologies are appropriate for the application is identified also by Ellegard and Nordstrom [2001] *"It (a question asked) should also teach us never to forget the social and cultural fabric in which these technologies are to be implemented."*

Strelneck and Linqiti [1995] identify an even broader range of contextual factors affecting technology transfer. They report that strategic planning theories and lessons from international development work *"demonstrate the need for critical thinking and a structured process to guide project development. This is especially the case with technology transfer efforts where success depends on the actions of multiple stakeholders with diverse technical, economic, administrative, political and cultural interests and needs."* And *"it is important to note that what works in one country may not work in another"*.

3.5.2 Standardisation

Inversin [2000] identifies that there are variety of options for reducing the costs of grid extension, including standardising materials and designs. However, cost is not always the most important factor; safety, reliability and flexibility must be considered.

Baker and Trémolet [2000] state that utility providers in developing countries tend to have high standards because *"investment designs are often based on developed countries' standards"* and *"the culture in such big organizations is often to derive 'professional pride' from top-quality uniform service, not from bold innovations in low cost alternatives"*. They also identify that the standardisation instruments depend on the frequency of changes to the standards and the number of participants needing to give their agreement.

3.5.3 Research and development

Munasinghe [1990b] discusses classifications of R&D proposed by other authors and the suitability of various types of research for developing countries. He concludes that developing countries should pursue R&D in areas where national needs may soon arise, where there is local comparative advantage such as in specific energy resources or skilled manpower, and where local contribution can be increased. At the same time, he acknowledges: *"most developing countries are chronically short of both local financial resources and foreign exchange"* and *"the lack of skilled manpower to undertake R&D work is another serious drawback in developing countries."* Therefore, he recommends protecting and using effectively the available staff, including those in universities and research institutions, building up new skills, effectively using foreign manpower resources, and improving the lack of understanding of critical issues within government and the general public.

3.6 Processes in electrification

Taking a systems approach to electrification, it is evident that the many elements and the interactions between them define a large number of processes that are all affected by the interactions or influences throughout the system. Despite this, most researchers consider only a sub-system in isolation from the overall complex system, either because of limited knowledge and interests, or because it simplifies the analysis.

Zomers [2001] states: *"No research is known of in which the effects of current developments and trends (in institutional and technical development) have been*

systematically and integratedly investigated." And, acknowledging that *"The reality of electricity supply to developing rural areas is very complicated and there are many relevant aspects"*, even he groups his conclusions into only three areas: the rural market, the available technology and institutional issues.

Generally, broad descriptions of electricity distribution technology in the context of financial, economic, social and environmental systems are mostly found in power system planning text books, like Berrie [1992], Lakervi and Holmes [1995], and Willis [1997]. Even these do not usually consider electrification as an overall process but as a collection of topics for analysis.

3.7 Assessing electrification

The logframe diagram (Figure 2-4) provides a useful framework for the assessment or evaluation of projects, including electrification. There is an obvious scope for differences according to the stage being evaluated. The output of an implementation project will be measured in terms of completion on time, within budget and according to specifications. However, these are insufficient to assess the outcomes of a project to supply electricity to a community. Instead, they should be assessed in terms of the financial viability of the utility, the usefulness of the electricity supply to the customers, and the quality of the technical operation and maintenance of the network. Assessing the overall impact would require assessment of the contribution to improving the quality of life or the macroeconomic environment. The World Bank identifies a similar hierarchy in their Comprehensive Development Framework: *"the CDF might allow participants to think more strategically about the sequencing of policies, programs, and projects"* [World Bank, 2000].

3.7.1 Assessing outputs (projects)

The outputs of projects relate to the completion on time, to specification and within budget. Most delays become insignificant and most deficiencies can be corrected a few years after project completion, but the cost of electrification is incorporated in tariffs and balance sheets for many years. Delays and technical deficiencies may be perceived as indicators of institutional or process problems, but outputs assessment usually gives costs the greatest significance.

Dingley [1988] reported that the costs of electricity connections varied substantially, from US\$340 per connection in Thailand to US\$3000 in the USA, but that some costs included associated transmission lines and the average demand was not the same in all countries. Data derived from his report is presented in Table 3.2.

Table 3.2: Connection costs reported by Dingley [1988]

Country	Utility	Design admd [kVA] for households	Cost/connection [US\$]
Thailand	PEA	0.55	340
Costa Rica	ICE	1	700 - 1300
Greece	PPC	about 1	1000
Brazil	CEMIG	about 1.5	1000
Brazil	COPEL	about 1	1700
USA	REA	about 3	3000

The cost breakdown between generation, transmission and distribution obviously varies for different countries and different regions in a country, but a World Bank report [1996] provided the data in Table 3.3.

Table 3.3: Effects of line length on cost of rural electrification

	Cost of energy [US cents/kWh, for 35 kWh/ household/ month]
Capital and fuel for generation	7
Transmission and sub-transmission	3
MV and LV distribution, 3 km spur line with 20 - 50 households	45 - 20
MV and LV distribution, 1 km spur line with 20 - 50 households	15 - 7

[World Bank, 1996]

Zomers [2001] gives the average cost of electrification as US\$1200 for the network and the total cost including generation capacity and service connections as about US\$1900. He also identifies the annual fixed costs for grid-based rural electrification slightly differently (see Table 3.4) and shows that, for a customer using 3000 kWh per year, the fixed cost is approximately half the total cost.

Table 3.4: Fixed costs for grid based rural electrification

Sector	Annual fixed cost/connection [US\$]
Generation	64.1
Transmission	14.4
Distribution	138.0
Service connection	9.5
Total	226.0

[Zomers, 2001]

According to this information, the cost of the rural electrification is dominated by the cost of the MV and LV distribution. It is not surprising then that: *"The high initial costs are a major barrier to service extension, but can be reduced appreciably by using design standards suitable for areas of lower demand (once demand rises standards can be increased). ... the costs of installation and wiring provided by the utility are high. Simplifying wiring codes and using load limiters (circuit breakers) for*

lower levels of consumption can reduce costs significantly." [World Bank, 1996]
However, no details are provided of how the technology can be adapted to substantially reduce the costs.

It should be of concern that a World Bank report [1975] had identified similar problems over twenty years earlier. According to this report, because the costs of subtransmission lines do not vary with demand over a wide range "*costs are very sensitive to the level and growth of demand ...*". The report also identified similar opportunities to reduce costs:

"Can the capacity of the networks and their equipment be matched more closely with the demand? Extending and reinforcing the networks, and changing the equipment as the demand develops, are obvious procedures. Though this is common practice, it is not uncommon to find considerable excess capacity in the networks, sometimes high enough to meet 20 years' growth in demand.

Can demand be met through one or two phases for a time, instead of three phases? This, too, cuts costs."

3.7.2 Assessing outcomes (programmes)

Electrification is usually assessed in financial and economic terms because the availability of finance for large investments is a significant constraint controlled by financial or social specialists. Therefore programme justification must be in terms familiar to financial controllers. Measures used include payback periods and net present value, but the most common techniques are the financial and economic internal rates of return.

Financial or internal rate of return (IRR) measures the effect of cash flows, for example, for the utility undertaking the programme, such as Eskom or a municipal electricity department. IRR is an indicator of the viability of a project within an organisation. However, the benefits of electrification also accrue to others, such as customers, businesses and health services. From the perspective of a policy maker, such as the Department of Energy or the National Treasury, the overall economic impact is important, and this is modelled by the economic rate of return (ERR). In an ERR the cash flow of the programme is modified by adjusting some financial values for market distortions, and ascribing "financial" value to non-financial benefits, particularly outside the organisation implementing electrification. In the evaluation of the National Electrification Programme described in Chapter 2, both the IRR and ERR of the various projects were assessed.

Schramm compared the projected values for ERR with the rates achieved in 11 electrification projects. Only one achieved the projected rate, and for some projects the ERR was negative. Also, the results were suspect because there were invalid assumptions, double counting of benefits, and confusion between financial and economic costs *"in the majority of cases"* [Schramm, 1991]. This is not surprising, since rate of return calculations are based on uncertainties and assumptions that are difficult to check before a project, so that *"the accuracy of the economic internal rate of return calculation for most projects is often highly questionable because of the difficulties in achieving reliable information"* [Zomers, 2001].

The rate of return is usually a hurdle to the release of project funds through a capital expenditure approval committee. There is little benefit (and only unnecessary risk) to the network planners in projecting significantly higher rates of return than needed to get approval of a project, so in some cases the load and electricity sales projections may be unduly conservative. Since the hurdle is known, projections of demand growth and losses, estimates of construction cost, and assumptions about operating and maintenance costs tend to be sufficiently optimistic to reach the hurdle value. A similar process to that seen in electricity network planning has been reported in relation to development projects in general: *"A recent review of the Bank's overall project portfolio (the Wapenhans-report) documented an increasing number of poorly performing infrastructure projects. One of the causes of this increase cited by the report was a tendency to concentrate in the appraisal process on loan approval, which can lead to an upward bias in estimating rates of return"* [World Bank 1994].

Other than the financial and economic outcomes of programmes, outcomes assessment could include the use of electricity by the customers, sustainability of the electrical system through operations and maintenance, sustainability of the utility and its institutional capacity, and so on. Usually, however, these are perceived only as contributory factors to the financial and economic viability of programmes.

3.7.3 Assessing impact (policies)

Assessing the impact of policies of implementing programmes and projects is complex because of all the contributory factors. Mostly, the effects of electrification programmes or electricity sector restructuring on a country's macroeconomics or the quality of life of the people cannot be determined in isolation from all other policies.

Assessment of policy is beyond the scope of this thesis, but the expectations are important because they guide society, politicians and financing authorities in distributing development funds and other resources.

3.7.4 Limitations of assessments

Research in China offers an interesting view of the effects of assessment on electrification decisions. Yang [2003] applied econometric models to the allocation of resources to electrification in various regions, according to the impact on rural economic development and poverty reduction. He found that where the objective is to facilitate economic development, *"the priority of capital investment should be given to highly economically developed provinces"*. However, *"if additional capital was injected, many poor people would jump above poverty lines"* in medium economically developed provinces where *"there were a large number of poor people just below the critical poverty line"*, so making the biggest impact on poverty there. In recognising the simultaneous contributions of rural electrification to economic and social development, it is clear that assessing their impact on poverty depends on a definition of poor as being below a poverty line.

The causes of failing to reach objectives are not easily identified in a complex electrification programme, so aspects that are already appropriate might be changed in the belief that conditions will improve.

Although not constrained to electrification, programme implementation in developing countries is often delayed by resource constraints or overestimates of capacity and characterised by cost over-runs. However, other problems in the power sector in sub-Saharan Africa include *"low operational efficiency and failure to recover costs"* [Picciotto, 1996]. Arising from an analysis of project performance in Africa *"in January 1993, the [World] Bank introduced a new policy that stressed the desirability of operating the sector on a commercial basis, the importance of energy conservation, and the requisites of environmental sustainability. This new policy, no longer emphasising access to basic electricity service by the poor, represented a notable shift."* [Covarrubias, 1996].

However, even the improvement of electricity utility management may be insufficient to address basic problems. A private sector management group appointed to attend to government interference and management inexperience in Burundi made some improvements: *"Another major accomplishment was the reduction of accounts receivable, excluding those from the public sector, ..."* [Covarrubias, 1996], but the non-payment for electricity by both public sector and domestic customers is a recurrent issue in Africa's electricity sector.

Subsidies are an institutionalised form of under-payment for electricity. They distort price signals from suppliers to customers about the costs of supplying electricity and may reduce the funds available for other public programmes. They include urban-

rural cross subsidies in uniform national tariffs despite differences in regional costs, and effective taxes on industry to support domestic customers. Subsidies exist in developing and developed countries. They also exist as simplifications in internal accounting systems.

Zomers [2001] writes: *"Given the high capital costs and operation and maintenance costs of grid-based rural supply systems and the present ability [inability] to pay by the majority of the rural dwellers in developing countries, it is unlikely that all costs can be covered in the near future"* and that some form of subsidy for rural electrification is needed. The relative inability of urban and rural customers to pay for electricity, and the relative capital, operating and maintenance costs of urban and grid or non-grid rural systems need to be assessed.

3.8 Poverty

The traditional definition of poverty as having low buying power (income and savings) has been extended to include low levels of health, skills or education [World Bank, 2001]. Many of the common factors present in countries where poverty persists appear to exhibit circular relationships giving rise to *"vicious circle"* theories *"of poverty and low wages leading to low investment, and low productivity of labour leading to poverty"* [Myint, 1973]. Even where there appear to be abundant natural resources, the poor seldom have access to them. As a result, a poverty sub-system can be conceived, illustrated in Figure 3-2 with the characteristics of poverty shown in shaded boxes. Clearly, the most abundant resource of the poor is labour, and other resources are in short supply.

The usefulness of this representation of poverty and the factors influencing it is that it illustrates the need for intervention in several areas to break the vicious circles. No single intervention, like electrification, will be effective in reducing poverty, even if it alleviates some of the conditions of poverty.

Measuring multi-dimensional poverty is difficult. Single measurements do not give the complete picture and composite measurements may obscure key aspects. However, it is useful to measure at least some dimensions of poverty if decisions have to be taken about the expected effectiveness of interventions or the allocation of resources.



The role of electricity supply in reducing and alleviating poverty (or the linkage between outcomes and impacts) is not clear, but the UN Commission on Sustainable Development identified access to and the use of energy as a key issue for both development and poverty alleviation, stating: *"Improving accessibility of energy implies finding ways and means by which energy services can be delivered reliably, affordably, and in an economically viable, socially acceptable and environmentally sound manner"* and recommending that governments *"support electricity services*

based on grid extension and/or decentralized energy technologies, particularly in isolated areas, as appropriate" and "establish financial arrangements to make rural energy services affordable to the poor" [UN, 2001].

Poor people, then, will be found in both urban and rural areas because *"Migration rates in excess of urban job opportunity growth rates are not only possible but rational and even likely in the face of wide urban-rural expected income differentials. High rates of urban unemployment are, therefore, inevitable outcomes of the serious imbalance in economic opportunities between the urban and rural areas of less developed countries."* [Todaro, 1977] Since 1977, broader exposure of "Western" culture has added impetus for migration: *"Telecommunications and information technology, and tourists from wealthier countries, enable the poor to observe the situation elsewhere, and the impulse to improve their own circumstances will become stronger."* [Zomers, 2001]

Therefore, meeting the energy needs of the poor through electrification has both economic and social dimensions.

3.9 Research questions answered

This chapter has provided three further answers to the original research questions.

How do social, institutional, political and ethical factors affect electrification? In particular, what are the effects on the structure, management and social culture of the electricity distribution industry (EDI)?

The systems approach, applied to electrification, illustrates a large and complex problem of dynamic interrelationships between many elements in the social, natural environment, infrastructure and utility sub-systems. The proposed system differs from those used by other researchers, identifying many more aspects needing to be considered. Most prior research still appears to have addressed only particular aspects of the overall electrification system, such as improved access to finance for the poor, or technologies for sustainable energy, often neglecting the other dimensions of the system. The assessment of electrification needs to be made from several perspectives simultaneously and at different levels of project, programme and policy. The effects on the culture, management and structure of the EDI will probably be different for every utility, because of the unique combination of the many elements having an influence. The effects on the industry in South Africa still need to be assessed by considering the particular circumstances.

What lessons can be drawn from electrification experience to apply to future electrification? Are they relevant in other countries and in what context could the lessons be applied?

The research literature shows divergence and confusion about the experience of implementing electrification for different objectives. The proposed classification of social, socio-economic and economic appears to be useful, but needs further investigation to assess its completeness and applicability.

How does information develop and the “transfer of technology” take place in respect of electrification?

Technology transfer generally depends on a range of factors including the suitability of the proposed technology to meet the needs in the intended application, as well as the diverse interests and needs of the various stakeholders in the transfer process.

One question does not appear to have been adequately answered by this review:

How are decisions taken, targets set and programmes planned and evaluated? How do decision-makers compare the benefits of electrification with the costs (in both short and long term)?

The models of financial and economic rates of return do not appear to provide useful answers for projects of social development. Very little information has been found of how decisions are taken where apparently non-viable projects are implemented.

3.10 Onword

At the end of Chapter 2, it appeared useful to review the literature on electrification and development to identify approaches to defining the objectives, processes, and assessment of the impact of electrification.

The review has provided preliminary answers to some of the research questions. Most of the literature appears to address the technological, financial, economic, social and institutional aspects of electrification separately, and Zomers came to a similar conclusion. However, there are clearly many differences between the theory formulation and the experience of electrification for development.

The main hypothesis is not contradicted by any of the literature. The viability of economically driven electrification is a simple business case. The analysis of electrification for socio-economic development is widely researched and reported. It is clear that the objectives of many electrification programmes since 1970 and the associated theory development and analysis of them has been socio-economic. Despite differences in some details, it appears generally assumed that electrification

benefits development by contributing to improved education and health and supplying the services that bring customers into the formal economy through improved production. Extensive literature shows that organisation structures, tariffs and technology have been developed on the basis that they should support the identified socio-economic objectives. However, the implementation of projects does not appear always to meet all the development objectives expected of electrification because, possibly, those various objectives are not differentiated.

There is little evidence of electrification undertaken for purely social reasons, that is, with the primary objective of poverty alleviation. The concept that social development or poverty alleviation can be a driver for electrification remains to be demonstrated by examining the electrification progress and decision-making in Southern Africa in greater detail. The practical examples will provide a basis for subsequent investigation of the theory underlying electrification programmes.

Finally, not all the interesting literature has been discussed here, as some findings are presented together with relevant analysis in later chapters.

Chapter 4

Appropriate Electrification Technologies

4.1 Introduction

Chapter 2 outlined the historical development of electrification from the start of electricity supply until the electrification programme of the 1990s. Chapter 3 reviewed the objectives of electrification and its role in development, as described by other authors, but little evidence of electrification for social development was found. This chapter examines the technology development associated with the electrification in Southern Africa. The starting point is taken as the technology of the early 1980s, from which the electrification programmes were launched, and which is still used in most countries in the region.

It is evident from Table 2.6 that significant changes occurred during the 1990s to electrification in South Africa, especially a reduction in the cost of rural electrification. However, the changes were not evident to all; even the National Electricity Regulator reported in 2000 *"rural areas are considerably more expensive to electrify with grid electricity"* [NER, 2000].

The analysis seeks to identify the technological changes and implementation procedures that, to a large extent, made electrification feasible, created opportunities and challenged the conventional wisdom on costs. The changes considered include metering, customer load modelling, some specific technologies adopted by the utilities to reduce costs, the approach to electrification coverage, loss control, and research, technology transfer and standardisation.

The description of the electrification technology and procedures indicates a close link to predominantly financial and political factors that contributed to or encouraged the changes. According to the overall hypothesis, different electrification technologies might correspond to different objectives - economic, socio-economic or social - of the electrification programmes. Therefore, the technological changes will be interpreted in the context of the development theory. The analysis also examines the preliminary findings regarding urban and rural electrification.

4.2 Technology in the early 1980s

Until the change in government in 1994 the municipal electricity utilities, as departments of town and city councils, were constrained by government regulations to supplying people in the municipal areas that, again by government regulations, were mostly closed to non-white¹⁴ residents. There were some areas where non-whites were supplied with electricity, such as Mitchells Plain in Cape Town, which was fully electrified when it was constructed, and Soweto, which was electrified in a large project in 1979-1981. Most urban black people lived in areas administered by Black Local Authorities (BLAs) under the Administration Boards (later called Development Boards) of the four provincial administrations. In most of these areas the general policy was to supply electricity to institutions, but not households, although some older towns were fully electrified as mentioned in section 2.3.

Most local authorities supplied electricity to households only when the developers paid the full costs of the installation in advance. All the municipal utilities and provincial administrations adopted conservative technical specifications for installations, so that they would be unlikely to incur subsequent capital expenditure on network reinforcement [Gaunt, 1988].

Escom supplied most customers in rural areas, but a few municipalities had, and still have, extensive rural distribution networks. Escom only supplied electricity to customers that could afford a connection, but there were various ways in which the connection charges were calculated, allowing for up to 2 km/customer of line extension at no cost. This approach favoured farm supplies. In the late 1970s and early 1980s, rising fuel prices made local generation very expensive in small towns like Calvinia, Agulhas and Struisbaai in the Cape. Escom extended the network to reach such towns, many of which had no or very small electricity utilities, when the regional councils gave guarantees for consumption revenue. Where larger urban development had occurred in Escom's licenced areas, like Midrand and Sandton near Johannesburg and Goodwood, Parow and Bellville near Cape Town, Escom was withdrawing by selling the networks to the local councils. Where possible, Escom positioned itself as a bulk supplier to large customers and local authorities, only taking responsibility for small-scale retail supplies in rural areas.

As a result of this institutional structure in the late 1980s, the municipalities and the consulting engineers serving local authorities had most of the urban distribution expertise, while Eskom had experience of rural MV distribution. Most MV distribution

¹⁴ The original terms used to denote the classifications based on race were white and non-white. The nomenclature used by the present government is white and black (including African, coloured and Indian).

systems (urban and rural) operated at 11 kV and provided three-phase supplies. Most LV systems provided three-phase supplies to larger customers and single-phase supplies from the three-phase distribution to smaller customers such as households. This technology followed UK practice, and local adaptations of the UK design guidelines were used [Gaunt, 1988]. Generally, the emphasis was on providing high quality supplies, with cost constraints applying only in a few situations.

4.3 New Technologies

The local experience demonstrates that significant cost reduction is possible, in particular through changing technology standards, design parameters, and project implementation. Technological development is relatively easy for engineers because it is within their training. Many of the 'solutions' implemented in the South African electrification programme arise from the adaptation of technologies, products or approaches used in other countries. Innovative design is a subtle combination of the conventional and the novel [Schwartz, 1987]. Even developing new ideas into complete systems, taking account of the effects of changes on the existing infrastructure, mostly remains within a familiar discipline. The constraints on innovation are standardisation, risk aversion and rigid business costing systems.

Frequently an idea or product was introduced by one utility and adopted by others after its usefulness was demonstrated, often with a consequent reduction in price as the local market for the item grew. The adoption of new technologies is examined in this section, and procedures in the following section.

Not every technological change can be described, and only significant ones have been chosen to illustrate the causes, processes and effects of changing technology. These include prepayment metering, load modelling, the reduction of conductor costs, and quality of supply.

4.3.1 Metering.

The first locally developed prepayment meters were introduced during the late 1980s. The objectives were to reduce non-payment, which was already a problem in many township areas, and reduce the costs of reading meters. Prepayment helped customers not to incur unaffordable consumption costs, reducing the non-payment probability, and was perceived as a benefit by many customers. Eskom and most municipalities only adopted prepayment metering on a large scale for the Electricity-for-All programme after 1990. The prepayment meters had the significant advantage that customers did not need postal delivery addresses for billing.

As expected for a new technology, prepayment metering suffered development problems, including high energy consumption by the meters, failures caused by insect excrement on the internal components, insulation breakdown from voltage surges caused by lightning, resetting of registers by interruptions, and so on. During the evaluation of the National Electrification Programme in 2000, utilities were still replacing large quantities of prematurely failed prepayment meters, illustrated in Figure 4-1.



Figure 4-1: Prepayment meters that failed within ten years of installation

Another problem with the early meters was the incompatibility of the proprietary systems with each other. This became a particular problem when early manufacturing companies went out of business or were taken over, or utilities wanted to change suppliers. In 1990, Eskom, the major municipalities and the meter manufacturers developed the first industry standard for prepayment meters, NRS 009: Electricity sales systems. It defined the elements of the prepayment system: customer meters, vending machines and master stations. The meters were only able to recognise tokens issued by vending machines from the same manufacturer. Later a common vending system with a standard transfer specification (STS) was developed and adopted under NRS 009 in 1995. The key development was standardisation of the information and its encryption so that all

meters could accept tokens from any vending station. The coding and decoding of the information is based on the serial number of each meter. The standard allows for data entry by a keypad or magnetic swipe card, but most manufacturers prefer the keypad. Most vending stations are stand-alone units, but some systems in urban areas operate on data networks. All vending of the meter tokens is computerised. There is about one vendor for several thousand customers in urban areas, and several hundred customers in less densely populated areas [UCT, 2002].

Prepayment metering is part of a system that includes vendors, meter inspectors, loss control managers and auditors. The circuit breaker rating of the meter is software configured, in the same way that credit is loaded but using different codes. This allows capacity-related tariffs, for example Eskom's tariff for a 60 A meter is higher than for a 20 A meter. Such systems depend on the integrity and management of the meter inspectors. Recent audits of customer installations have found many installations where the meter rating is not in accordance with the records. The problems are increased by the replacement of failed meters, requiring the customer records to be amended. In addition, the collection of data from the vendors into the central data system requires careful management to identify and correct errors, if loss management is to be effective.

The prepayment meters did not overcome problems of meter tampering and electricity theft:

One of the major threats to the Electrification programme is that of electricity theft. The theft of electricity costs Durban Electricity approximately R30 million per year. Due to the location of the meter inside the customers home it is readily available for tampering or by-passing by the customer. When a meter is found to be tampered with or by-passed, the fuse in the conductor feeding the home is removed. The customer is then obliged to pay a reconnection fee of R420 (including VAT). If the customer by-passes or tampers with the meter again, the meter and conductor is totally removed from the home.

From a recent inspection project undertaken in the Northern region it is estimated that approximately 15% of all pre-payment meters installed have been tampered with.

A pilot method now being tested in the Southern region to counteract the theft of electricity is the introduction of the split pre-payment meter. Here the measuring and isolation portion of the meter is placed on the pole outside the customer's house and only the customer interface portion is placed in the home." [Martens and Williamson, 1996]

Despite the problems with prepayment meters and the fact that they cannot prevent electricity theft, they are considered by most utilities to be a successful technology, and over three million meters have been installed. Of these about two million are STS meters. South African prepayment meters have been introduced to other countries, including Argentina, Ghana and several countries in Southern Africa.

4.3.2 Load Models

Significant changes have been made during the electrification programme in the modelling of household electrical loads.

The size of the system needed to supply electricity to a customer or group of customers is determined by the maximum rate at which they use the energy, which is the power. In general, as a system's capacity to supply power increases, the physical sizes of conductors, transformers, insulators and other equipment increase, all increasing the cost. This effect extends as far as the power stations, where the maximum simultaneously occurring demands of all customers determine the number and size needed. The technological objective of the electricity utilities is to reduce the costs of delivering the energy to customers, by developing appropriate (or low cost and adequate) systems that meet the constraints of quality and security of supply needed for the customers' equipment and processes.

A power system consists of sources (generators in power stations), links (networks) and loads (customers). Given that the sources and links are usually defined in detail, the greatest uncertainty in distribution system design is in the assumptions about the loads. The models of domestic loads used by most utilities in Southern Africa were based on the work of American and European researchers in the 1940s and 1950s and guidelines developed in the UK, despite obvious differences between customers there and in South Africa. Feeders were designed to supply loads assumed to be the average value, modified by a diversity factor and making allowance for unbalance between the phases. Some municipalities were specifying design loads of 7 kVA/household, referred to as the after diversity maximum demand (admd). The diversity and unbalance factors were empirical parameters, based on models of the loads as being normally distributed. A comparison of various aspects of the load models identified the sensitivity of the feeder calculations to various parameters, and concluded: *"The adoption of standards which are different from the present practice in some South African supply authorities is recommended; in particular for the design demand, loss of diversity, unbalance and permitted voltage regulation"* [Gaunt, 1988].

Some research into urban domestic load behaviour in South Africa had started in the early 1980s, but Herman made a significant advance by developing data loggers that

could continuously make time-synchronised measurements of individual customer loads averaged over short periods of typically 5 minutes, and from which the data could be downloaded every several weeks. This novel measurement technique provided strong evidence to review the long-held assumption that the loads were normally distributed [Herman and Gaunt, 1991]. Herman's work led to the development of a Beta distribution load model, instead of a normal distribution, and an algorithm to calculate the voltage drop in LV feeders [Herman, 1993].

Several municipalities collaborated with the academic researchers in a Load Research Project from 1993 and Eskom joined in 1997. The project co-ordinates load data collection from several communities, including urban high- and low-income and rural customers [Dekenah et al, 1998]. The recorded data has been used to identify parameters for the design of low voltage feeders [Dekenah and Gaunt, 1998] and to study network performance [Dekenah and Heunis, 1999]. Using cluster analysis, a strong correlation between time electrified, household income and customer demands and energy consumption has been identified for use in planning [Heunis et al, 2000]. The load data collection is managed in order to obtain the best possible representation of customers in the whole range of income and time electrified, as illustrated in Figure 4-2. The collection of data from low income, low consumption customers with long access to electricity is limited by the history of electrification.

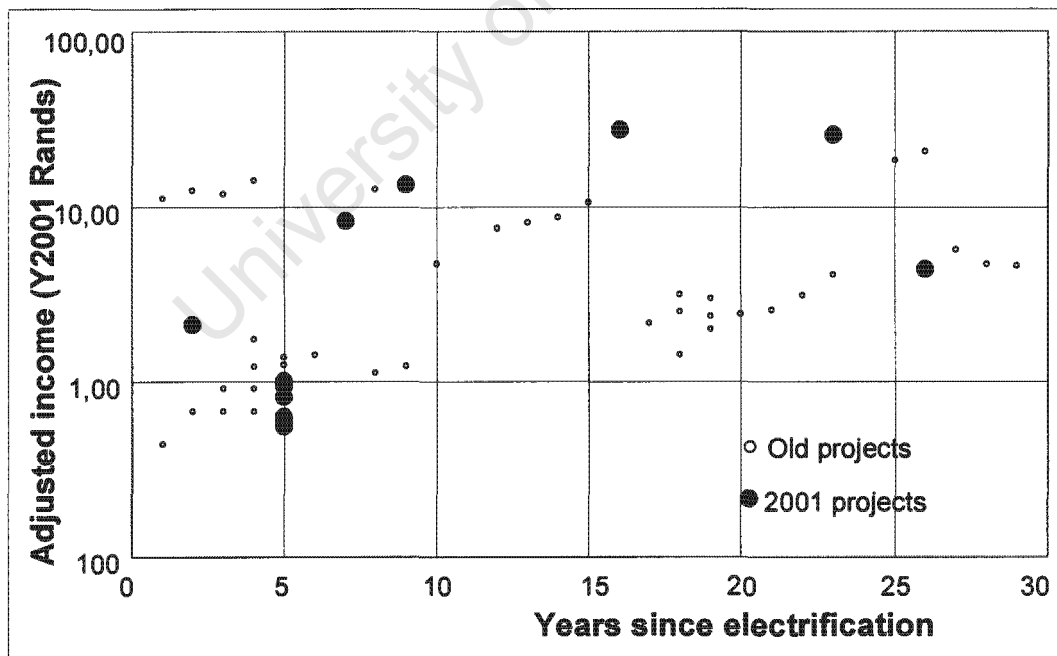


Figure 4-2: Load research sites by time electrified and income.
[Source: Dekenah, personal communication]

The research into loads and feeder design and the results derived from it have been reported widely [Sellick and Gaunt, 1995, Herman and Gaunt 1997; Herman et al, 1998 and 1999; Gaunt, 1999a; Gaunt et al, 1999]. The probabilistic technique, developed in the academic environment, was brought into use for the utilities within five years of development and the Herman Beta algorithm became the basis of the national design guideline for the design of residential distribution systems [NRS 034-1, 1997]. The method has been extended to include three-phase and bi-phase LV feeders supplying mixed single- and multi-phase loads. The very substantial database of measurements, household surveys and customer sales data now allows detailed modelling of customer behaviour and load forecasting. Further work on relating the design procedure more closely to the quality of supply standards continues [Heunis and Herman, 2000].

The load research project has effectively removed the uncertainty that prevails in many countries regarding the loads on electrification projects. There is sufficient data to relate electricity consumption and demand to household income and size, and now to measure some price elasticity effects. The data and methods of analysis have allowed the sizes of feeders to be calculated more consistently, and the performance of the systems after implementation to be analysed for capacity to add loads without feeder reinforcement. Eskom has reported *"Research into more appropriate design parameters, and calculations amounted to around R3m per annum for the five years."* [Stephen and Sokopo, 2001] and the total cost of all data collection, collation and analysis has been approximately R10million over the past ten years. This represents less than 0.1% of the investment in the National Electrification Programme. The benefits of consistent and representative design parameters, the avoided over-investment in robust systems, and reduced costs of remedial action to improve unexpected low voltage problems on under-designed feeders are significantly greater than the costs of the research.

The Load Studies Group, the loose association of all the participants in the research, adopted the policy that all data is freely available to anyone participating in domestic load research. However, later requests for assistance on further load studies have included confidentiality clauses, as the information represents potential commercial advantage in a competitive electricity distribution industry.

This research has gone much further towards understanding the character of electricity customers than Munasinghe [1990a] possibly had in mind when he identified the importance of field surveys as a tool for load forecasting.

4.3.3 Distribution lines cost reduction

Sometimes utilities adopt slightly different standards, such as for LV aerial bundled conductor (abc) cables, which were first used in South Africa in the early 1980s. Durban Electricity adopted the German standard of equal area phase and neutral conductors supported together, the other municipalities adopted the French standard with an insulated neutral supporting conductor, and in about 1994 Eskom adopted a bare neutral supporting conductor. Each alternative has different supporting clamps and connectors, and its advantages and disadvantages. Eskom adopted the bare neutral variant after some incidents of incorrect installation in which a phase conductor was mistaken for the neutral conductor, and to reduce costs, but is now investigating the suitability of the bare neutral in coastal areas after several corrosion failures. Although abc cables are now widely applied, some designers consider bare wire lines to be more cost-effective.

MV line designs have been improved incrementally, reducing the cost and improving the performance. Gaunt [1982] demonstrated that significant savings of about 30% could be achieved by omitting the earth wire (shield wire) from MV distribution lines. Macey and Dickson [1987] showed that omitting the crossarms on MV structures and using vertical or staggered vertical arrangements of the conductors could reduce costs further.

Activities were not only directed to reducing costs. A four year research project into the time, duration, causes and effects of outages on MV lines was undertaken in association with 91 distribution utilities with the objective of improving the quality of supply [Gaunt, 1994]. Among other findings, the research concluded that storm related incidents cause over 40% of outages, with approximately one third of all outages being caused by lightning, and that distribution system performance could be improved by attention to transformers, surge arresters, conductor joints and jumpers. There was no clear relationship between lines with shieldwires and improved performance in terms of the frequency and duration of outages, which was a useful finding in the context of the high cost of building shielded lines. The significant effect of lightning on overhead lines requires designers to give greater attention to the response of lines and systems to lightning. (See case study 4)

Based on substantial research into lightning by Eskom and the Council for Scientific and Industrial Research (CSIR) [Eriksson and Meal, 1982; Stringfellow and Meal, 1984], a guideline for the insulation coordination of MV lines [Gaunt et al, 1989] contributed to improvements in the lightning performance of distribution lines and the technology was disseminated internationally [Geldenhuys and Gaunt, 1990; Gaunt, 1991a; Kawamura et al, 1999]. The approach recognises the difficulty of achieving a

sufficiently low footing resistance for shielded MV distribution lines to protect them from back-flashovers initiated by direct lightning strikes. A dry insulation level of about 300 kV on the unshielded distribution lines ensures that induced surges from nearby lightning strikes do not initiate flashover along the line, and is low enough to flash over when a line is struck directly, protecting the associated transformers and surge arresters from the very high energy levels associated with direct strikes.

Case study 4: 66 kV rural feeder

Consultants identified the possibility of reducing the costs of electricity in several small towns in Transkei by building a rural network at 66 kV supplying 2.5 MVA transformers. The region had low to moderate lightning intensity ($N_g=4$) and it was proposed that an unshielded wood pole line be built to reduce costs. After the design review, the client was told that unshielded lines and such small transformers did not comply with Eskom standards and would not give acceptable performance. The first consultant's appointment was terminated and the system was re-designed with a line with two shield wires. The tenders received were double the cost estimates, so a further project review decided to revert to the original concept and the project was completed within budget using in-house resources. The line is still in use, 20 years later, with occasional incidents of damage by lightning because of inadequate insulation co-ordination on some structures.

Source: Own experience

Analysis

- (1) It was possible to provide an economical supply by taking an innovative approach to the system planning. The high costs of standard designs made a conventional network too expensive. The advantage of slightly fewer lightning-initiated interruptions was not enough to justify significantly higher expenditure.
- (2) The resistance to changing or not complying with standards can be powerful.

Therefore, much progress had already been made in reducing line costs and improving performance by the time the Electricity-for-All programme was initiated in 1990, but there was still a need to further reduce costs. Optimisation of line design (see box 2) could not offer significantly more savings than had been already achieved, and more radical changes were needed. Basically, it was necessary to dramatically reduce the costs of the structures or the conductors.

Box 2: Optimum line design

Line design requires optimisation of:

- pole material, length, thickness and planting depth
- alternative pole top configurations
- material and labour costs
- span length, taking into account line route, topography and customer density
- tension and Aeolian (wind) vibration of conductors
- voltage stresses and insulation strength

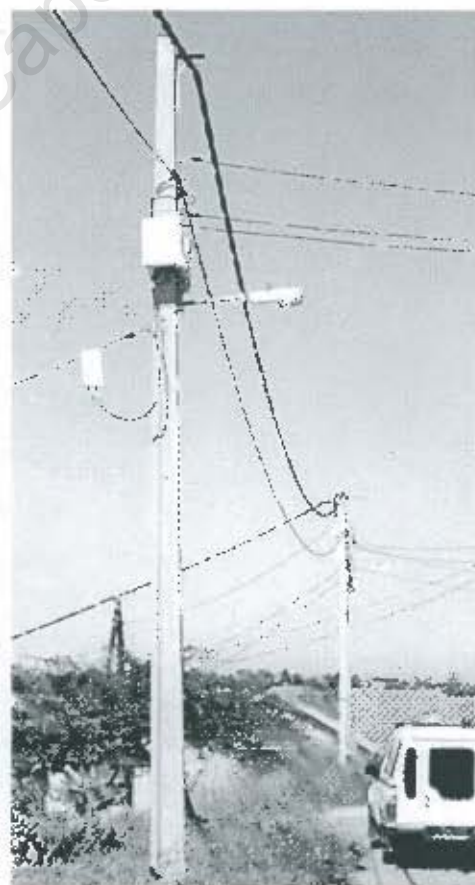
to obtain the lowest cost within physical and electrical performance constraints.

Reducing the costs of structures

Pilot projects were built using concrete poles, as used in many developed countries and in Brazil by some utilities. Part of the justification for the higher initial cost of concrete poles was that they are more durable and cheaper fittings could be used because of the smaller range of dimensional tolerances. Also, there was concern that supplies of wood poles would be inadequate during an accelerated electrification programme. Later, it was found that the reliable supply of wood poles was maintained, they were lighter to transport and easier to handle, and the initial cost was significantly lower. However, wood poles potentially suffer from fungal rot and termite attack, so need to be adequately treated. Creosote impregnation appears to be the most effective, but research is proceeding to determine the best initial treatment, find methods to detect pole rot at an early stage, and remedially treat damaged poles. Durban Electricity continues to use concrete poles in its predominantly urban supply area, but Eskom has reverted to using wood poles for its predominantly rural networks, illustrating the importance of the context for the selection of the appropriate technology.



Bare MV conductors, LV abc on wood poles



MV and LV abc on concrete poles

Figure 4-3: Examples of alternative overhead distribution systems in urban areas

Another way of reducing the cost of structures, especially in supplying communities along the route of major transmission lines, is to operate the shield wires of the transmission line as insulated MV phase conductors. The technique, described by Iliceto et al [1999], has been applied in Ghana and Brazil, reducing the line costs for supplies to communities near the main line to about 10% of conventional costs. The constraints on the implementation of this technology in South Africa were the opposition from the Transmission Group, concerned that it would reduce the reliability of the transmission line, and the relatively small portion of any country that can benefit from the approach because of the limited coverage of transmission lines. However, this technology has potential in appropriate circumstances.

Reducing the cost of conductors

The costs of conductors can be reduced in many ways: different material for the conductor; designing for lower currents (higher voltages or less over-design); and using fewer conductors.

Adoption of higher voltages reduces the current and voltage drop in feeders for the same conductor, or allows use of smaller conductors. The saving in conductor, and therefore also of poles because of the lower weight and wind loading, more than offsets the small increase in the cost of line insulators and equipment insulation. Eskom increased the standard voltage on its rural distribution network from 11 kV to 22 kV in 1982, allowing more power to be distributed with very little increase in the costs of insulators and transformers. An interesting aspect of this change is that Eskom already used some 33 kV lines. The adoption of 33 kV as the new standard could have further reduced distribution costs; instead of the conservative increase to 22 kV as chosen. The decision was apparently based on Eskom's expectations of supplying mostly large customers with indoor switchgear, for which the higher voltage would have cost significantly more. 33 kV would probably have been adopted if the need for dispersed rural distribution had been better understood.

Several alternatives to the 6/1 ACSR conductors¹⁵ used for most MV distribution lines have been investigated. Some AAAC¹⁶ lines have been built in areas exposed to corrosion, and some high strength 3/4 ACSR conductors have been used for longer spans. In most cases the standard conductors are the most efficient and only small savings are achieved by using other conductors. Reducing the number of conductors on a line offers much greater savings.

¹⁵ Aluminium conductor, steel reinforced, with six strands of aluminium and one of steel.

¹⁶ All aluminium alloy conductor

The British or European 3-wire, three-phase system is used in most of Southern Africa. Until 1990, nearly all spur lines were three-phase lines, because they allowed subsequent extension of the spur to other loads. North American MV systems use 4-wire backbone feeders (3 phases and a neutral conductor) with 2-wire single-phase (phase and neutral) spurs to small loads. Conversion to the North American system was considered briefly because savings could be made on the spur lines, but similar savings are achieved using two phase conductors for a single-phase spur from a conventional three-phase line, with the additional advantage that neutral currents flowing in the ground are avoided. Therefore omitting the third phase for supplies to small loads made a substantial saving in conductor costs, and also in the costs of structures. From there, the next step was to omit another phase conductor, adopting single wire, earth return (SWER) technology with only one phase conductor. However, it took many years from the initial proposals [Dingley, 1988; Gaunt, 1990 and 1991b] and the construction of a few pilot projects by Eskom in 1992 for the benefits and practicality of the SWER technology to be accepted and adopted for standard use [Irving and Gaunt, 1997; Gibb Africa 1997; Irving et al, 1998; Geldenhuys et al, 1998].

There were two main obstacles to overcome in adopting single-phase supplies: perceptions that single-phase supplies are inadequate for motor loads; and perceptions held by utility staff that the systems represented a decrease in standards because single-phase lines are inefficient or less reliable.

Single-phase systems meet the needs of most customers. In a few cases three-phase supplies are needed, such as for large motor loads, but a 20 kW single-phase motor was developed by Witwatersrand University and a local manufacturer, and locally made power electronic single-to-three-phase converters are also available. A 25 kVA converter was delivered to a Botswana Power Corporation SWER project because the government department responsible for school buildings required a three-phase supply for the laboratory in a secondary school, to comply with their standard specification. The cost of the converter was insignificant compared with the savings made on the distribution scheme as a whole, and the converter will probably never be used.

Classical theory indicates that a three-phase feeder constrained by voltage drop uses conductor material more efficiently than two-phase or phase and neutral feeders, as illustrated in Table 4.1. According to this comparison, SWER feeders use conductors only slightly less efficiently than three-phase feeders, and more efficiently than two-phase feeders.

Table 4.1: Relative feeder efficiency, based on conductor volume, for 10% volt drop

Line type	3-ph +N	3-ph	2-ph	Ph+N	SWER	Bi-ph
No of conductors	4	3	2	2	1	3
No of phases	3	3	2	1	1	2
Relative power	1.00	1.00	0.58	0.17	0.30*	0.67
Relative kW/cond	0.75	1.00	0.87	0.25	0.91	0.67

*Terminal earthing assumed to be 10% of line impedance.

However, this approach considers only the power transfer capability and the cost of the conductors, represented by the conductor area. In practice, conductors need to be insulated and, for overhead lines, supported above the ground with adequate clearance and sufficient strength to resist the force of the wind on the conductors. The spacing of the poles supporting a line depends on many factors including pole length, planting depth, pole strength, the size of the conductors and the line route, but typically three-phase MV wood-pole lines are built with spans of about 100 m. Typical parameters and the impact of changes are illustrated in Table 4.2, based on the cost structure indicated in Table 4.3.

Table 4.2: Relative feeder efficiency, based on estimated costs, for 10%volt drop

Line type	3-ph +N	3-ph	2-ph	Ph+N	SWER	Bi-ph
No of conductors	4	3	2	2	1	3
No of phases	3	3	2	1	1	2
Span length [m]	80	100	140	140	210	100
Conductor/km [m]	4000	3000	2000	2000	1000	3000
Poles/km	12.5	10.0	7.1	7.1	4.8	10.0
Insulators/km	37.5	30.0	14.3	7.1	4.8	20.0
Total cost/km	12125	9500	6286	5929	3619	9000
Relative cost/km	1.28	1.00	0.66	0.62	0.38	0.95
Relative power	1.00	1.00	0.58	0.17	0.30	0.67
Relative MW.km/cost	0.78	1.00	0.87	0.27	0.80	0.70

Table 4.3: Assumed relative cost/unit installed

Component	Units	Cost /unit
Conductor	m	1
Poles	no.	500
Insulators	no.	50

Notes: (1) According to Macey and Dickson [1987] the staggered vertical construction on a pole without crossarms is an efficient design for three-phase lines, so this simple comparison is representative of practical designs. (2) Costs include all materials and labour.

The analysis indicates that the North American systems are less efficient than three-phase and two-phase lines, though there will be small changes in the details of the comparisons when transformer costs are included. Such analysis confirms the decision not to adopt the North American feeder technology in Southern Africa.

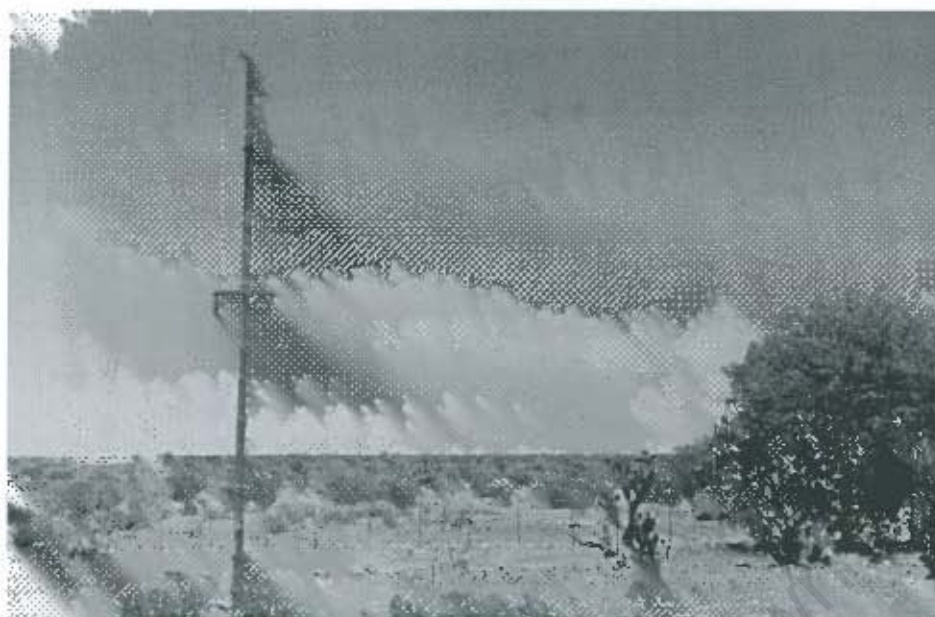


Figure 4-4: Sectionalising link on SWER line with long spans in Namibia

The relative efficiency of the SWER feeder decreases slightly when practical constraints are included, such as span lengths limited by ground clearance, as illustrated in Figure 4-4. A more significant constraint is the current allowed to flow in SWER feeders, sometimes limited by induction into nearby telephone circuits. Comparing with lines operated at 22 kV and imposing a nominal limit of 25 A for SWER feeders, their relative power transfer cost efficiency is reduced substantially, as illustrated in Table 4.4, but the associated voltage drop also reduces. The operating voltage of the SWER line can be increased by 50%, equivalent to a 33 kV system, for a small extra cost of insulators, with a consequential increase in the power transfer capacity and relative efficiency.

Table 4.4: Relative feeder efficiency, with limits on SWER feeder current

Line type	3-ph 22kV	2-ph 22kV	SWER 12.7kV	SWER 19.1kV
No of conductors	3	2	1	1
Total cost/km	9500	6286	3619	3643
Relative cost/km	1.00	0.66	0.38	0.38
Relative power	1.00	0.58	0.13	0.20
Relative MW.km/cost	1.00	0.87	0.34	0.51
Volt drop % of nominal	10.00	10.00	4.33	2.89

The two-phase lines are cheaper per unit length than three-phase lines, and SWER feeders are considerably cheaper, but the power transfer capacities are different. The most suitable line technology depends on the extent to which the power transfer capacity of the feeder is utilised. In rural areas with small dispersed loads, the power transfer needed for many feeders is within the capacity of two-phase or SWER lines,

so they are effective systems, while the extra capacity and efficiency of a three-phase line cannot be used except for the feeder backbone. In Figure 4-5, illustrating the power transfer capacity of three lines limited by conductor current and voltage drop, the distance between the SWER line and either of the lines above it represents unused capacity if the SWER line is adequate to supply the load. Any extra investment in the costlier, higher capacity lines will be unproductive. Similarly, the unused capacity of a three-phase line where a two-phase line would be adequate is also over-design.

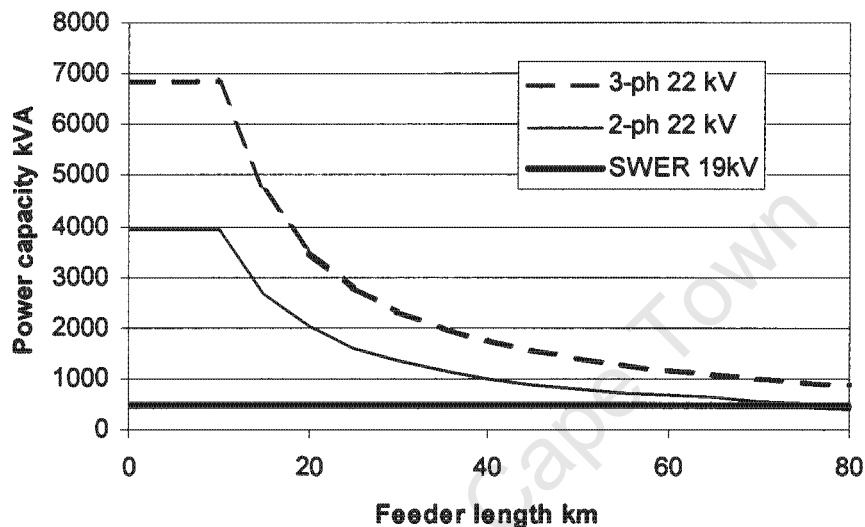


Figure 4-5: Power transfer capacity of typical MV feeders

The adoption of single-phase technology (two-phase and SWER) contributed significantly to reducing the cost/connection during the Eskom electrification programme. The magnitude of the savings is clear from Table 4.4. For the cost of a three-phase line, almost three SWER lines can be built, reaching more small customers in low-density rural areas. The adoption of the single-phase technologies was enabled by parallel development in design parameters. Without it, the system planners would have been specifying feeder capacities that forced the choice of more expensive lines even though higher power delivery capacity was not required.

In discussion of optimal reliability and traditional least cost planning, Munasinghe [1990b] implies that cost is proportional to reliability: *“determining the optimal capacity level is equivalent to establishing the optimal level of reliability, since capacity additions do improve the reliability level.”* Planning and operational staff widely hold such beliefs, but they are not always valid. In particular, the reliability of SWER feeders is much higher than the reliability of conventional three-phase lines, which have higher supply capacity. The reliability of SWER lines arises from the much lower exposure of components to environmental stress, simply because there

are fewer conductors, insulators, poles, surge arresters and transformer bushings for the same length of feeder.

The acceptance of single-phase supplies and lower design parameters were important changes, because the customers most easily supplied had been connected using conventional three-phase feeders during the early years of the programme. The costs of retaining the technology during the later years would have exceeded the available funds and derailed the programme.

This analysis has considered only initial line costs, but the relationships do not change much when lifetime costs are calculated for the complete systems. SWER systems have higher earthing costs, but lower circuit resistance and losses for the same conductor, because of the low resistance return path. They also have lower maintenance costs and fewer outages because of the exposure of fewer line components to damage.

The most suitable SWER transformer sizes need to be selected according to the customer characteristics. Eskom adopted 16 and 32 kVA transformers, while the Botswana Power Corporation adopted 10 and 25 kVA units. All of these ratings are significantly smaller than the three-phase 50 kVA transformer used as the smallest standard supply until the early 1990s, illustrated in Figure 4-6.



Figure 4-6: Typical three-phase small transformer installation with excess capacity

There are some operating constraints associated with single-phase feeders. Where backbone feeders supply customers with three-phase motors utility staff must

balance the single-phase supplies to avoid the de-rating effects of unbalanced voltages on the motors.

Other technologies to reduce line costs

The path to reducing costs was not as simple as may appear from the above description. Several other technologies have been considered and projects built. Many combinations of transformer and conductor sizes have been investigated for suitability according to different customer densities. Intermediate voltages (1 to 2 kV) have been used to avoid the high costs of MV insulation and reduce the conductor costs of LV feeders, but the technology appears to be more suitable for cable systems than overhead distribution.

Distribution with electronic voltage regulators at the customers' meters has been proposed to overcome poor voltage regulation [Meyer et al, 2001]. However, the costs and performance have not yet been demonstrated.

Schemes based on capacitor tapping of HV transmission lines or capacitive coupling between HV lines and insulated shield wires [Lategan and Swart, 2001] add the cost of the special conversion equipment to the cost of electricity generation and distribution. Like the use of shield wires for MV distribution, the schemes may represent the lowest cost solutions in isolated places close to HV lines and far from distribution networks, but their application is restricted by the high cost, limited capacity and limited geographic range.

4.3.4 Supply quality

Not all customers require the same quality of supply. Customers with continuous production systems and sophisticated machinery are financially sensitive to voltage unbalance, voltage dips and interruptions. In one area, frequent voltage dips caused disruption and financial losses in a motor assembly plant connected to the same busbar as a long rural feeder. Opening a bus-section switch reduced the disruptions without incurring costs, but with a small increase in interruption risk should a transformer fail, and not all problems can be solved so easily [Knott, 2001]. On the other hand, most domestic customers are relatively insensitive financially to voltage dips, and short interruptions and low voltage are more a nuisance than a cost.

The allowable voltage regulation on LV systems in South Africa was increased from $\pm 6\%$ of nominal voltage to $\pm 10\%$ in 1996, although the broader range had been in general use for some years already. Sellick [2000] has shown that even the broader limits may not be the most economic for low cost distribution. Poor customers with

very low loads and load factors do not incur significant energy losses in distribution systems. Costs can be reduced by deliberately designing the systems for higher peak-load voltage drop than presently allowed by the quality standards for voltage regulation. Using load data from typical electrification communities, Sellick showed that a voltage drop in an LV feeder of up to 18% of the nominal voltage provided overall savings, even including the cost of energy losses. This was not a surprising outcome, in hindsight, because the customers have very low monthly energy consumption and a short peak load, for which the voltage drop is calculated, and the cost of losses during that short period is low. This aspect is taken up again in section 4.4.5 on loss control. Without suggesting customers should tolerate unreliable supplies, Sellick recommended that regulators responsible for defining the acceptable conditions for utilities' supplies to poor customers consider the results of his analysis.

In particular, where the distribution is to reach poor customers with subsidised tariffs, there is a significant incentive to reduce costs to a minimum. The issue is whether a customer not meeting the full costs of supply is entitled to receive a supply of the same quality as customers paying the full costs or even premium costs. An evaluation of the National Electrification Programme reported the following regarding the quality of supply and service standard:

".. the design standards have been changed substantially or vary widely between the distributors, indicating that the initial designs generally, and designs in some projects, may have been unduly conservative. On the other hand, most staff were unaware of the performance of many of the ... systems designed using very low values of average demand, and so the systems may not be adequate."

and

"Some communities resisted the introduction of 20 A capacity limits on the supply. ... However, the suitability of this standard became apparent as the low consumption levels and associated poor financial viability of the electrification programme were confirmed by experience". [Borchers et al, 2001]

Obvious questions arise. Are the design parameters and the quality of supply delivered both consistent with the needs of the customers, without being 'unduly conservative' in the use of expensive resources? Such decisions cannot be made without understanding their ethical basis, which is introduced in the next chapter.

The quality of voltage regulation is not only a function of the design, but also depends on the operation of the networks, in particular the setting of tap switches on the distribution transformers. Analysis shows that better operation of the networks

improves voltage quality and defers the need for feeder reinforcement, thus reducing capital expenditure [Carter-Brown and Gaunt, 2001].

The technology and quality of supply are the result of the electrification project conceptualisation, not an inherent characteristic of the customers. For example, independently of the customers, networks may be designed as robust, with lots of spare capacity and redundancy, but incurring high investment costs. Cheaper, “lighter” systems require other ways to respond to problems, such as by having quick-response teams to attend to outages or better operations management. In fact, network planners and designers must have an impression of the expected operational management in mind when making network decisions, even if the impression is informal and not quantified.

4.3.5 Distributed Generation

Technological and regulatory changes in electricity supply introduce opportunities for distributed generation (DG). In some countries, small and renewable energy generation contributes to electrification, being the focus of new networks (minigrids) and supporting the main network as the minigrids are integrated. Most developments of this type are based on widespread small hydro, such as in Asia, but the conditions for small hydro in Southern Africa are generally unfavourable. DG from other sources, including co-generation, could develop in Southern Africa with re-regulation of generation, but is unlikely to be significant in the short term unless there are major changes in energy policy. In terms of electrification, about 3 million households need to be connected, representing a demand of about 1200 MW (admd = 0.4 kVA), and the present generation reserve is about eight times the new demand. The potential for DG depends on its economic competition with the efficient central power stations that use low-grade coal. So new DG is technically feasible and could contribute to energy generation, but in most cases is not financially viable.

The introduction of DG changes passive distribution networks into active ones with power flow possible in different directions. They incur extra costs for control and protection equipment, and management. As found in the literature survey, a large part of the price of electricity is for the fixed investment in distribution infrastructure, so reduced costs for central generation and transmission would be off-set by increased local costs. Therefore, DG does not represent a lowest cost solution to the energy needs of most customers and, for the purposes of this research, the effects of DG on electrification can be disregarded.

4.4 New Processes

The technologies alone are not sufficient to explain the changes that occurred during the electrification programme. At the beginning of the programme the knowledge of the technologies was held by different groups, as described in section 4.3. The sharing, development and adoption of knowledge affected the achievements of the programme.

4.4.1 Objectives determine responses

The initial proposals for electrification targets grew from Dingley's 350'000 per year [1988], to 500'000 per year at a cost of R1.2 billion annually, proposed by the National Electrification Forum, and settled at 450'000 as presented in Table 2.5. However, there was not much discussion about costs, and it was generally assumed that the cost would be R2'400 per connection.

The adoption of numerical targets had the advantage of being clear, unambiguous and easy to monitor. It was easy to prepare plans and to identify utilities that did not meet the targets. Information was presented simply in tables and on regional maps.

The absence of strict cost constraints led to some anomalous situations where, for example, part of a rural region furthest from the existing network was recommended for electrification, at costs exceeding R5000/customer plus network extension, because it was part of an integrated development plan, when nearer areas with costs of about R4000/customer were deferred.

Similar problems occurred in urban areas: *"When electricity-for-all activities started in 1991, there was acknowledgement of the need for changes to existing practice. For example, reports to the Durban City Council stated that appropriate technical solutions would have to be developed to overcome some of the problems foreseen. However, it appears the nature of the initial electrification target – 'to connect N domestic customers per year' – provided insufficient pressure to change standard methods and procedures. Pressure to change the standards only increased in 1995, when it was becoming clear that budgets (average connection cost was initially budgeted as R2400) were being significantly exceeded."* [DME, 2001]

Reaching and surpassing the ambitious connection targets was a substantial achievement, illustrating the benefits of simple result-focused objectives. However, simple targets are unsuitable for reaching complex objectives, and future electrification will require greater attention to budget and comprehensive specifications of viability and social impact.

4.4.2 Blanket approach to electrification

One of the critical aspects of an electrification programme is whether to connect only the customers applying and paying for connections, or to provide supply to all potential customers, referred to by Eskom as blanket electrification. For example, Dingley reported that customers in Brazil paid a basic connection fee plus a further fee for connections over 400m, but that the Rural Electrification Administration (USA), CLP in Hong Kong and PEA in Thailand all adopted "area coverage" without a capital charge. The advantages of the blanket approach are *"that no-one is without electricity, that the supply authority can plan on a long-term rather than an ad hoc basis, and that no cumbersome quoting or payment procedures are involved (as for example in the case of a new consumer on a line paid for by someone else)".* [Dingley, 1988]

The alternative approach to blanket electrification is selective electrification. Hourcade et al [1990] described it as having three phases: extension, densification and reinforcement. In the evaluation of the National Electrification Programme the selective approach was assessed: *"The selective approach focuses on ensuring the financial viability of the programme by focusing on those who are likely to be significant users of electricity, and indeed the TED programme is the only one from amongst the sample where small positive financial returns may have been realised. Disadvantages of the selective electrification approach are that it appears to result in the poorest household groups being connected last, or not at all, and that electrification areas need to be revisited to identify new customers who can afford connections. This means that social goals such as improving access to electricity among the poorest, may not be effectively met by this approach. The advantage of selective electrification (with regular follow-up), however, is that it matches the economic development of the community and improves the financial viability of electricity utility operations."* [DME, 2001]

Disadvantages of the blanket approach are that the average consumption of the customers will be lower and operating costs higher than with selective electrification, but it has several advantages. Blanket electrification contributes to achieving connection targets at lowest total cost, with low cost/connection, is the approach applied in most urban electrification, and makes savings by virtually eliminating Hourcade's 'densification'. Reduces perceptions of unfairness or economic discrimination tend to improve political support for the programme. Also, by reaching a higher proportion of poor households, it establishes the potential for subsequent poverty alleviation with tariff subsidies; however, there is an associated risk that introducing free or subsidised consumption could result in rapid load growth.

In the context of the blanket approach adopted by Eskom after 1995, the argument that supply-oriented household energy policies will fail is relevant. *"Any electrification programme which focuses only on increasing the number of supply points in the household sector will inevitably result in a poor allocation of resources. ...most households are unlikely to use electricity for purposes such as cooking and heating when they still have access to free supplies of wood ... Under a supply-oriented electrification programme it may therefore be that efforts initially target rural areas vigorously in response to political demands for electricity, but that utilities will 'get their fingers burnt' once they realise that consumption levels remain extremely low in rural areas, even long after connection."* [Eberhard and van Horen, 1995]

4.4.3 Planning and design

Network planning is the activity of conceiving the implementation of schemes, identifying the key parameters and establishing the priority. Design is the selection and detailed arrangement of the components of the networks to meet the planned capacity, reliability, quality and safety objectives.

Many writers identify the need to reduce the interference by politicians in the activities of electricity utilities and propose objective criteria for selecting communities for electrification. However, if planners extend electrification in the order of cheapest first, there will be less pressure to keep costs down and rural disadvantages will probably be reinforced. If the electrification is extended on another basis, lobbying to influence the choice or modify the criteria for selection must be expected. In a large programme there will always be not-easily-quantifiable but good reasons for selecting particular target groups, such as willingness to co-operate, perceived potential, or integration with other aspects of development.

Clearly understood objectives and constraints, such as targets and budgets, constrain planning but allow sufficient flexibility to respond to factors that are difficult to define in objective criteria. Municipal utilities inherently have standard processes, including budget control and political structures, to guide planning. Other utilities, like Eskom, have to develop appropriate mechanisms, and Stephen and Sokopo [2001] identified community liaison as one of four activities contributing to the success of Eskom's electrification.

Existing infrastructure often constrains planning, and sometimes refurbishment is needed. For example, in electrification projects in KwaZulu Natal some lines were uprated from 11 to 22 kV operation, sections re-conducted, and defective structures replaced. The accounting of such activities as maintenance or part of the capital expenditure of electrification can distort cost control. Detailed inspections to

ascertain the condition of the lines also inflate costs compared with planning and designing new feeders, and not all utility contract managers understood this.

As soon as designers make provision for subsequent reinforcement of electrification feeders they incur extra costs. Load growth by individual customers is slow, and most growth arises from connecting new customers and extending feeders. Eskom's decision to adopt blanket electrification reduced much of the uncertainty regarding the subsequent connection of new customers in electrification areas, and extra capacity was needed only for extending feeders to reach further areas.

Processes that contributed to better planning and design included greater use of techniques and tools for comparing alternative plans, modified IRR methods, computer-based asset management and software for feeder design. All these needed to be supported with better network records and several processes were adopted to improve data collection.

4.4.4 Contract structure

The changes in implementation processes during the electrification programme are summarised effectively in the evaluation report. *"The project management and control processes changed during the programme, initially to ensure the numerical targets were met, but later to increase the financial control. In most cases, the distributors used conventional contractors or in-house construction teams to build the networks according to designs by own staff or consultants. Quality control of planning and design appears not to have been applied uniformly. Eskom introduced turnkey projects late in the NEP, but limited evaluation has been undertaken on this type of project implementation."* [DME, 2001]

The effectiveness of the contract management is illustrated by Eskom's achievement of *"300 000 connections per annum, with a variation in capital and connection numbers of well under 1% for the five years"* [Stephen and Sokopo, 2001].

Employment of local labour was a requirement for all projects. Generally this did not lead to continued employment (see study 3 in section 3.4.3) because fair labour practice requires recruitment for permanent positions to be open to all applicants regardless of place of origin.

One of the problems inherent in all contracting is the tendency to reduce costs by lowering standards. The high cost of failures in service requires that specifications set appropriate performance standards and equipment and materials meet those standards. The tendering process establishes competition on price; but both tender

adjudicators and officials taking delivery of equipment and projects must be able to determine whether the specified requirements are met. In a recent case (during 2002) a local manufacturer copied the physical characteristics of another suppliers' line components, without meeting the performance specifications. Several electricity utilities in Southern Africa purchased and installed thousands of the components before it was shown that they could not carry the rated current without overheating. The costs of future failures will significantly exceed the savings made in purchasing the cheaper copies. This type of problem becomes even more difficult to detect and prevent when utilities use turnkey contracts for network construction, as even the design processes might be inadequate. Suitable specifications, testing and inspection are essential components of all contracts.

4.4.5 Loss control and reduction

The technical losses¹⁷ in distribution networks depend on the peak loading and load factor. If the voltage drop at maximum load is about 15% (from +5% to -10% of nominal voltage), the peak power losses will also be about 15%. The loss load factor in distribution feeders is typically between 0.15 and 0.25 [Sellick, 2000], so the energy losses in a feeder operating at its design load might be less than 2% or as much as 5% of the energy delivered, and most feeders operate with maximum loads below the design load for most of their lifetime, so the losses will be even lower. This analysis is supported by Munasinghe's recommendation [1990a] that *"target loss levels for the entire distribution network should be less than about 5% of generation, whereas conventional wisdom has allowed for losses up to 10% or more"*. Utilities that assume technical losses in distribution systems to be 10% are probably over-estimating the practical technical losses.

The other losses are non-technical losses. Most arise from theft: *".. many of the participants in implementing the NEP were convinced that the installation of these (prepayment) meters within the household would inevitably lead to increased meter tampering."* [SALGA, 2001a]

Reduction of non-technical losses requires careful monitoring of network losses. This needs an understanding of network conditions, reliable data collection and processing, and management attention and willingness to take action. Political activity (see case study 6 in section 5.2.5) and poverty are stated to be causes of high non-technical losses, and even in 2001 losses exceeded 60% of the energy sent into some areas, that is customers paid for less than 40% of the energy [Qase et al, 2001a]. Such losses are not sustainable for small utilities. Larger utilities survive by charging paying customers more to cover the losses.

Attitudes to non-technical losses are a good indicator of the underlying perceptions of the role of electrification. High non-technical losses would not be tolerated if electrification were intended to be for economic development.

4.4.6 Technology transfer and adoption

The adoption of new technologies is not easy to identify or manage. By definition the ideas come from outside the organisation, or even the country [Gaunt, 1991b], and many suffer from the “not invented here” syndrome. Yet, at the same time, ideas are recognised, adapted and incorporated.

Recognising the value of an idea requires first that it be shared. Sharing occurred formally at workshops and conferences including:

- the annual national meetings of the AMEU;
- Cost Effective Power Distribution and Reticulation, SAIEE, August 1987;
- The Electrification of Developing Communities, SAIEE, November 1991;
- New Technologies for Electrification seminar, SAIEE/Eskom, March 1998;
- annual Domestic Use of Electrical Energy conferences since 1991; and
- Cigré Southern African Regional Conferences in 1990, 1994, 1998 and 2001.

Many of the new ideas were introduced from research in universities. Dwolatsky [2001] has identified the importance of a cohort of specialists and activity prior to commencement of the NEP. The openness of results from academic research directed to practical problems increases its potential value, usually not restricted by copyright or trade secrets. Contributions from staff and students who have carried out research leading to applications in the NEP include Herman [1993] and Sellick [2000], already mentioned, as well as many more.

One of the drivers of innovation was evident even before the national electrification started, as described by Theron et al [1992]: “... *most consultants aim to maintain their long-term credibility and market share by producing cost-saving and innovative designs ... This, coupled with the efforts of private suppliers of electrical equipment, has resulted in the development of a number of innovative approaches to the installation of low-cost electricity systems*”.

Funding authorities also contributed to sharing ideas. For example, through its technical assistance to many utilities the Development Bank of Southern Africa made suggestions for reducing costs and improving project effectiveness.

17 Technical and non-technical losses are defined in the glossary.

The experience of Eskom illustrates another aspect of technology transfer. Because of its greater size, decisions to change a technology have greater financial impact, so the organisation tends to be conservative. However, once a decision is taken, substantial resources can be made available. The greatest constraints are the internal training to enable and promote acceptance by the staff implementing the technology, and managing the results.

Innovation is not without risks. Early prepayment meters were prone to failure and the early vending systems were made obsolete by adoption of the STS protocol. A more subtle risk is illustrated by an extract from the discussion of the evaluation of the National Electrification Programme:

"Based on results from the load research project and early returns of sales from their electrification customers, Eskom adopted, half way through the NEP, an innovatively very low design parameter of ADMD=0.4 kVA for electrification network design. This innovation allowed Eskom to make substantial capital savings in the NEP.

However, recent results from the load research project (only being measured as the Evaluation Report was being completed in August) indicate that this design parameter is being exceeded in most of the Eskom electrification projects being monitored, well inside the expected design life of the networks. This technical innovation, therefore, risks being an enormous liability for Eskom, as feeder reinforcement will be needed for which the cost has not been taken into account in the financial and economic evaluation.

The financial implications may be even more serious than those arising from the problems of the prepayment meters." [EDRC, 2001]

Based on the experience of the electrification programme, technology transfer clearly requires opportunities for sharing and testing ideas, willingness to adopt new technologies despite potential risks that they will not be suitable in the new context, and training and courses to improve knowledge and the probability of success. At this stage, the factors promoting technology transfer and adoption in monopolistic organisations such as electricity utilities are not evident.

4.4.7 Standardisation

Continuous innovation in a programme like national electrification prevents benefits being derived from the economies of larger markets and familiarity with the technologies and processes. Standards improve efficiency in design, equipment selection, construction, technology and processes, but incur costs in several ways.

- There is the cost of agreeing, producing and complying with standards.
- If standards are inappropriate or impose conditions that are unnecessary, extra costs are incurred. For example, proposals to change the wiring regulations to require LV surge arresters in all households, even in regions with low lightning incidence and extensive underground cable distribution, would incur expense without financial or economic return.
- If the requirements of standards are inadequate there may be costs of unexpected and high failure rates, such as with the prepayment meters.
- Finally, unchanging standards can stifle innovation by excluding non-compliant equipment and processes.

Since balance is needed between the restrictions and compensatory benefits of standardisation, it requires both changing and retaining standards:

"Distribution standards in South Africa have changed steadily in respect of network design parameters and processes, the capacity of the customer supply, line designs and conductor ratings, protection, the sizes and types of cables, substation design, and many other details. In this respect standards are like quality assurance – participation is an investment in continuous improvement.

On the other hand some standards change very little. The South African mines have used a voltage standard of 550V for so long that nobody remembers its origin. The voltage, although it is not an international standard voltage, is very suitable for mining applications and widely used, so there would be no benefit in changing.

Standards must be totally revised when a new technology is introduced, for example SWER distribution. Omitting one or two conductors from a conventional feeder can improve overall efficiency, but the "new" technology changes the whole design approach, earthing and safety, system protection, component ratings and the processes of commissioning, operating and upgrading." [Gaunt, 2001]

The electrification needs of Africa have many similarities, so there is scope for regional co-operation in innovation and standardisation. Eskom and the municipal utilities co-operate in the NRS standardisation for the electricity supply industry, and in the standards activities of the Power Institute of East and Southern Africa¹⁸ and UPDEA. NRS has issued a wide range of standards on equipment, such as prepayment meters (NRS 009) and photovoltaic systems (NRS 052), and guidelines such as for the provision of electrical distribution networks in residential areas (NRS 034) and quality of supply (NRS 048).

¹⁸ The members of PIESA are the utilities of Congo, Malawi, South Africa, Swaziland, Uganda, Zambia and Zimbabwe.

It is not economic to replace all existing equipment when new standards are adopted or existing ones changed. So, despite standards, networks will accumulate a variety of equipments and ratings that need to be accommodated by maintenance and operations. Even now some utilities have different standards that will increase the complexity of proposed industry restructuring. For example:

- there is a range of specified low voltage ratings, from 400 to 420 V for purchasing distribution transformers supplying 400 V systems.
- the rated voltage for MV equipment in Cape Town is 11.6 kV, while the comparable national standard is 11 kV.
- Eskom introduced 22 kV distribution in addition to 11 kV, and dismantled the 33 kV networks, but most municipalities retained 11 and 33 kV as their standard medium voltages.

4.5 Non-grid electrification

Photovoltaic (PV) systems were sold privately in South Africa from the late 1970s until about 1994. At that time, the government instituted a public sector programme for PV installations, initially by establishing the Renewable Energy Foundation (REFSA) and then by licensing areas for Solar Home System (SHS) concessions, financially supported by government subsidies. The SHSs provide a service for a monthly fee. Each unit consists of a PV panel, battery, inverter and controller, into which a code must be entered every month, in the same way as a prepayment meter. The typical SHS capacity is 50Wp, and they deliver about 8 kWh of energy per month. About 8000 installations were made by the end of 2002.

The cost of SHS installations has been reported as R3.5 million for 593 installations in a project that started in 1998 [Mehlwana, 2001].

The lack of reliable information about operating and maintenance costs complicates the viability assessment of isolated or non-grid electrification projects. In a grid-connected project, the financial costs of energy supply, including distribution system operation and maintenance, can be modelled by electricity tariffs. For an isolated project they must be modelled directly, including the costs of failures in the whole supply chain, such as in the delivery and storage of fuel for a diesel generator, spares and breakdown maintenance for a wind generator, and battery failure for a PV system. South African experience indicates PV systems are no easier to install, service and manage than grid, especially as the grid expands and the PV gets embedded in the grid area. Also, other risks need to be included: *"In 1995, Eskom initiated an off-grid electrification programme for schools with financial support from*

the European Union, with the ambitious goal of installing PV systems in 16'400 schools by the end of 2000. The target was not met, due to such factors as vandalism and climatic disruptions ..." [Mehlwana 2001].

Despite economic and financial calculations showing that isolated systems can compete with grid-connected electrification, practical experience indicates that when grid-connected electricity becomes available it usually replaces the isolated sources of supply, as illustrated in case study 5.

Case study 5: Langeni sawmill power supply

In 1982 a distribution line project was proposed for the extension of the MV network to a sawmill at Langeni in Transkei, which supplied its own power using diesel generators. The proposal was considered sufficiently economic by the managers of the sawmill to proceed, but the diesel generators were kept for backup supply in case the network supply failed. Despite occasional outages caused by lightning, fires and other incidents, the sawmill disposed of all the generators within two years.

Source: Own experience.

Analysis of impact:

- (1) Electricity generation was not part of the core business of the sawmill and incurred costs for space, management attention and asset financing that are not usually taken into account in a viability assessment.
- (2) Under stable pricing conditions the grid-connected supply was more economic for the sawmill than own generation, despite the high costs of connection and occasional interruptions of supply. However, under unstable conditions, such as management and operational failure of the electricity utility or electricity tariff increases at a higher rate than fuel prices, an isolated supply may become more economic. This is illustrated by grid-connected industries having to obtain their own generation when the utility supply becomes too unreliable, such as in Guinea Bissau (in 1998) and Kenya (in 1999).
- (3) The cost of the grid-based supply is distorted by the urban-rural subsidy inherent in regional tariffs. The higher costs of rural electricity distribution are not reflected in the electricity tariff, but the distribution costs (for fuel, maintenance parts and labour) are a significant part of the costs of supply from an isolated system.

The replacement of isolated supplies with grid-connected supply also happens in household electrification. When a network reaches communities previously reliant on SHS installations, most customers change to the network supply. For the same cost as the SHS tariff, (about R55/month, depending on supplier), a grid connection will supply more than 150 kWh, instead of the less than 10 kWh available from a SHS. The financial advantages for a customer of the grid supply are obvious, even if an economic assessment including the environmental advantage of renewable energy and the distortion of tariff subsidies indicates an alternative ranking of desirability.

4.6 The impact of technology and process changes

Munasinghe [1990a] stated, on the basis of work by others, that electrification costs, and particularly the initial investment, can be reduced substantially by:

- improved design of lines and substations
- higher primary distribution voltage
- improved design of line supports
- revised specifications for distribution transformers, switching and protection
- advanced metering and billing
- more effective operation and maintenance
- revised service quality standards

The electrification programme in South Africa included changes in all the areas identified by Munasinghe and, in addition, reduced the need for billing, thereby avoiding the limitations of the postal system, improved the knowledge and use of load data, and introduced new approaches to conductor selection. Table 4.5 shows that many changes to reduce investment were incorporated into a single Eskom project at Orange Farm between 1994 and 1999. Figures 4-7 and 4-8 illustrate typical installations from each period.

Table 4.5: Distribution system standards in Orange Farm (1994-99)

	1994	1999
MV system	22 kV three-phase covered conductor overhead lines on concrete poles, situated in mid-block.	Bare conductor overhead lines on wood poles, in road reserve.
Transformers	CSP (completely self protected) pole mounted transformers.	Transformers to SABS 780 without integral protection.
LV system	Three-phase abc insulated-neutral cable on concrete poles.	ABC bare-neutral cable on wood poles.
Meters and tariffs	60 A keypad and magnetic card prepayment meters, proprietary systems.	20 and 60 A keypad meters with standard (SMS) coding.
Connection and wiring	Single phase overhead using 16 mm ² Airdac (concentric neutral cable), entry through the walls of the houses. Ready board supplied as connection. House wiring by customer if desired.	Meters on outside of house (for easier access by checking staff). 10 and 4 mm ² Airdac.
Design parameters	Characteristic admd: 2,5 kVA Planned voltage variation at customer: $\pm 10\%$ Expected average domestic consumption: 350 kWh/customer/month.	Characteristic admd: 0,7 upgradable to 1,2 kVA Planned voltage variation at customer: $\pm 10\%$ Expected average domestic consumption: 75 kWh/customer/month for 0,7-1,2 kVA.

Source: Qase et al [2001a]

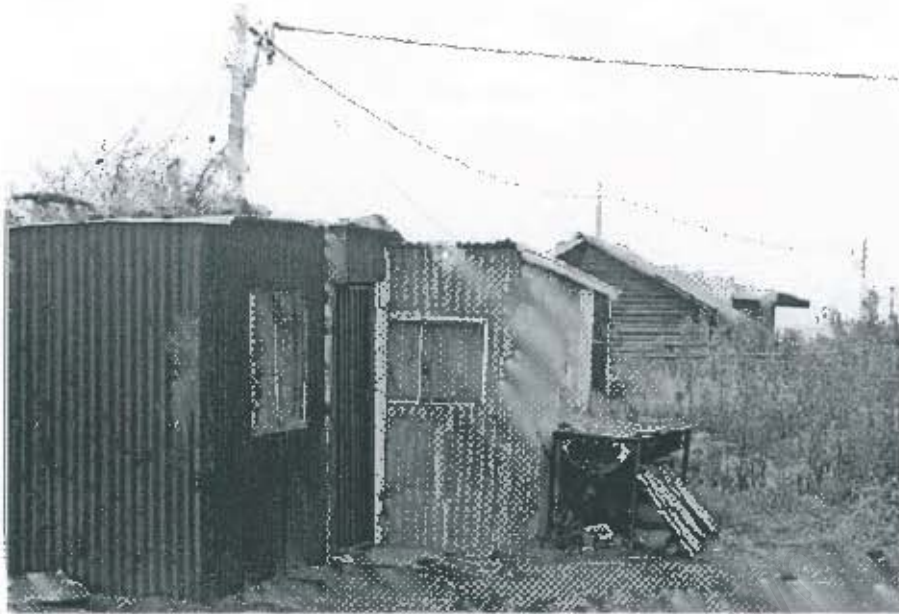


Figure 4-7: Orange Farm standards in 1994 - concrete poles and indoor meters.



Figure 4-8: Orange Farm in 1999 - wooden poles and external meter boxes.

4.6.1 Results of technology change, as measured by cost

Technology can be measured in terms of the contribution it makes to reducing the cost/connection, which is a measure of the inputs used. Zomers [2001] identifies a relationship between the cost/connection and the number of customers connected, showing it as a single line on a graph. Conceptually, it is easy to imagine the greater efficiency in planning and design, procurement and project management achieved by carrying out larger projects than smaller ones. However, there are many confusing factors that distort such analysis carried out across many countries:

- The exchange rates used to bring all project costs to a base currency are dynamic, but may not significantly affect the costs of electrification.
- The range of costs within one country depends on the density, size (electrical demand) and location of the projects, as well as on the technology used.
- The inclusion of utility management and overheads costs, financing costs, transmission and generation costs distort the apparent scale of any project.

Comparisons within South Africa, instead of across countries, should be more consistent.

The size of Eskom's programme was steady for several years, at about 300'000 connections/year. Each year the programme consisted of many projects carried out in the Distributors. There were 12 Distributors initially, having been restructured from six in 1985. They were consolidated into five in 1994 and rearranged to seven in 1998. The allocation of connections to each Distributor in each year varied; and there were reallocations during the year according to progress and costs. Typically, the Distributors were implementing 40'000 connections per year in projects of between 300 and 3000 households.

The municipalities implemented many connections per year, but distributed among more than 100 utilities, not all active every year, in projects from under 100 to about 2000 connections.

National data for all electrification [NER 2002b] indicates a generally declining trend in electrification costs per connection, in current terms¹⁹. After allowing for inflation, using the Producer Price Index or a more stable currency like the US dollar, a strong reduction in real costs through the electrification programme is clearly evident in Table 4.6 and Figure 4-9.

¹⁹ Note there are small discrepancies between data derived from various NER sources, such as between the overall cost/connection in 2001 in Table 4.6 and the urban/rural split in Table 2.6.

Table 4.6: Connection costs, Eskom and municipalities: 1994-2001

Year	Connections	Capex [Rm]	Cost/con [R] in current values	PPI ave	Cost/con [R] after inflation adjustment	Rand/ US\$ at July	Cost/con US\$
1994	435882	1482	3400	66.7	5097	3.40	1000
1995	478767	1412	2949	73.0	4040	3.55	831
1996	453995	1473	3245	78.1	4155	4.34	748
1997	499311	1176	2355	83.6	2817	4.54	519
1998	427426	1235	2889	86.6	3336	6.05	477
1999	443290	1186	2675	91.6	2920	6.02	444
2000	397019	1009	2541	100	2541	6.79	374
2001	336918	910	2701	108.4	2492	8.05	335

Sources: NER publications, PPI from Stats SA, exchange rate from Oanda [2003]

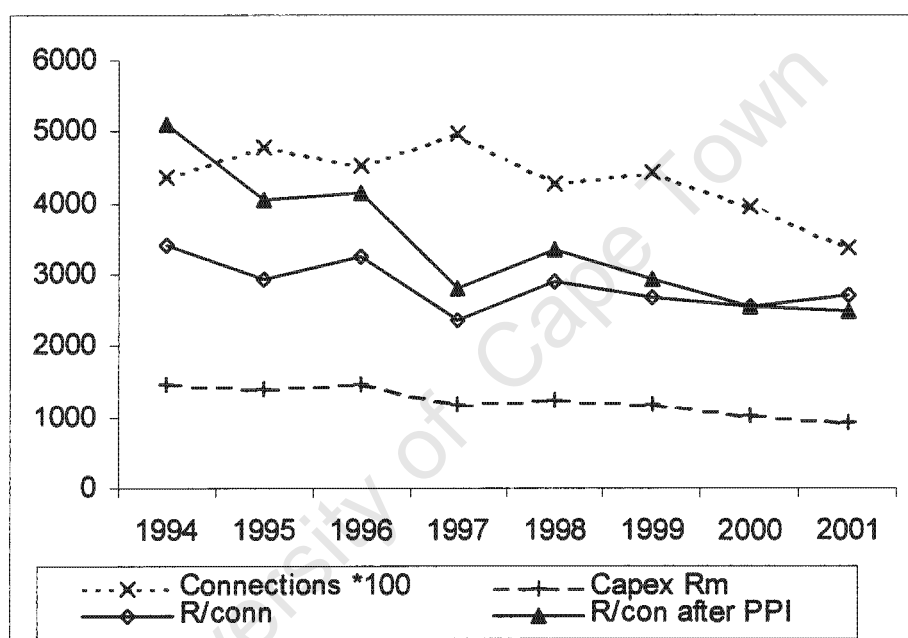


Figure 4-9: Cost/connection in current prices: 1994-2001

By contrast with the relatively smooth trend illustrated above, the average cost/connection for various provinces, as presented in Table 2.6, shows high variability within one year. Similarly, the costs of eight electrification projects evaluated during 2001, illustrated in Figure 4-10, also demonstrate large differences in electrification costs.

Municipal utilities frequently install area or street lighting as part of the electrification. "Streetlighting is an important part of the electrification process as it provides an amenity for motorists and the public" [Martens and Williamson, 1996]. Eskom does not provide lighting, and where it carries out the distribution in a local authority area it only provides lighting under special agreements with the local authority. However, this makes only a small difference to the costs of municipalities and Eskom.

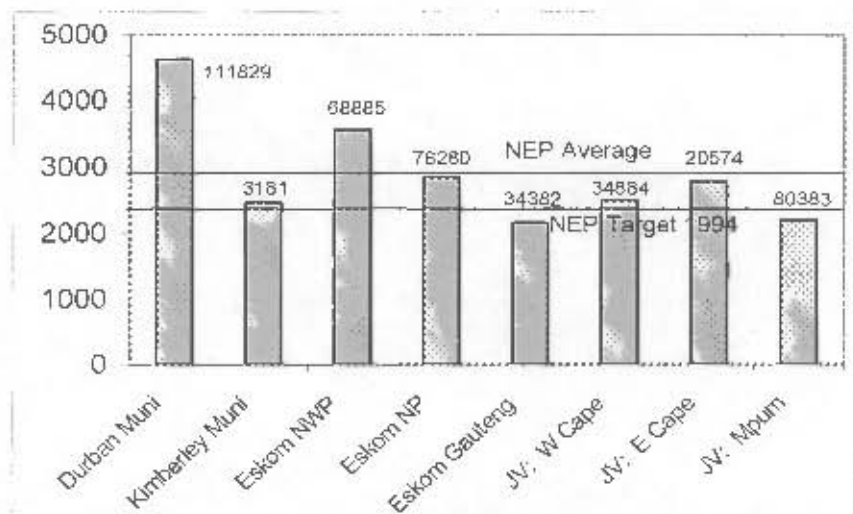


Figure 4-10: Variability of project costs (In Rand). [Borchers et al, 2001]

The size of a project does not appear to be a significant factor for the cost. All the programmes were large and Figure 4-10 indicates the number of connections made in each. The average cost of the projects is independent of the programme and project sizes, and other causes of variation must be identified.

4.6.2 Results of process change

It is difficult to separate the cost impact of process changes from that of the technology. Analysis would require investigation of the direct project costs and overheads in consistent accounting formats, but such records are not compiled by the utilities.

Changed contract processes have increased the competitiveness of the industry, but also introduce a tendency not to meet needs, but to comply with specifications. This increases the importance of good specifications, and the understanding of how to prepare them. There were evident problems in preparing performance specifications.

4.6.3 Implications for non-grid electrification

Only brief reference to the substantial literature on non-grid electrification was made in Chapter 3, leaving the topic for this chapter. PV supplies are the most common form of small-scale renewable energy for non-grid electrification, and the following analysis uses PV as representing the most viable alternative to grid supplies.

In some developing countries, PV and SHS have been marketed for and by the private sector. For example, the PV programme in Kenya has been praised for the

private sector participation and the evident capacity of PV to meet rural needs. *"In Kenya, a series of rural electrification and other programs has resulted in the installation of more than 20'000 small-scale PV systems since 1986. These PV systems now play a prominent role in decentralised, sustainable electrification."* [EIA 1999]. Even on this scale, these PV systems reach only a small proportion of rural households. They meet economic needs as represented by wealthier households or adding value to commercial enterprises, but the contribution to socio-economic development or poverty alleviation is insignificant in numbers and energy supplied.

Demand for PV systems is stimulated by the relatively high cost of network electricity and its non-availability. Acker and Kammen [1996] reported costs of grid connections in Kenya of typically US\$1640 or more, and considerable bureaucratic delays. By contrast, the costs of PV systems in various African countries have been reported as being between US\$600 and US\$1200 so that *"conventional wisdom on how to increase modern energy use in rural sub-Saharan Africa often perceives solar PV as the most attractive option"* [Karekezi and Kithyoma, 2002]. Zomers [2001] gives comparative costs for a PV supply and a light grid connection and, acknowledging the high costs of the PV installations, states they *"would seem the most attractive renewable option and the potential is large"*.

The different energy capacities of PV and grid electrification make comparison difficult. Dos Santos and Zilles [2001] showed that household energy consumption must be included in the decision criteria for the application of photovoltaic SHSs in Brazil. Except in areas with high grid connection costs, they found that SHSs were suitable only for households using less than 5 or 10 kWh/month. *"Although 15 kWh/month was identified as the upper level of typical SHS users, at the present price conditions, only occasionally will it be the best option."*

Seeling-Hochmuth [1997] used grid connection costs of R3800 or R7000 for 20 kWh monthly consumption, while the SHS cost was assumed to be R2500. By contrast, the practical results of recent grid and non-grid connections reverse Seeling-Hochmuth's cost order. Grid connection costs of about R4500 in 2000 include R2000 for generating capacity (see Table 4.6), compared with R5900 for an SHS installation (see section 4.5). The PV costs are of similar magnitude to Zomers' estimate and the grid costs are consistent with the costs in other years, so the comparison is consistent. Zomers' results and South African experience are presented in Table 4.7.

The South African experience indicates a much greater ratio between the costs of PV and grid supplies even than reported by Zomers, suggesting a larger cost reduction will be needed before PV becomes attractive.

Table 4.7: Investment costs of PV and grid related to energy capacity

	Zomers' data		South African data	
	PV	Light grid	PV	Grid
Investment cost	US\$750	Not given	R5900 each	R2541/customer + R2000 for capacity
Energy delivery [kWh/year]	100	1000	100	1000
Investment cost/kWh/year	US\$7.5	US\$1.9	R60	R4.60

It appears that PV systems are only viable:

- where comparisons of the costs of renewable systems are made against high costs of grid electrification, distorted by high energy capacity and possibly inefficient procedures,
- with aid support and aid subsidies, or where electricity utilities fail to meet the needs for connections, such as in Kenya, and
- when the authority and financial power of government officials dominates individual choice by customers with limited means.

In Southern Africa, the large pit-head power stations using very low grade coal, and the large hydro stations with the capacity to regulate the uneven seasonal water flow have economies of scale that are not yet matched by small electricity generating technologies. Technology may have the potential to develop renewable energy and isolated power supplies without the disadvantages of small scale, either in the supply of the primary energy or the capital and operating costs, but this is not yet achieved. Because PV systems as presently conceived are limited by the small energy available, they represent a poverty trap for customers because of the high further cost of moving to the next level. *"If PV cannot be scaled up, with reasonable costs for high wattage energy storage, it will begin to look decidedly shaky as off-grid communities increase their income and energy-using activities, and hence their demand for power - a principal, long-term aim of providing modern energy services in the first place."* [Leach, 2001]

Until the limitations of low energy capacity and high costs change, renewables and non-grid supplies must be considered generally irrelevant to large scale electrification:

"The reasons why everyone is in favour of renewable energy sources are familiar. Because they are seen as having a special relevance in the rural areas of the developing world they have been the focus of a large number of development assistance efforts. Yet in spite of twenty years of effort, their penetration scarcely registers in the overall energy consumption scale in most developing countries." [Foley, 1997].

4.6.4 Impact of changes on research

Research as a component of technology transfer and adoption was discussed in section 4.4.6, but the technology and process changes during electrification also affect the importance and nature of future research.

Avoiding over-investment by matching supply capacity to the needs of the customers has achieved substantial, almost radical, changes in respect of the investment costs of electrification. Less attention has been given to operations and maintenance.

Apart from their substantial contribution to load research, municipal utilities have not carried out much technological research, largely because of their need to minimise costs ahead of uncertain proposed restructuring. Most investigations and developments reported at recent annual AMEU conferences and technical meetings have been into business processes. In contrast, Eskom has a substantial technology research programme addressing topics in distribution planning, systems and automation, and distributed generation. Eskom also contributes to academic research with tertiary education support grants to universities and technikons, and research contracts.

Munasinghe's findings [1990b] on the scarcity of research resources in developing countries and his recommendations regarding the use of staff in universities and research institutions were noted in Chapter 3. It is clear that the electrification in South Africa benefited from having such resources. Despite the strong incentives for research directed to international, high impact journals, there are many areas for research appropriate to developing countries. They include developing a better understanding of loads, low cost distribution technologies, demand management, losses analysis and reduction, methods for evaluating proposals and tariffs for economic and social development, and of technologies to cope with quality of supply problems. All these research topics require relatively little capital and offer scope for significant change and potentially quick returns on the investments. However, an obstacle to such research is the need to supplement "technical engineering" with local knowledge, applications understanding and information from other disciplines.

A critical area requiring research concerns the cost and viability of electrification for poor customers. As noted in section 4.4.6, rapid growth of demand to levels above those used for network design represents a risk for the utilities. The customers' average energy consumption during the first five years after connection has been reported as 83, 95, 106, 121 and 138 kWh/month [NER, 1996b]. The same report stated *"The low consumption by newly connected dwellings in the disadvantaged communities poses the biggest threat to the viability of the electrification programme."*

A consumption per household of 400 kWh per month is needed to break even but the growth is much lower than that. [NER, 1996b] And two years later: *"If one considers that consumption of 350 kWh per month at least is required to break even, it becomes apparent that the electrification programme is uneconomic and unsustainable without cross-subsidisation."* [NER, 1998] Since these statements were made, the costs of rural electrification have reduced substantially, and the breakeven level of consumption and appropriate design parameters apparently still need to be determined for this dynamic situation. At the same time, the conditions on the low cost networks need to be monitored to ensure that the quality of supply remains acceptable even when the loads increase. Suitable low cost methods of monitoring quality and losses, and approaches to evaluating reinforcement alternatives are required.

4.6.5 Life of distribution assets

The economic life of power stations is usually at least 40 years, and transmission systems have similar physical lifetimes but need to be supplemented with extra lines. The physical lifetimes of distribution systems also appear to be at least 40 years. Regular replacement of poles, insulators and conductor in response to faults and failures creates an asset that is generally maintained on a continuous basis. Complete replacement of a whole asset, such as replacing one line with another of higher voltage, is usually justified only by a need for increased capacity. In the approach adopted by Eskom, light distribution systems can be supplemented with additional feeders, without incurring penalty costs of under-design. This has implications for system planning and operation, in that the need for reinforcement must be identified before the quality of supply becomes unacceptable. It also affects the distribution costs included in tariffs analysis.

4.7 Reasons for the changes in technology and processes

The changes evident in the electrification technology and processes are interpreted in this section. The key changes are summarised, then differences between the utilities are considered as possible reasons for change, and an attempt is made to identify the change-drivers and the significance of technology transfer. The implications of the technology on development for economic or other objectives are discussed and, finally, the possibility of bias in the research method is considered.

4.7.1 Summary of key changes

The changes in electricity distribution include:

- a need to reduce the costs of new assets;
- technology development, but distributed generation, power electronics and information technology were less significant than reducing the costs of feeders by reducing the number of conductors;
- the aging of existing networks and growth of loads on them;
- increasing difficulty and cost of operating and maintaining remote systems, whether grid or non-grid;
- proposed restructuring of the institutions making up the electricity distribution industry;

all arising from a requirement to provide access to electricity for poor and deep rural communities.

The analysis indicates that substantial cost reduction was achieved by:

- reducing design standards for rural projects from about 2.5 kVA/hh initially to 0.4 kVA/hh, and for urban projects from about 3 kVA/hh to between 1.0 and 1.5 kVA/hh.
- maturing prepayment meter technology, reducing prices in real terms.
- adoption of cheaper lines, smaller transformers and less expensive technologies, such as single-phase instead of three-phase systems.
- adoption of blanket electrification for rural areas, it having been the standard already in most urban areas.
- improvements in project planning and implementation procedures.

4.7.2 Differences between municipalities and Eskom

There appear to be three important differences between the municipal utilities and Eskom, indicated in Table 4.8.

Table 4.8: Differences between municipal utilities and Eskom

Characteristic	Municipal utilities	Eskom
Answerability of management	To local government councils.	To central government (Minister of Public Enterprises).
Customers	Wide range of industry and business, plus many rich and poor households. Smaller proportion of new customers.	Mostly large customers and many mostly poor domestic customers only recently given access to electricity
Financial resources	Most expect to make a contribution to rates from their electricity trading account.	Funded the electrification programme mostly from revenue. Contributed to municipal electrification from sales to municipalities.

The differences created an environment where comparisons could be made between the municipal utilities and Eskom. This could have stimulated efforts to improve

performance, and allowed a broader introduction of new ideas. It appears that benefits may have been derived from the diversity between the characteristics and management of the two groups of utilities. The question arises whether further benefits will be derived from this structure, or could there have been (and be in the future) a greater benefit from restructuring, considered in a later chapter.

4.7.3 Forces behind technological change

Only two reports on methods to reduce technical costs of electricity distribution elsewhere in Africa have been identified. Cost reduction techniques proposed for rural electrification projects in Ethiopia [Mariam, 1992] include the use of locally available wood poles, labour intensive construction methods, and shifting costs to other authorities and sectors of the economy because electrification has complementary benefits. However, no mention is made of adopting fundamentally more appropriate electrical technologies. Similarly, Ramasedi [1992] suggested technology transfer, changing designs to suit the local environment, and using cheaper poles for service connections as ways of reducing cost.

The changes in South Africa are radical by comparison, and the changes must have been driven by strong forces. The following are probably the most significant.

- There were changes in the economic and political systems interacting with the electricity distribution industry. Electrification was not a direct political challenge to the government and offered an opportunity to break out of the economic stagnation of the late 1980s. Electrification was a visible way for the new government to demonstrate change and benefit the previously disadvantaged sector of the population.
- Commercial and political threats to the established utilities arose from the interest of foreign companies in entering the South African market, and social and political threats, such as of takeover and restructuring, if utilities failed to meet social and political targets, including electrification.
- External observers monitored the financial performance of the utilities. Even where internal reporting systems and cultural constraints limited the transmission of unacceptable reports within utilities, informal and external routes conveyed the information. The public reporting of the Regulator contributed to information sharing after 1996.
- Utilities were relatively restricted in their alternatives. Changes in operating costs did not reduce expenditure sufficiently quickly and commitments to reduce tariffs in real terms were monitored by influential customer groups, so revenue could not be increased easily.

- The commercial environment of consulting engineers, equipment suppliers and contractors fostered new ideas, reinforced by academic research in several centres.
- Alternative technologies were already available to be adapted and adopted.

4.7.4 Significance of technology transfer

Technology transfer is about doing things differently because circumstances have changed. Usually it is related to a new technology, equipment or process, and refers to the familiarisation of the utilities' staff with its use, operation and maintenance. At the conceptual level it requires new skills and techniques in thinking, problem identification and solving, and at an operator level it requires increased knowledge derived from training on the physical components. In all cases, improvement of skills depends on the existing skills base. A research project into the outage performance of overhead lines reported *"One of the reasons for involving a wide variety of participants was to use the project for education in aspects of line design and operation. However, the skills levels of the participants were probably over-estimated. The extent of the support needed in data collection and verification exceeded expectations."* [Gaunt, 1994]

Technology transfer takes time. The adoption of SWER technology for rural distribution took eight years from first proposals to serious implementation, first in Botswana and later in South Africa. Only when the costs of rural electrification using conventional approaches were seen to exceed the available budgets, was there sufficient incentive to learn and use the technology. By 1999, SWER and single-phase feeders had become standard technology in Eskom, although the data management systems used to capture and display network information still did not accommodate single-phase systems.

Technology transfer of the probabilistic methods of LV feeder calculations was much quicker. The need for calculation methods existed in many utilities but involved only specialised designers, and a university provided training courses at low cost, so the knowledge transfer requirements were relatively limited. The implementation achieved demonstrable results without significant expenditure.

The experience indicates that factors accelerating technology transfer include:

- Awareness among the technical staff in planning, design, construction and maintenance; familiarity with their systems and equipment; realisation that changes are necessary; and confidence that support of change will not threaten individuals' positions or influence. New objectives indicate a need

for change but financial pressures (budget cuts) strongly stimulate innovation and acceptance of new technologies.

- Confidence in the suitability and reliability of proposed changes and that they will not increase the risk of failure. Concerns are justified by the history of failures of new equipment, materials and techniques caused by inherent weakness or application, such as the early prepayment meters, covered conductor, and integrated computer systems.
- A strong base of existing knowledge into which the new skills can be integrated easily. Formal training systems reduce the time taken to learn new knowledge. Without prior knowledge and formal training the adoption of new methods takes many years.
- Low costs of experimentation and adaptation of new methods, including detailed engineering, standards, administrative codes, staff training, and management.
- Management attitudes that reward innovation and tolerate reasonable failure.

4.7.5 Implications for the theory of economic, socio-economic and social development

This chapter has considered the role of technology and the changes evident during the electrification programme carried out since 1991. Technology development appears to have had a significant effect on the viability of electrification. Comparing the new standards with those in use before the programme started indicates that the original standards were not appropriate to meet the real needs of the customers at affordable costs. The most significant changes have been the adoption of technologies that minimise the initial capital cost of electrification. The costs of losses, the need for subsequent reinforcement and the quality of supply are all less important planning criteria.

Electrification standards affect the generation and network capacity needed to meet the demand. The apparent lack of clarity in respect of the total cost commitment made in respect of electrification indicates that the main objective is not economic development.

The licences of electricity utilities in most developing countries exclude other network suppliers, but non-electrified areas represent markets that are not satisfied. Other energy suppliers can meet the customers' needs, through a range of energy products from paraffin to electricity supplied by diesel engines, photovoltaic arrays or wind generators. Without external support, only economic development of non-grid electricity supplies will take place, with customers limited to those that can afford the full cost of an installation. With support from government or aid agencies the supply

of non-grid electricity has been achieved in several developing countries, eg Kenya and Zimbabwe, often working through the private sector. In South Africa there used to be a small private sector supplying alternative solutions. However, with the advent of the government's Solar Home initiative, based on the selection of new companies to be given licensed areas, most older companies have disappeared. The introduction of official financial assistance and licensing changed the market structure and introduced new objectives to replace the economic objectives of the past.

4.7.6 Evaluation of investigation into technology and processes

Electricity supply is a technologically based activity. The technology significantly affects the operations, cost of services and support processes needed. The core technology must be sound. Innovative financing, creative marketing or excellent management is insufficient to make an unsuitable technology effective, but may conceal some discrepancies. Therefore it is necessary to identify the best technologies and then support them effectively.

The analysis of electrification in South Africa indicates that the process changed progressively through the programme. It indicates continuous learning from experience, and that the objectives, processes and issues were not fully understood at the start of the programme if, in fact, a starting point can be identified. Statements from persons and organisations involved in the programme indicate a lack of understanding of the objectives. In this respect, the evidence appears to support the hypothesis of this research.

The electricity supply systems in South Africa have not broken down in the ways reported from other African countries. The electrification programme, despite some apparent deficiencies and criticisms, has been successful by many measures. Weaknesses in the financial and economic viability have been identified (though not perceived as fatal flaws), which leads to the idea that the objectives must include other aspects than financial and economic development. Several statements about poverty alleviation require serious consideration that the programme has a significant social element.

The details of the case studies and examples used to illustrate the technology analysis, and the results and other evidence presented to support the hypotheses, inherently risk having a bias towards the intended conclusions. The scale and complexity of electrification dictate that an experiment with an appropriate control cannot be carried out. Cases that contradict the intended conclusions (that is, disprove the hypothesis) have not been concealed, but are difficult to identify.

Alternative interpretations of the experience of the national electrification might be that the process and outcomes were completely expected before commencement, or that the utility management was inadequate and should have identified the needs and trends at an earlier stage. Personal involvement supports the available objective evidence of responsive changes as the programme progressed, negating the former possibility, and receipt of awards for excellence by several utilities and individuals make the latter unlikely.

4.8 Onword

The achievements of the national electrification in South Africa from 1991 virtually doubled the number of domestic customers in 10 years. The electrification was characterised by a continuous and substantial change of technological standards. The changes included the greater application of single-phase instead of the traditional three-phase distribution, the adoption of new technologies in line design and feeder conductor selection, the broad application of prepayment metering, and revised industry standards and implementation procedures. The result was lower electrification connection costs.

The adoption of new technologies was enabled by innovative research and development in the private sector and universities, which already had close relationships with the utilities and received their financial support for research. However, a change from the approach of meeting numerical targets for connections was largely driven by recognition of the high costs of the existing standards and methods.

The development may be viewed as an engineering approach to problem solving. As the challenges changed, so the staff of the electricity distribution industry responded with better technology.

The scale of the change was such that it challenged several conventional ideas of electrification. It was generally accepted that capital investment costs per customer in rural electrification are high, but the experience shows that appropriately planned rural systems may not be more expensive than urban systems. Further, the financial constraints and customer needs that forced down the costs of electrification also challenge the standards, technologies and approaches to non-grid electrification so widely supported by some development assistance agencies.

Technology improvement is not unique to South Africa. Its importance in the context of this research is that it was stimulated by an awareness of costs that was symptomatic of new needs in distribution and electrification, even if the nature of the change was not clearly understood. The technological achievements of the electrification programme also created opportunities to extend further the concepts of the benefits of electrification, and this aspect is investigated in the following chapters.

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Chapter 5

Electrification Ethics - Rights and Responsibilities

5.1 Introduction

The analysis so far has shown that financial constraints can be a substantial driver of technological standards, and that the new standards create opportunities for extending the benefits of electrification towards social development. However, the development needs to be understood in the cultural and social context of the people being served and the demands made on those who support the development. This leads directly to a consideration of the role and objectives of aid organisations, which define and support development by providing project funding and imposing conditions on borrowers. The broader issues of responsibility for electrification and public safety also affect electrification and, with the current focus on sustainability, the impact of electrification on the environment needs to be assessed. Therefore, this chapter examines some of the ethical issues relevant to electrification, particularly in Southern Africa, with the intention of establishing a basis for examining further the supply of electricity for social objectives.

Expressed slightly differently, the chapter develops answers to the following questions:

- What responsibility/obligation is there to support people who do not have or cannot afford electricity supplies?
- How does this obligation affect aid policy and practice?
- What public safety liability accompanies the broader development of electricity networks, especially where electrification is for social development, and what can be done to reduce the liability?
- What impact does electrification have on the natural environment?

And, ultimately, how do these aspects affect electrification practice and costs?

5.2 Responsibilities and obligations relevant to electrification

The obligation of the rich to support the poor in the national or international community is a difficult ethical and political issue of modern society. A responsibility for looking

after the children in a family is common to all cultures, but responsibilities to those outside the family and to other cultural groups within a country or beyond it are not felt as strongly. That responsibility is founded in ethics - the principles behind the code of behaviour of society.

Some development is undertaken for purely economic reasons. The revenue from sales of water and electricity will pay for investment in a dam. The risk of losses in a stable country is small, so low rates of return on such an investment are acceptable. Therefore, the development can be justified using financial models of the market economy that operates in most countries. The concept can be extended to socio-economic development: the infrastructure services for a region may not be financially viable, but the benefits to the broader economy may justify the investment. However, an investment in social development may give neither financial nor economic return, and can only be justified for other reasons, basically for an ethical obligation or political gain. These ethical and political aspects are examined in this section, for the purpose of understanding the pressures for electrification and the assistance that is received as aid and government support.

5.2.1 Ethical obligations

Ethics is related to law, but not directly. The law attempts to interpret the rules developed by ethics, translated through legislation, precedent and custom. Much of the formal law in Western countries, developed over hundreds of years, is aligned with Judeo-Christian principles, from when countries were nominally Christian states and the religious principles were the basis of the law. In post-Christian modern society, ethics are in flux, being founded on ideas of equality and fairness expressed in the human rights charter, which is less narrowly defined than the principles that led to its formulation. However, except that they come from the Bible and so are not acceptable in that format to everyone, the religious basics of social development ethics in the western cultures were described effectively in the letters of Paul of Tarsus nearly 2000 years ago - see box 3.

Box 3: Religious obligation for social development

See to it that no-one takes you captive through hollow and deceptive philosophy, which depends on human tradition and the basic principles of this world. [Col 2:8]
Be careful to do what is right in the eyes of everybody. If it is possible, as far as it depends on you, live at peace with everyone. [Rom 12:17-18]
Command them [those who are rich in this present world] to do good, to be rich in good deeds, and to be generous and willing to share. [1Tim 6:18]
Source: NIV Bible, 1978

By contrast, in most of Africa the recorded law is relatively young compared with that in developed countries. Although most of the formal law has been derived from colonial days, modifications to include customary law have created a uniquely different structure. Property rights are significantly different, with alienation of property by decree (as for example in Zimbabwe), communal property, and differentiated property taxes being widely practiced. The elements of Ubuntu ("I only exist in relation to you") can be recognised in those communities with access to electricity considering it unfair that they should receive subsidised tariffs while neighbouring communities still do not have access to electricity²⁰. At the same time, electricity theft and vandalism of the property of electricity utilities is condoned or justified in some communities by a "right" to have electricity at the cost of others (see case study 6 in section 5.2.5). The utilities have to enforce property protection and control energy theft that, as criminal acts, should be prosecuted by the police. Inherently, then, there are conflicting concepts of rights and obligations in many African countries.

Rights given or denied affect even the structure of the electricity industry. The electrification of squatter households is prevented by the argument that services provision would convey property rights to the illegal occupants over the rightful owners. But the politically best-connected receive monopoly concessions, including the legislated takeover of the VFP assets by Eskom and the administered restrictions preventing municipalities from establishing or expanding their own generating plants. Similarly, Karekezi and Kimani [2002] identify a seldom-mentioned group of beneficiaries associated with greater local participation in the power sector that *"invokes the involvement of the political-connected rent-seeking class that has been largely responsible for poor performance of the state-owned power utilities."* They continue: *"The challenge for future reform measures is how to promote local participation without handing over significant chunks of the electricity industry to the same rent-seeking class that has been responsible for running down the industry"*.

The problem is that some well-meaning regulations can create opportunities that distort the economic system. For example, in South Africa, preferences given to Black Empowerment Enterprises as part of the corrective action since the change of government in 1994 quickly gave rise to an alternative meaning for the acronym: black enrichment enterprises, as ways were found to profit from the regulations.

Participation by well-connected, rent-seeking individuals, adding little value, is not found only in developing countries, but the apparent cultural tolerance in Africa for such activity is so extensive that it distorts the economic system. By developed country standards such actions are an abuse of privilege and unethical, and the

20 Comment received during fieldwork for research into a basic electricity support tariff.

management and governance systems act to limit them, even if they cannot be entirely prevented.

From a philosophical point of view (see box 4), arguments to support the right to retain wealth and the obligation to share it can both exist within one culture. As a result, arguments to support electrification are often applied inconsistently. Property rights, obligations to share, religious convictions, and relativism and social justice instead of absolute morality, all confuse the ethical basis of development.

Box 4: Philosophical obligation for social development

"If we can prevent something bad without sacrificing anything of comparable significance, we ought to do it.

Absolute poverty is bad.

There is some absolute poverty we can prevent without sacrificing anything of comparable moral significance.

We ought to prevent some absolute poverty."

Objections to the argument include giving priority to ones own group, protecting property rights, not being able to make a difference, and that the obligation sets too high a standard. But *"helping ... is something that everyone ought to do"*.

An equal consideration of interests, for the rich and the poor, may require more help to be given to some than to others. Scarce resources will limit just how much more in each particular situation.

Source: Singer, 1993

5.2.2 Political base

Only religious principles and a humanist "feeling sorry for the destitute" provide ethical grounds for the apparent responsibility for charity. Another powerful reason for sharing with the poor is to gain something in return. Politicians will promise development to communities from which they want voter support, businesses will contribute to community schemes for commercial returns from affiliation, and nations will give to other nations where they want to influence decisions, to win support from their own communities or for peer recognition. These reasons for supporting development can be described as pragmatic (see box 5).

Box 5: Pragmatic obligation for social development

"Quite simply, the gap is getting too wide between the rich and the poor countries and between the rich and the poor within countries" [Visser and Sunter, 2002]

Some people accept neither a religious nor a philosophical obligation to help others less fortunate than themselves. The preparedness to help may instead be based on a perception that the assistance will be good because it generates a benefit for the giver, such as political advantage or trade opportunities, or that it will delay or avoid something bad, in the sense that it is rooted in fear of the alternative.

In general, the wealthy can influence the law to protect and promote their rights and restrict and outlaw the actions of those seeking to oppose them. Yet, there is a growing sense that the wide gap between the rich and the poor in the world threatens the safety and security of the rich. They can, to a limited extent, protect themselves from the poor, and punishment and sanction are used to deter behaviour judged by the authorities to be unacceptable. However, protection does not address the basic problem of the perceived inequalities. Poverty and deprivation are blamed for theft and physical abuse, so poverty reduction is seen as a way to improve moral behaviour. Locally and internationally, aid for development and direct transfers for poverty alleviation are necessary strategies to reduce the risks of aggression, including crime, property invasion, illegal immigration and terrorism, although the public justification of these aid and assistance strategies may be described as being for humanitarian or religious reasons.

Political action is not limited to governments or business. The rise of NGOs (non-governmental organisations) can be ascribed to the perception that people have only limited say in the processes of government and business, but can use other mechanisms, including communication technology, social responsibility and sustainability issues to draw attention to their objectives. Sometimes the NGOs provide better representation of the interests of the intended beneficiaries, such as the poor and women, than the decision-making processes in government and business.

5.2.3 Support for electrification

The responsibility for electrification or poverty alleviation or both, therefore appears to be based on:

- reducing socially inspired terrorism and aggression,
- increasing political influence,
- humanitarian reasons,
- religious beliefs, and
- generalised feelings that it is "right" to support the weak in their weakness and hope for a better future.

Arising from this variety of religious, ethical, humanitarian, political and pragmatic arguments, there is widespread support for electrification and for grants or subsidies to help the needy. As a result, *"The question is no longer whether rural areas will be electrified, but when"* and *"Obviously, the actual costs of rural electrification have to be determined, but one should also ask the question what it would cost society, in quantitative and qualitative terms, if rural areas remain deprived of electricity"* [Zomers, 2001].

Responsibility for economically viable electrification is a trivial problem - banks will support financially viable schemes and development finance institutions will fund socio-economic programmes. The ethical issues of economic electrification involve limiting the rights to supply electricity, the size of the profit that is permitted and who carries out the regulatory functions.

Where the benefits of poverty alleviation and political gain exceed the financial and economic costs, a government may still rationally decide to implement social electrification, meeting the costs by reallocating resources. The decision is basically a political one, as reported by the Regulator: *"... it was understood from the beginning that the primary motivation for the massive electrification of disadvantaged communities was not to achieve economic benefits. For socio-political reasons it made sense at the time, as it still does, to improve the quality of life of millions of South Africans while at the same time creating opportunities for jobs and prosperity"* [NER, 1998]. Clearly, financial and economic viability are not the principal objectives, nor even obvious constraints on the electrification decision. The dominant ethical issue is whether the government has the right to use the resources for the political gain derived from poverty alleviation. This is particularly sensitive in a developing country context, where resources are already scarce.

5.2.4 Balancing other responsibilities with that for electrification

As already quoted at the start of the thesis: *"The annual budget of R1.2 billion from the fiscus needs to be maintained in order to achieve universal access"* [Mlambo-Ngcuka, 2001]. Although the government is committed to electrification, its responsibility is limited by the constraints of other responsibilities for education, health, other social services and the economy as a whole.

The beneficiaries of social electrification are an undetermined group, including customers and society as a whole. Many of them have only very indirect benefit and, if asked, would be unable to assess what share of the costs they could reasonably share. Usually, then, the responsibility for electrification belongs to the government. Zomers [2001] similarly found that *"It should remain the responsibility of the government to look after the interests of the poor"*.

The government can support a utility's social electrification by direct funding or through regulations and directives. In a completely market oriented system the administration of poverty alleviation is a commercial transaction, defined entirely by contract between a utility and the government department responsible for poverty alleviation. Where national and local government own the electricity industry, the social actions of poverty alleviation can be regulated by policy and control with much greater flexibility.

However, there is also greater scope for distortion by political interference, incompetent management and corruption because of the looser definition of the objectives and processes compared with commercial contracts.

Another approach to poverty alleviation is by grants directly to the needy. However, practical problems arise. In some cases, the public service does not have the administrative capacity to deliver the child support and other poverty alleviation grants introduced in South Africa during the past 10 years. Channels of delivery are susceptible to fraud and the grants do not reach the families for whom they are intended²¹. Other problems associated with some poverty relief grants include the attitudes inculcated by them. For example the support grant for children up to the age of 7 (and proposed for extension to 18²²) can be a significant portion of household income, and exerts pressure to use children as a source of income despite the difficulties of registering for the support.

Therefore electricity delivery and consumption subsidies can potentially extend the benefits of poverty alleviation in a way that is less open to misuse than other poverty alleviation policies.

Of course, it is generally assumed that electrification for socio-economic or social reasons will be good for a country. However, any investments and subsidies for electrification divert resources from other uses. All government expenditure, whether for infrastructure or social support, incurs a cost for the economy. Unless the future benefits exceed the costs, an "investment" is only a form of consumption. Over-investment in infrastructure that is unproductive or under-productive, and subsidies that do not promote development are all consumption. If too many resources are allocated to alleviating poverty, the economic capacity of the country and its sustainable support of the social action can be crippled, leading to external intervention in national affairs by creditors. So, in the extreme, an electrification programme may have significant negative impact on a utility, government and economy as a whole, particularly if the performance is not as good as predicted, as has been the result of many electrification programmes.

21 Z Skeweya, Minister of Social Development, in radio interview SABC 25 Oct 2002

22 51st ANC National Conference, Stellenbosch, 16-19 December 2002.

When a country no longer has sufficient outputs to trade for its requirements, and no reserves, it becomes functionally bankrupt. The transition from apparently normal conditions to one where the currency collapses against others can be quick, as illustrated in Figure 5-1. It is for this reason that rapid changes are usually taken very seriously by financial authorities, such as happened in South Africa when the Rand fell so sharply against other currencies in December 2001 before recovering again at the end of 2002.²³ It is the responsibility of the politicians and government officials to take the effects of subsidies and low productivity investments into account in their policy development, limiting them to sustainable levels over the long term, even where funds are provided by aid organisations.

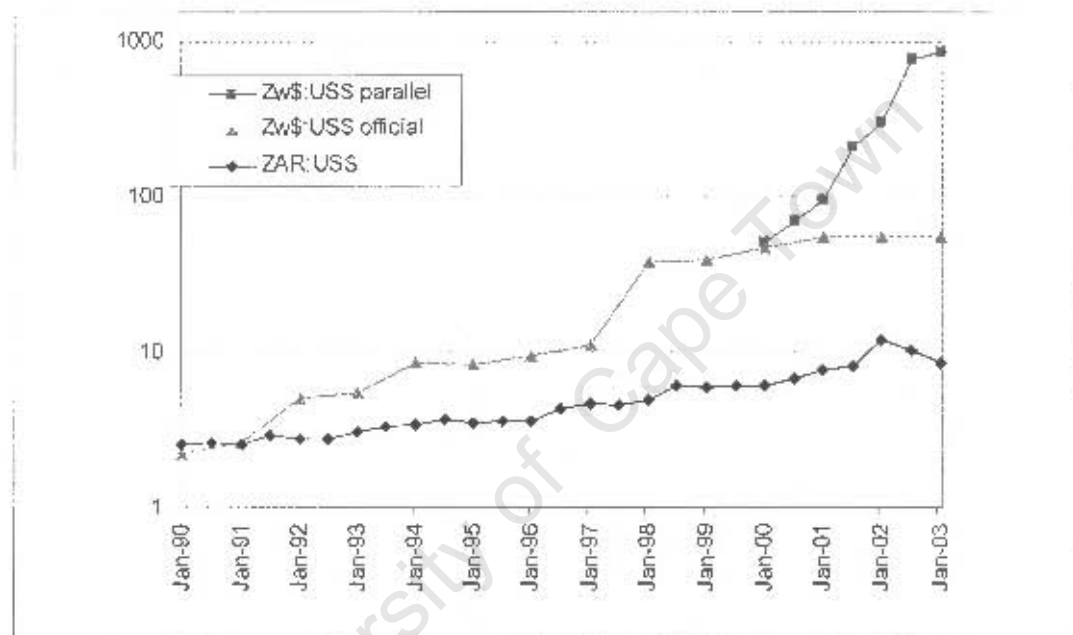


Figure 5-1: Depreciation of the SA Rand and Zimbabwe Dollar against the US\$

Sources: Mangwengwende [2002] and Oanda [2003]

National bankruptcy has severe implications for the poor and aged. For example, the buying power of a pension of an electrical engineer, after a career with an international firm in Zimbabwe, has been reduced to less than US\$0.5/month and the company can do nothing about it²⁴. For those outside the inflation-adjusted wages of the formal sector, economic mis-management and structural adjustment programmes, which have similar effects, are the cause of poverty increase. As well as having apparently unfair impact, national bankruptcy caused by excessive social "investment" is simply the result of not giving equal consideration to the interests of all parties. The implications for decision making are considered further in the next chapter.

²³ Rates were 9.0 on 1 Nov 2001, 12.1 in Jan 2002, 10.4 in Jul 2002 and 9.3 in Dec 2002. [Oanda]

²⁴ Private communication with Chairman of PB Power, December 2002

5.2.5 Accountability, corruption and theft of service

The consideration of ethical responsibility has concentrated so far on the obligation to help the poor in their need. But rights bring responsibilities, for beneficiaries of assistance and those who give, direct or influence it.

Common problems in developing countries detracting from the performance of electricity utilities and government include both illegal practices and unethical behaviour:

- theft of electricity and of components of grid and non-grid electricity supply systems, including conductors, earth wires, structural steel, PV arrays and batteries.
- corruption of utility officials, including installation inspectors, meter readers, electricity vendors and electricians, who are prepared to ignore unacceptable conditions or provide an unauthorised service for a personal consideration.
- officials allowing themselves to be unduly influenced by potential contractors in the adjudication of tenders, formulation of standards or appointment of staff.

The causes of these problems relate to the culture of the society as a whole, including concepts of entitlement derived from physical strength, mass action or positional power; opportunism; gender discrimination; respect for elders even when they are wrong; and to the weaknesses of organisation management in such an environment. Corruption and theft have implications for the broader economy also. Both involve taking for personal use the property belonging to others. Where little attention is given to prosecuting corruption and theft or, in the extreme, legal provisions sanction such activities, they undermine the whole economic system. Some of the problems are illustrated in case study 6. Neither law enforcement nor other remedies are easy. Zomers [2001] reports *"the widespread corruption in some developing countries is one of the most difficult impediments to an adequate performance of parastatal organisations. Practice shows that these ingrained institutional practices are not easily redressed by technical assistance."*

Case study 6: Non-payment for electricity in Soweto

Patrick Bond, a business professor at the University of the Witwatersand and co-director of the Municipal Services Project, acknowledges that it is expensive to provide electricity to the poor, who use little electricity and are unable to buy it in bulk through their municipality, which results in duplicate costs for equipment, administration and labor. But he said Eskom could largely resolve the debt problem in Soweto by charging big industries a few cents more for each kilowatt of electricity, subsidizing a cheaper flat rate for poor customers.

by Jon Jeter, Washington Post, 6 November 2001

On these streets, Matseone and other members of Operation Khanyisa - "Reconnect the Power" in Zulu - are familiar figures. They roam the township openly defying police and the state-owned electric utility, Eskom, by re-connecting power to thousands of households whose electricity has been cut off for non-payment. "Electricity and water are a right, not a privilege," said Matseone, wiping sweat from his bald pate and adjusting his track suit. "We're just taking what the government has promised us." ... When Nelson Mandela's black-led government took power, it canceled utility debts with a tacit agreement from residents that they would start to pay their bills. But in the eight years since, more than 1 billion rand (about \$100 million) in new debts have piled up. Non-payment, while it is most pervasive in Soweto, is a pattern in black townships across the nation.

by Samson Mulugeta, *Newsday* 19 May 2002

The bottom line is that the citizens of South Africa have a constitutional and human right to basic services. Harsh cost recovery measures are undermining these rights. The government is faced with a clear choice: either abandon the dogma of cost recovery or face the wrath of thousands, even millions, of citizens victimised and criminalised because they cannot afford to pay the price of the essential requirements of life.

by David McDonald and John Pape, *Mail & Guardian*, 30 August 2002

Analysis

- (1) The participants in the Canadian-funded Municipal Services Project are strong proponents of free basic services in South African townships. The project's research results are disseminated in several forms including the popular media, as above, and mostly represent the interests of those not paying for services.
- (2) The issue of municipalities getting bulk electricity cheaply does not take into account the costs of distribution. The municipality distributed electricity in Soweto until 1994 when Eskom took over the supply rights and the network assets.
- (3) The right to free services, espoused by politicians during the elections, is not financially viable except for a limited supply of basic requirements to the poor. Privatisation, as promoted by international finance agencies, cannot implement economic tariff reform or achieve cost recovery under conditions of widespread, unlimited free supply.
- (4) The arguments for free services neglect the equal consideration of the interests of all.

5.3 Aid policy and practice

International aid is given for a variety of reasons and under a variety of conditions. Many aid organisations require the involvement of foreign specialists, that is nationals of the donor, leading to the introduction of "foreign" standards. Sometimes aid introduces a new technology. The implications of these practices are examined in this section, including the responses of the utilities, and a review of the objectives of aid.

5.3.1 Standards introduced by foreign aid

Two case studies illustrate the adoption of inappropriate technical standards in projects with significant foreign influence. Case study 7 is a typical case of bilateral international aid, in which the consultants and contractors are required to be domestic companies of the donor country.

Case study 7: An HV overhead line

An aid agency provided the capital for a new HV line. The conditions of the grant required that the consultant and contractor be national firms of the donor. Designs and specifications for a line on steel lattice towers were issued and the lowest tender was by a local company as a subcontractor to the main contractor. Alternative tenders were invited for a wood pole line based on sketches provided by the consultant, and an offer was received at a significantly lower cost. The donor requested an independent review, during which it became clear that:

- the utility wanted a steel tower line because it felt it did not have capacity to carry out line maintenance.
- the specifications defined that the life of a wood pole line would be 15 years and a steel tower line 40 years.
- the conditions of the grant from the donor required that the utility would repay to the government the on-lent loan with interest.
- a substantial saving was not desirable because the approved project budget allowed for the expensive steel tower line, and the alternative offer was an embarrassment.

As a result, severe assumptions were made about the failure and replacement of the wood poles, based on another project in the recipient country for which wood poles had not been treated properly nor had they been maintained. The project proceeded with the main tender of a steel tower line, and was profitable for the local contractor and the national firms of the donor.

Source: Own experience.

Analysis of impact:

(1) The comparison of the lifetime costs of the alternatives was very sensitive to the assumption about the life of the wood poles. Extending by 5 years the assumed average life of 15 years made the wood pole alternative significantly less expensive to both the donor and the utility. Alternative cost-saving designs identified during the evaluation and based on practice in the region could not be considered because of the tendering conditions.

(2) Independently of the outcome of the alternatives, it was evident that the capacity of the utility to operate and maintain its network needed urgent attention.

(3) The different terms of funding, free to the government but with interest to the utility, created a conflict of interest.

Possible alternative:

The use of consultants without local knowledge incurred extra costs for both the donor and the utility. The utility would have benefited from using local designs and contractors and obtaining loans at commercial interest rates instead of using the soft loans from international aid with the attendant constraints.

Case study 8 analyses the construction of a new industrial site at HaNyenye in Lesotho was undertaken by the national development agency, where the national electricity utility imposed standards that demonstrated significant foreign influence.

Case study 8: HaNyenye Industrial Site

Lesotho is a country entirely surrounded by South Africa. During the years of struggle against apartheid substantial international aid was directed to Lesotho. Among other activities, the Lesotho National Development Corporation (LNDC) developed industrial sites for factories producing goods mainly for the South African market. The electricity infrastructure was provided according to the Lesotho Electricity Corporation's (LEC) specifications. There were several disputes between the two organisations over standards, such as the fault level ratings for which the specifications called for much higher capacities than were found in practice.

At the time of the development of an industrial site for about 30 factories at HaNyenye in 1989, the LEC had adopted standards prepared by French advisors. Therefore, although the whole supply to HaNyenye and the MV distribution within the scheme was by overhead line, three indoor switching stations with French manufactured switchgear were required. LEC also required that all the planned MV/LV pole-mounted substations be built and equipped with transformers to meet the full projected load and all the LV cables be installed to every site. Despite the high costs of this infrastructure, LNDC had no option except to comply.

Within a few years of completion of the site development, political changes in South Africa removed the artificial demand for expensive manufacturing facilities in Lesotho, as companies were now able to use competitive facilities closer to their markets.

An independent visit to HaNyenye ten years after its construction revealed that only about 20% of the sites were developed, the switching stations had been vandalised and the switchgear had not been repaired, and the oil had been removed from several pole mounted transformers. See Figure 5-2.

Source: Own experience.

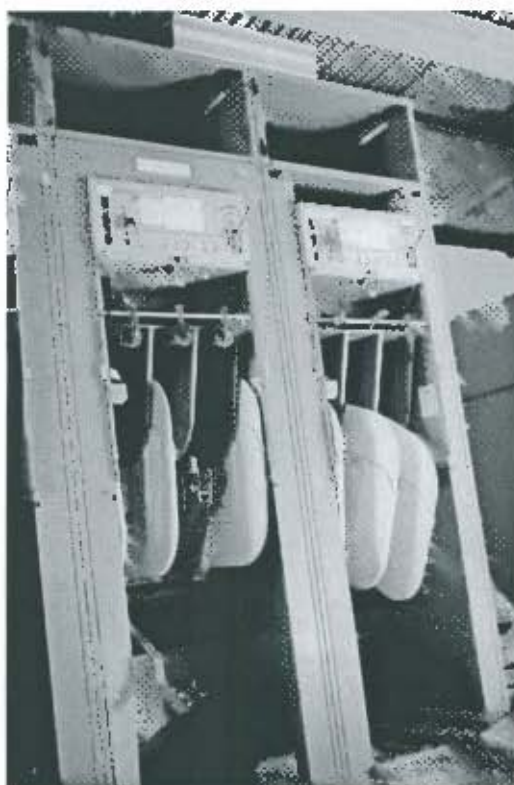
Analysis of impact:

The inappropriately 'high' technical standards imposed on the development had increased costs to uneconomic levels. When conditions changed, as frequently happens in developing country economies, the project, with its high fixed costs, was not financially viable and fell into disrepair. Expensive facilities were bypassed to provide supply to the few customers.

Possible alternatives:

(1) Investment in developing countries has particular risks and uncertainties different from, or more extreme, than those in developed countries, as reflected in the higher discount rates typically used for assessing capital expenditure proposals in developing countries. Financially, the higher rates indicate that initial investment should be kept as low as possible. High technological standards based on possible future long-term development may not be suitable. Later upgrading or reinforcement can be paid for out of early savings when discount rates are high. From this point of view, the costs of infrastructure at HaNyenye should have been kept to the minimum possible.

(2) The LEC was concerned that it would not have the financial resources for upgrading at a later stage. The weaknesses of the utility should have been managed separately, instead of being compensated by charging excessive costs to another government agency.



Indoor switchgear, now bypassed.



Pole-mounted transformer, emptied of oil.

Figure 5-2: Vandalised equipment, ten years after installation at Hanyenye

The characteristics of the overhead line and the industrial site development projects are not unique, and in my experience have been repeated in similar conditions in at least three other countries, involving different donors and different projects for network improvements. In some instances, the specifications for the projects require locally available materials to be supplied from distant sources. Others, such as a World Bank worker in the context of tropical West Africa, have reported similar experiences: Bergman stated, "Transmission lines in Burkina Faso were built according to French specifications, to withstand ice loads" [quoted in Applewhite, 2002]. Similarly, Ellis and Tveit [1986] reported:

"A red line through many of the reports is the description of problems caused by the abundance of consultants, entrepreneurs and industries from several donor or aiding countries which have supplied their service. As a consequence the electricity systems in the developing countries are too often a conglomerate of different solutions, a great variety of equipment and with specifications which are not suited to the local conditions. This is more or less imposed on countries where the technology and education level is behind that of the aiding countries. Consequently the developing countries lack operations, maintenance staff and spare parts to keep the plants in a

satisfactory operational shape. Thus aid given and accepted in this way may in the long run be very costly, and may hamper a reasonable development."

Ramasedi [1992], commenting on projects in Botswana, puts it as follows:

"On many occasions a donor's objectives have turned out to be completely different from those of the recipient - for example, the donor's priority may be the creation of employment in his country. That these misunderstandings arise is not the fault of the donor alone, but also of government officials in developing countries who are sometimes prone to corruption."

Finally, Miller et al [1995] identified specific concerns about donor support, including:

- *"Donors tend towards high-profile projects in politically appealing and visible cities and provinces, and so ignore more poverty-stricken areas;*
- *the priority for visiting experts is to serve their clients, the donors, rather than the host country and they are therefore constrained to politically correct policy recommendations; and*
- *the insights provided by visiting experts funded by donors are often viewed as misleading and empirically incorrect."*

5.3.2 Foreign aid support for renewable technology

PV systems are considered particularly appropriate for developing countries because they will reduce future emissions (environmental externalities), are modular so they can meet any size required, have low maintenance and are suitable for local entrepreneurship. Such properties should also make PV systems very suitable in developed countries, but experience there indicates that they are only economic (and often only marginally so) in particular circumstances. In fact, by adding the risks inherent in a developing country environment (theft of panels and high cost of failure of the systems²⁵), PV systems appear to be more risky and less attractive than in developed countries.

Although PV technology is mature, obstacles to its widespread implementation include the high cost per unit of energy; the lack of institutional structures to finance, maintain and manage the systems; and the large initial capital and foreign currency component of lifetime cost. (Chapter 4 illustrated the need to keep initial costs as low as possible in developing countries because of the high cost of capital and the uncertainty of development, so high initial cost is a significant disadvantage.)

²⁵ According to Acker and Kammen [1996] only 60% of systems visited by them in Kenya were fully operational and 10% were completely out of operation.

The strong support by aid agencies for PV electrification indicates that the problems are not being fully understood by the agencies or that there are other objectives weighing the decisions.

5.3.3 *Utility response to aid*

Important ethical and practical issues arise:

- The decision makers in aid donor organisations, recipient governments and utilities are answerable to different entities in respect of decisions that incur extra costs.
- The objectives of various organisations can directly conflict with each other.
- Utilities have difficulty assessing whether their advisors are giving good advice.
- Responsible officials in the utilities are often insufficiently informed to be able to make judgement decisions when aid is offered on restrictive terms.
- What utility employee given the choice of managing an impressive project or a smaller “appropriate technology” project will choose the latter, considering that the choice will have little or no impact on personal salary, and the former brings opportunities of foreign “training”?

The response of the Botswana Power Corporation to similar problems with projects funded by foreign aid was to develop a system of standards to inform and control the introduction of new equipment [Scales et al, 1993]. However, such an approach can still cause problems where the standards are inappropriate for the network, as illustrated in the case of the HaNyenye industrial sites.

5.3.4 *Reviewing the objectives of and alternative approaches to aid*

Resolving the ethical and practical issues is beyond the scope of this thesis, but they need to be taken into account in the giving and acceptance of aid.

Where aid agencies support technology beyond the capacity of the local community to adopt the standards for their own, because of constraints imposed by financial or skills resources or because the technology is basically inappropriate, the number of installations that will replicate the aided projects is very small. In fact they will probably be limited to the demonstration models for which a donor agency is willing to pay [Foley, 1997]. Therefore, aid organisations also need to consider the alternatives.

There is wide resistance to subsidies, particularly from international monetary authorities, yet the same and similar organisations are donors of aid. The differences and similarities between aid and subsidies include:

- Aid is under external control, but subsidies are under the management of officials in local organisations subject to political interference and having weak controls over misappropriation.
- Most aid is of a capital nature, but regular aid can have a similar effect to long term subsidies.
- Subsidies (particularly for productive enterprises, but also for assistance to the poor) are criticised as distorting the economic allocation of resources within a country, but may not differ from aid at a national level.

The ethical basis of aid applies also to subsidies. In the same way that development has different objectives (economic, socio-economic and social), subsidies may be used for economic and socio-economic development (political influence, business opportunities) and for social purposes (humanitarian, religious objectives).

Making electricity more affordable to the poor has several components, including²⁶:

- matching the capacity of the supply to a level which is appropriate for the level of poverty (poverty in Europe and Africa have similar elements but are not the same), such as by providing load-limited supplies;
- adopting technical standards that are appropriate to the level of poverty, and including in the standards a wide range of aspects like technology choice, power quality, component standardisation, electrification project management procedures, etc;
- reducing the tariff to a (possibly) sub-economic level and subsidising shortfalls from elsewhere;
- administrative procedures for the “marketing” of new connections and the ongoing maintenance of the commercial relationship between the supplier, customer and subsidy provider; and
- managing and regulating the electricity supply process to reinforce good practice.

These approaches are related to each other and cannot be considered separately, though many people do and make the unavoidable mistakes. “Best practice” is a combination of the sub-practices in a way that is totally appropriate to the “problem” and the environment or country in which the practice is being applied. A solution in one country, or in one utility in a country with several utilities, may not be good practice in another setting, but some practitioners do not appear to be aware of the limitations of some “solutions”, as already described by Ellis and Tveit (section 5.3.1).

²⁶ Edited extract from Gaunt [1999b]

The role of aid for electricity system development and the underlying principles of "development co-operation" appear to be changing [World Bank, 1994]. The smaller size of electrification projects, compared with large power station developments, appears to suit bilateral aid. Also, there is more private capital funding, because the international finance community expects that privatisation is more likely to be successful in overcoming the inefficiencies associated with political interference in public utilities in weakly governed countries. From the point of view of the recipients, this may not appear to be much of a change, in that the funds are only made available on terms largely outside their influence.

Electrification for socio-economic objectives is a low-profit activity, and for social objectives it is inherently not profitable. Support in the form of subsidies or aid or both are required, with appropriate conditions applied by donors. To the effect that aid and subsidies are structured to meet the real needs, they have the capacity to be very effective.

5.4 Safety and liability for risk

An ethical issue arises regarding public safety in the context of electrification. Widespread extension of the network potentially exposes more people to electrocution accidents. At the same time, many lives are saved and injuries avoided by the reduced use of and exposure to candles, open fires and paraffin (fires, burns and poisoning by ingestion).

The assessment of safety is complicated by the results of dishonest activity. There were more than 2000 cases of cable theft and illegal connections reported in Eskom countrywide between 1995 and 2001. During 2001 there were 82 deaths caused by tampering with electricity, many as a result of conductor theft and illegal connections. There were 23 deaths, including 13 children, and 34 injuries from attempted conductor theft during the first four months of 2002 [Misrole, 2002]²⁷. These Eskom figures do not include the municipal utilities serving a similar number of customers.

This section considers some of the implications of safety for electrification programmes.

27 The Eskom annual report [2002] records 87 public safety fatalities in 2001 and 45 in 2002.

5.4.1 Aspects of safety

A system or technology could be considered to be safe if those exposed to the system are aware that there are risks, and accept them. Generally, safety risks are offset by benefits, otherwise implementation of the technology or system would not be considered. Modern society has a large technological component that is likely to increase in future, and in which complete safety is not attainable and marginal improvements carry a high cost.

Taking overall benefit, while accepting increased risks of damage to a few, assumes that the greater good for large numbers of people is more important than individual harm. The ethical and cultural validity of this approach affects the liability for compensation for those disadvantaged.

Electrification has a direct impact on the quality of life and, although safety is important, welfare is too. The advantages derived or perceived from electrification appear to far outweigh the risks, or electrification would not be so widely desired. However, it is important that the planners of electricity networks understand the constraints that apply. Greater safety is a benefit, but it usually incurs costs. The costs of improving safety compete with other applications, so without standards (constraints) the lowest cost will dominate system design, compromising non-monetary properties (safety, quality and reliability).

All society is responsible for promoting safety - schools, government, media, utilities, and parents. Improving the understanding of the risks associated with electricity, particularly among those with limited experience of it (the poor), contributes to greater safety.

Therefore, it is necessary to examine the extent of the risks and the responsibility for reducing them.

5.4.2 Safety improvement by electrification

The introduction of electrification has a demonstrated benefit of lower death and injury from poisoning, burns and fires, and indoor air pollution.

Wood, coal and paraffin combustion causes significant indoor air pollution, consisting mainly of particulates and carbon monoxide. Models indicate that greater use of electricity for household energy would reduce the annual cost of clinic and hospital treatment for acute respiratory infections in children under 15 years, closely linked with indoor pollution, by about R67 million [UCT, 2002].

Coal, wood, paraffin, gas and candles are often the cause of accidental fires and burns, resulting in injury and loss of life and property.

"The close proximity of informal housing units to one another often results in a fire in one unit destructing many other units, and causing many cases of burns (particularly in children). For example, the Salt River State Mortuary in Cape Town attributed 75% of children's deaths between 1990-1991 to residential fires (van Horen, 1994). In 1996, a paraffin related fire destroyed over 1000 homes in Duncan Village, East London (Bank and Mlomo, 1996)." [UCT, 2002]

Another safety risk associated with the widespread use of paraffin is the accidental ingestion and poisoning, particularly of children. A recent market survey [Markinor, 2001] led to estimates of about 120'000 incidents of paraffin ingestion annually, resulting in 55'000 hospital admissions and 4'000 deaths. The estimated treatment costs exceed R330 million per year [UCT, 2002].

Obviously, electrification (access to electricity) will not prevent all these injuries and deaths. Some households will continue to use fuelwood, where it is available and can be collected at no financial cost, and paraffin because its direct cost for heating is lower than the cost of electricity. Despite the limitations, the economic benefits of electrification arising from reduced risk of injury and death are significant, but the electricity utilities receive no benefit.

5.4.3 Risks introduced by widespread electrification

The risks arising from widespread electrification are associated with the greater length of overhead lines, the larger numbers of equipment installations and the exposure to electrical appliances in the homes. The principal dangers appear to be:

- exposure to electric shock by customers' incorrect use of appliances, or use of faulty appliances.
- exposure to accidental contact by construction equipment operators, and farm workers carrying irrigation pipes or riding on full trailers.
- damaged or broken conductors, insulators and poles, caused by storms, lightning, insects and other natural causes, particularly where the result is a low hanging conductor or a fault condition that cannot be detected by the network protection systems.
- human interference, see figure 5-3, including theft of electricity or network components, vandalism, and curiosity, especially when resulting from exposure of live parts of the system caused by theft of padlocks or fences.



Figure 5-3: Low hanging conductor as a result of attempted cable and conductor theft by cutting two wood poles

Many contact incidents, but not all, cause serious injury and some result in death. In South Africa all contact incidents should be reported to the Inspector of Occupational Health and Safety, but electricity utilities may not even be aware of accidents causing only minor injuries, especially where they arise from theft or vandalism. For example, in an incident of attempted cable theft, the damaged saw used to cut into a live cable was left behind but whether anyone was injured was never established.

It is very difficult to assign values to accidental death or injury. One approach is to compare it with the life insurance of about 3 to 5 times salary that is provided for many employees, but this does not help much in the case of people operating in the subsistence economy. A serious injury may be much more expensive than a fatality because of ongoing medical and support costs. Working with an annual salary (or equivalent) of about R30'000 to R50'000, typical personal insurance cover would indicate that the value of a fatality would be about R150'000 and an injury R500'000.

This sum might be taken as the cost that a utility would be prepared to spend to avoid an accident. Considering that it is unlikely that all accidents can be prevented, the annual expenditure on accident prevention must be justified by each utility according to their accident history. Monitoring the costs of accidents would allow estimates to be improved, but the information regarding settlements is not in the public domain. One of the problems that could arise from a formal and public approach to accident valuation is that it could inflate the claims made against utilities on the grounds that the risk was foreseen and therefore should have been prevented.

5.4.4 Responsibility for improving safety

The law appears to penalise an electricity utility for electrical accidents (see case study 9 in section 5.4.5), but does not allow the utility to benefit from the reduced costs of damages arising from other causes, such as shack fires and respiratory disease, that were not recoverable by affected persons prior to electrification.

Rural development and the improvement of the conditions and quality of life of the “previously disadvantaged” are being addressed with urgency in South Africa, and attitudes to development have transformed quickly during the past 15 years. Social perceptions and policies have changed, and new solutions are being adopted for new conditions. There is inherent risk in adopting new policies and practices, but the social risks and penalties of not making the changes are even greater. It appears, however, that the speed of change of electrification has outstripped the system of legal precedent and regulations.

The continuous change in perceptions is illustrated by the *Grootboom vs Graaf Reinet* case [2001 (3) SA 373 (E)]. It arose from injuries sustained by a youth who climbed a wood pole structure and was injured by electric shock. Evidence was led and not challenged in court that it was a standard Eskom practice to install anti-climbing guards on poles, even though this was not true. The judge found that historically disadvantaged communities cannot be held to be aware of the dangers of electricity, that the structure was inadequately protected against climbing and that the utility was negligent. This case has created a legal precedent by which the omission of anti-climbing guards on all structures could now be found to constitute negligence.

Ultimately the rest of the economy will carry the extra costs arising from regulations or decisions that require additional safety to be incorporated into electrification. Higher construction costs will increase the grants needed for extending electrification to the community. Compensation claims will be settled from the operating accounts of the utilities, and recovered in higher tariffs.

5.4.5 Reducing the liability arising from safety requirements

Electricity is not inherently dangerous and the risks of electrical accidents are much lower in all communities than the exposure to injury and death arising from vehicles²⁸, alcohol consumption²⁹, paraffin ingestion and smoking.

28 1092 died in vehicle accidents on South African roads during December 2002 [Cape Times, 3 January 2003]

29 “Nearly all” the 10 murders in Cape Town on Christmas Day 2002 were “liquor-related” [Cape Times, 27 December 2002], and alcohol is associated with many motor vehicle accidents.

Nevertheless, the existing presumption in law of the electricity utility's negligence requires the utility to prove in any civil action that it was not negligent (see case study 9). The regulation had its origin in the deliberations of the Selbourne Commission of Inquiry into the Power Companies in 1909 that recommended the supply of electric power *"be placed under government control and subjected to regulations which shall secure the equitable supply of power, the public safety, and public interests generally."* [quoted in Christie, 1984]. The safety regulation reinforces the normal liability arising in delict. The possibility exists to argue that the delict is offset by a greater good, but this would be unlikely to succeed in the context of the present regulations.

Case study 9: An overhead line accident

A youth climbed an overhead line steel lattice structure and stretched out in an undefined way with the intention of touching an insulator. A flashover occurred and the youth was injured. A claim for damages was made against the utility. According to Section 26 of the Electricity Act (Act 41 of 1987) in any civil proceedings *"damage or injury caused by induction or electrolysis or in any other manner by means of electricity generated or transmitted by or leaking from the plant or machinery"* is presumed to have been caused by the negligence of the utility, unless the contrary is proved.

It could be argued technically that the current giving rise to the injury was a current deliberately diverted from the conductors by the interference of the injured person, even if the result was not foreseen by him, so that Section 26 would not apply. If Section 26 were held to apply, the utility would rely on multiple approaches to showing it was not negligent. They should include:

- ✓ compliance with regulations regarding overhead lines.
- ✓ compliance with standards, guidelines, and other industry norms regarding:
 - the reasonably practicable protection of structures against climbing,
 - danger notices on structures,
 - the inspection and maintenance of structures, and
 - the protection devices to interrupt supply to the line.
- ✓ programmes for community education.

Source: Gaunt: briefing notes for case attorneys, 2001

Another approach to reducing liability might be to challenge the constitutional fairness of the imposed negligence, considering the broader context. A recent Constitutional Court judgement in South Africa [2000 (11) BCLR 1169] in respect of housing requires the availability of the country's resources to be taken into account, such that the cost of achieving a level of service (in this case electrical safety) will affect the standard of the service provided. Examination of the constitutional fairness would require assessing many aspects. Comparisons would not be made with first world standards, but with other developing countries. Also, the changes that have occurred since the existing regulation (now section 26) was introduced to regulate the safety of lines installed for economic purposes by private companies should be taken into account³⁰.

30 Wishart S: Personal discussion. 16 May 2002.

There are practical as well as legal approaches to reducing the liability by reducing the numbers of incidents of death and injury.

A utility's defence against a claim will be much stronger if it can show it adopts good construction and maintenance practices and can demonstrate compliance with them. The maintenance system should include programmes for inspection, testing and maintenance, replacing components approaching the end of their serviceable life, and tree management. However, as previously noted, not all utilities in Southern Africa have the capability for safe operations and maintenance of their networks.

Utilities should investigate all incidents that compromise safety. Not all incidents cause injury or death, and many might not be recorded normally. However, analysis of potentially dangerous incidents provides useful information for identifying system weaknesses and improving them. Data needs to be collected in a planned way for it to be available for such analysis, such as in the outage survey [Gaunt, 1994] already described. At this stage, though, few utilities collect or analyse the data available from normal operations on LV networks, and some do not record incidents on MV networks even for safety critical incidents.

Finally, utilities can contribute to safety education, particularly for the young, even if it should be the responsibility of government departments, schools, community organisations and families.

5.5 Environmental ethics

The most important source of energy in Sub-Saharan Africa is biomass. Outside South Africa it provides 86% of the energy needs of the region [EIA, 1999]. Although biomass is considered to be renewable energy, it can be utilised at rates that are not sustainable. *"Deforestation is now one of the most pressing environmental problems faced by most African nations, and one of the primary causes of deforestation is wood utilisation for fuel."* [EIA, 1999]. Therefore electrification appears to have significant potential to reduce environmental degradation. At the same time, the environment affects electrification policy and practice.

5.5.1 Impact of electrification on the environment

"It is often supposed that the electrification of rural areas will more or less automatically lead to a switch from fuelwood to electricity for cooking. This is not the case, except in special cases ..." Zomers [2001]. This situation is easily explained by the fact that the financial cost of fuelwood is very low where it is locally available. It

has already been pointed out that the poor have labour available (their most abundant resource), so the cost of collecting fuelwood is low. On the other hand, the cost of purchasing electricity is high because they first have to convert their labour to cash (for which opportunities are limited) before they can purchase the electricity and the appliances to use it. The switch from wood to electricity will continue to be slow until the locally available wood and, indeed, all forms of vegetation have been depleted.

Deforestation (or the depletion of vegetation) is not entirely due to meeting energy needs. Even where electrification significantly reduces the consumption of vegetation for fuel, other uses including overgrazing, clearing of land for crops and removal of vegetable matter for construction can denude the local environment. So, although electrification can replace or reduce biomass consumption for energy, substituted use of the vegetation may nullify any benefit to the vegetation environment from electrification. There are, however, at least some cases, such as in Durban, where a noticeable difference in the appearance of residential areas has occurred within ten years of electrification.

Electricity is highly efficient for lighting, even allowing for generation and distribution inefficiencies, and electrical cooking can be more efficient than wood stoves because of the shorter period of use. Electrification, therefore, can contribute to global energy efficiency, but may increase the useful consumption of energy where previously restricted by limited resources. As analysed in the research on basic electricity support tariffs, the greenhouse gas balance of limited domestic electricity consumption is almost neutral [UCT, 2002].

Electrification increases the capacity of the poor to use centrally-generated energy. To the extent that the electricity is produced in a non-sustainable way, the benefits of improved living conditions for those previously limited by inadequate access to energy are gained at the expense of the environment. The damage is not done by the electrification itself, and environmental impact needs to be addressed at the stage of electricity generation. The alternative of using sustainable sources of energy, instead of carbon-based central generation, does not appear to be viable under the present rules of economic assessment, but this may change in future. Some proposed technologies, such as large-scale wind generation, are only viable in combination with networks or energy storage systems, and would support grid electrification. While wasteful use of energy would have a negative effect on the environment, energy wastefulness is not expected to be a dominant characteristic of electrified poor communities. Giving equal consideration to the interests of all, electrification cannot be denied to the poor because of environmental impact, nor can it be restricted to electricity supplied by renewable resources.

The funding available from the environmental funds is small compared with the subsidies needed for electrification. Despite the importance of climate change strategies and environmental action, poverty alleviation and social development are as important and possibly even more urgent.

5.5.2 *Impact of the environment on electrification*

The capacity for man-made error in technology is enormous. The CFC industry created the hole in the ozone layer in 15-20 years, but the atmosphere will take much longer to return to its original state, despite the current restrictions. The positive impacts of electrification, including health and safety improvements, are significant, but widespread electrification will provide the means to significantly increase energy consumption in developing countries, with potentially negative environmental impacts. Despite and because of the risks, electrification will become even more complex:

- The human desire for development will continue to stimulate electrification.
- New technologies for electricity generation, distributed generation (also called distributed resources), distribution automation and electricity utilisation will change the distribution networks.
- Global awareness of sustainability will require more attention to energy efficiency, resource efficiency and loss reduction, and there is potential for conflict between advocates of new technologies and the immediate availability of conventional technologies to meet existing needs at lower financial cost.

5.6 Ethical issues in electrification

The analysis in this chapter provides the following responses to the questions raised in its introduction.

5.6.1 *Responsibility to support those who cannot afford electricity*

Religious, philosophical and pragmatic approaches identify an obligation for poverty alleviation and poverty reduction, and electrification has the potential to make positive contributions, but there is a price to pay. Politicians and officials have to determine the sustainable level of support where electrification is not financially viable.

5.6.2 *Effect of ethics on electrification practice and costs*

An obligation to implement social electrification must be matched by responsibility from the beneficiaries to pay for the service and providers to supply it to the highest ethical standards. Within that context, a variety of interventions is feasible.

5.6.3 *Effects of ethical obligations on aid policy and practice*

It appears that the objectives of aid donors and recipients frequently differ, so that although both may act ethically, they may frustrate each other. It also appears that the process of aid needs to be reconsidered by both donors and recipients to avoid inappropriate solutions such as have been adopted in the past.

5.6.4 *Liability for public safety associated with electrification*

Electrification delivers substantial benefits by reducing the health and safety risks associated with other forms of energy, but also exposes the public to dangers of electric shock. Utilities will be blamed for injuries and death caused by their installations, but derive no advantage from the benefits delivered. However, they can reduce their liability in accidents by good construction and maintenance practice, safety improvement, and public education.

5.6.5 *Impact of electrification on the natural environment*

Electrification increases the capacity of people to use electricity, with potential negative effects on the environment, but the advantages for the new customers given access to modern energy and the benefits of reduced consumption of biomass mitigate the possible disadvantages of using more electricity. The need to produce electricity in a more environmentally sustainable way is no justification for limiting electrification, as electrification associated with better electricity production will have positive environmental impact.

5.7 Onword

This chapter has considered the religious obligations to help the needy, the philosophical principle of giving equal consideration to the interests of all, and political or pragmatic reasons to help the poor. It also examined the deficiencies and effectiveness of aid and the contribution that electrification makes to improving safety and the environment. From all perspectives, electrification to alleviate poverty is justifiable and even desirable.

It is not that the world lacks the resources for social development and poverty alleviation through electrification, but that the mechanisms for using the resources are insufficient. African countries, particularly, do not have a good reputation for efficiency and integrity. Financiers and supporters need to have confidence in the institutions and processes for using funds and technology, first in identifying acceptable objectives

and then in management to reach them, without resource waste and benefit leakage through corruption and inefficiency. There is still a need and a role for aid and subsidies, but they need to be designed to achieve the objectives with minimum disadvantages.

Aspects of the interactions between electrification and society, and suitable tariffs to achieve the objectives of social development are considered in the next chapter. Understanding of the ethics underlying social electrification also provides a context for planning and evaluating development, considered in chapter 8.

University of Cape Town

Chapter 6

Society, Economics and Electrification

6.1 Introduction

Technology was examined in Chapter 4 and the ethics of electrification for social development in Chapter 5. Now, referring to Figure 3-1, the understanding of technology and society's values allows more effective consideration of the interaction between the infrastructure and social sub-systems. In particular, this chapter considers the interaction between customers, technology, and costs reflected in tariffs.

The main topics of this chapter are:

- The influence of society on electrification, affecting objectives, targets and processes of electrification as a contribution to development.
- Tariff structures and subsidies.
- Research into a basic electricity support tariff intended to alleviate poverty.

The concept model of electrification for social development provides a framework for understanding domestic tariff subsidies that are difficult to justify within economic or socio-economic development.

6.2 Electrification for economic development objectives

The South African government's energy policy defines economic objectives for electricity supply. The NER [2000] interpreted the White Paper on Energy Policy published by the Department of Minerals and Energy in December 1998 to include (among others for energy generally) the following objectives for the electricity supply industry:

- *"use of electricity to promote rural and economic development"*
- *"introduction of cost-reflective electricity tariffs"*
- *"restructuring of the distribution sector of the ESI and of Eskom".*

Elsewhere in Africa electrification is also seen as an economic activity:

"The record of disseminating energy technologies into rural areas of East Africa has not been particularly good ... Kenya has been the major success story in terms of commercial PV development, largely in the form of household systems capable of providing a range of basic power needs." and of a system in Tanzania: *"there is a willingness to pay significantly higher prices for electricity than that currently charged by TANESCO."* [Salter, 1997]

Successful electrification as measured by profitable supply and premium-paying customers can apply only to a small proportion of households and commercial enterprises, and cannot meet the extensive need for energy for poverty alleviation. While economic electrification is very important, widely successful technology must achieve more.

6.2.1 Evaluating financial and economic return

Financial and economic viability is typically measured by net present value (NPV), internal rate of return (IRR) and economic rate of return (ERR), as described in chapter 3.

The return expected from projects and programmes depends on the perceived risk and availability of resources. The risks associated with investments in developing countries are high, because many projects do not meet the expectations and the countries are characterised by having few resources - technical skills (technological and economic), finance, and infrastructure. If these were not constraints they would not be developing countries. Therefore the hurdle discount rate for deciding whether projects should be implemented is higher in developing countries than in developed countries. Typically net discount rates of 4 to 6% are used in developed countries, reflecting the cost of capital. In developing countries 10 or 12% is used as the target discount rate, reflecting a higher cost of capital, because it is a scarce resource, and the higher risk. (These rates are the net rates, after inflation.)

The Development Bank of Southern Africa was using a hurdle rate of 10% for water supply projects, and 12% for electricity projects, because the latter had a lower priority. Using all these figures, approximate components of the rate for electricity projects can be estimated as:

base cost of capital	6%
add rate for developing country risk	4%
add rate for capital scarcity	2%

Assessing the projects after completion requires a different interpretation of the discount rate. The net discount rate is no longer a hurdle for project approval. Instead, if a project achieves a return higher than the cost of capital, say 8 - 12%, it can be said that the risk component of the project was adequately managed. A higher rate is, of course, completely acceptable, and a rate lower than the cost of capital indicates that the resources were not well used. The interpretation of the economic rate of return is similar to that for the financial rate of return, and in a simplified economic model the base cost can be reduced so that a return of 2-6% would be adequate. The financial analysis of eight programmes included in the National Electrification Programme evaluation showed that seven would not reach financial breakeven. Using a net discount rate of 6%, the economic analysis, excluding external grants, was neutral for the eight programmes as a whole, but five gave negative returns, with benefit:cost ratios down to 0.84 [Borchers et al, 2001].

Zomers [2001] identified an advantage of PV systems as being *"a lower risk bearing option when compared with the large and future-orientated grid extensions because no initial over-investment occurs"*. It is necessary to understand that risk has several aspects. The risk associated with financing a PV system is low in the context that the capacity is likely to be used, but risk also arises from loss of revenue through component failures, theft of units, and when customers convert to grid connections, possibly accelerated by outgrowing the capacity of the PV system.

The risk Zomers associates with grid connections is the possibility that over-design will establish under-utilised network capacity, which gives no financial return. Other risks include low financial return because of theft of service, which can be monitored, theft of network components (though the value per customer of stolen components tends to be smaller than for PV systems), and tariffs that do not cover costs. All these risks could be modelled directly in the project cost and revenue model, but they already form a small part of the premium in the discount rate for developing countries, together with risks like bad management, political interference or other causes of general project failure that are common to both PV and grid options.

6.2.2 Suitability of economic contribution as measure of success

Measuring successful development in terms of economic objectives has limitations:

"Business has become used to viewing its economic contribution (profits, foreign exchange earnings, jobs) as a justifiable end in its own right, irrespective of what social and environmental side effects it might cause in pursuit of this definition of success. The tragedy is that our political and economic system perpetuates this back-to-front power relationship and

makes it virtually impossible for governments, civil society or business itself to reverse the roles." [Visser and Sunter, 2002]

One way to better meet the social needs is to identify social objectives and ways of assessing whether they are achieved. This approach has the advantage that the need-objectives-achievement process is familiar to politicians and economists, but is not constrained to being expressed in financial terms. An approach to environmental needs may be part of that proposed for social needs, but is beyond the scope of the present research.

Electricity supply and electrification have both economic and social impact. The definitions of the objectives and supporting policies become the context in which decisions are made about allocating resources, reflected in capital budgets, tariffs and subsidies. It is possible to improve the social benefits of one group at the economic cost of another, and the decision to do so requires a value judgement by the decision maker. Where a change in allocation achieves a fundamental improvement in the effectiveness of electricity supply, substantial benefits may be achieved at low cost. This, then, is the goal in changing tariffs or the industry structure, whether now or in 1923.

6.3 Electrification as a response to a social need

Electricity cannot be considered as important as water and food since as many as two billion people live without access to it, according to World Bank estimates [1996]. However, electrification has a social objective, defined in this research as reducing the effects of poverty. Having provided access to electricity, the benefits depend on the capacity of people to use it for lighting, cooking, ironing and media access. Very poor households may not be able to afford much electricity, even if the cost is low, because there are competing needs for whatever money is available.

Fuelwood is still available in some rural areas for the cost in time and personal energy of collecting it. Until the fuelwood resources are depleted, rural households can choose 'free' fuelwood for cooking and space heating instead of commercial energy, including electricity if they are electrified. Choice of a commercial energy source is mostly made only when the 'free' energy is almost exhausted, and then availability of other forms of energy becomes an important factor in the choice. There is often a cost in the fuelwood option that is not immediately apparent, in that an unsustainable source can be exhausted in a few years. (Electrical energy is also criticised as being not sustainable, but the period of sustainability is different and in the meantime the needs of the poor have to be addressed.) Therefore, "*Poverty*

remains a barrier to electricity use, so that while the benefits of rural electrification should be maximised, greater attention must be paid to the provision of energy services other than electricity. ... Electricity may not offer the desired panacea to rural energy needs, but its real, potential and symbolic value is considerable and should, over the medium term, be extended to all." [Annecke, 1998].

Most poor people in urban areas no longer have access to 'free' fuelwood, and must pay for fuelwood, paraffin, coal or electricity. With urbanisation, housing completely replaces fuelwood areas, as illustrated in Figure 6-1. Although it appears that the largest impact of electrification might be obtained where the people who need to buy energy are most concentrated, it is insufficient to use the limited resources only on giving access to electricity to the urban poor. Equally, restricting electrification to the rural poor may not be effective until fuelwood is scarce, and leaves urban needs unmet. Therefore, a balance of resource allocation must be found.



Figure 6-1: Urban electrification in Khayalitsha.

20 years ago this area was completely covered in Port Jackson trees, but urbanisation has completely consumed all the fuelwood. Electricity now provides the energy needs of most poor households. See case study 2.

If the objectives of the electrification are socio-economic, then a contribution to economic activity is expected of the electricity customers and, in concept, it should be possible to define an optimum quality of supply to match the use of the electricity. However, if the electrification is to alleviate poverty, a lower quality of supply (wider voltage regulation, more interruptions) will be acceptable if it does not diminish the

efficiency of delivering the benefit. In practice, it is difficult for a utility to operate a system that gives different levels of supply quality because specific customers are not easily assigned to each development objective.

When the target of socio-economic development is the very poor, they generally lack the other resources needed to undertake the economic aspects of development that the availability of electricity is meant to complement. Therefore, socio-economic electrification directed at very poor people will probably fail without substantial complementary interventions. This raises questions about the usefulness of area (blanket) coverage in socio-economic electrification, though it is clearly appropriate for social electrification.

6.4 Tariffs and subsidies

A tariff is a schedule of prices for electricity under various conditions. Different prices may be applied to different classes or groups of customers, such as domestic or commercial, or limited by parameters of the supply, such as voltage or maximum capacity. Tariffs are significant because they determine the revenue and financial viability of a utility, send price signals to customers, affect the allocation of economic resources, and define the subsidies received by customers paying less than the full cost of electricity. Various tariff structures have been applied in South Africa for domestic customers in efforts to overcome non-payment, make prices reflect costs and achieve various social objectives, as indicated in the Table 6.1 and illustrated in Figure 6-2.

Table 6.1: Basic tariff structures for domestic customers

Tariff	Advantages	Problems
Flat fee: constant monthly payment Independent of consumption.	Simple administration. No meter required. Allows household to budget.	Not cost-reflective. Perceived as unfair because it permits very high energy consumption. Maximum current needs to be limited.
Single consumption rate based on energy only.	Simple administration. Relatively simple meter. Rate can be adjusted according to capacity (eg 20 or 60 A). Suitable for prepayment metering.	Not cost-reflective. Does not recover fixed cost from small consumers. Leads to over-collection from large customers.
Multiple rate block tariff: decreasing block rate or increasing block rate.	Decreasing block rate tariff can be designed to be cost reflective. Increasing block rate tariff gives subsidy to small consumers.	Difficult to take meter readings on same day every month. Special prepayment meters needed for more than two blocks. Increasing block rate tariff not cost reflective.
Two part tariff: fixed monthly fee plus single rate for energy.	Approximates cost structure modelled as fixed plus variable cost. Can include different base rates according to capacity.	Must collect monthly charge even if no energy consumed.

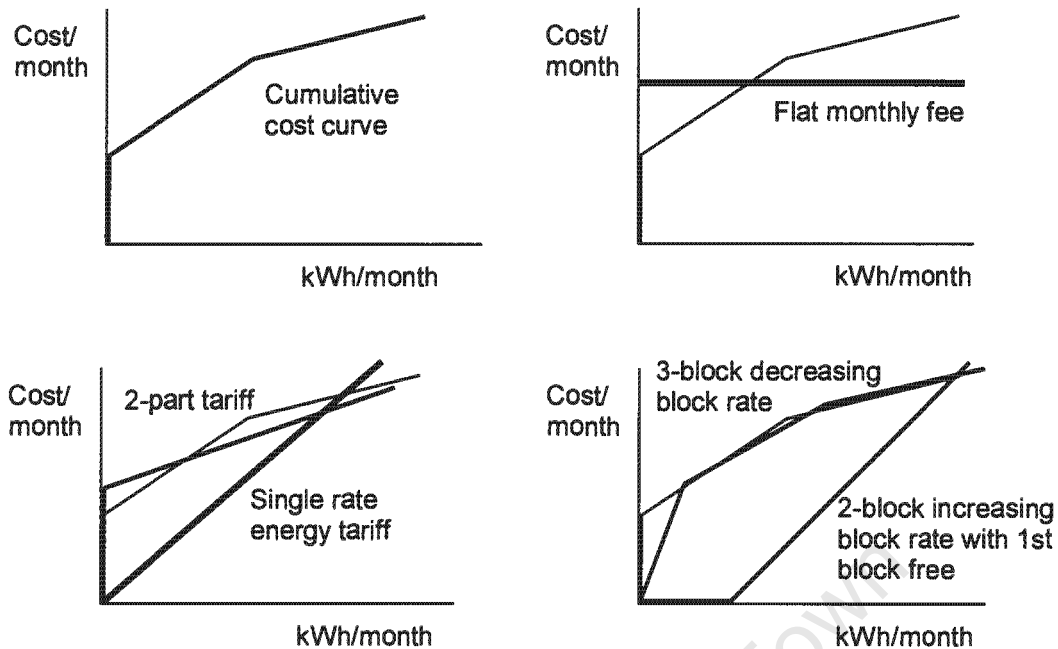


Figure 6-2: Cumulative cost and various cumulative tariffs

6.4.1 Cost allocation

The costs of supply include:

- a fixed component for the investment in the supply system, with the magnitude depending on capacity of supply and location relative to the energy sources, and
- a component varying with the energy used.

The definition of the fixed and variable costs of electrification is a simple concept, but not exact. The fixed cost component represents the capital investment in the distribution network, but could include an allocation for generation and transmission capacity also. The valuation may be on historical asset cost or, if the capital was provided externally from the utility, as an asset replacement value. Some costs of administration, maintenance and repair may be allocated as fixed costs. The variable costs include energy purchased for sale and losses, which may depend on the time of use, and might also include costs associated with operations, maintenance and repair, although they are not directly proportional to consumption. Cost allocation makes it difficult to unambiguously determine the fixed part of a tariff.

The cost of supplying small customers, with small monthly consumption, is high in terms of cost/kWh. If cost-reflective pricing were applied strictly, in accordance with the energy policy, many poor customers would be unlikely to afford the supply, even though their energy needs are low, because of the high fixed cost component of a

network connection or PV installation. For the same reason, there is little competitive advantage in supplying small customers or rural areas. Therefore cost reflective tariffs, rural electrification, affordability and poverty alleviation are generally conflicting objectives unless subsidies are provided.

The decreasing block rate and two-part tariffs are the closest to cost-reflective tariffs. Where the cumulative tariff line is below the cumulative cost curve, the difference is a subsidy received by the customer. The cost of the subsidy has to be recovered from customers above the breakeven point, or customers on other tariffs (cross-subsidies), or from grants from outside the electricity distributor. Clearly the biggest subsidy to a small customer is given by the increasing block rate tariff in which the first block is very cheap or free.

6.4.2 Eskom domestic tariffs

Eskom implemented various flat fee tariffs on a pilot project basis at Tambo and Mafefe, limiting the current to 4 A, and omitting energy metering. The intention was to reduce the cost of making the supply available. The projects were generally not acceptable to the customers, partly because of the limited capacity and partly because the very poor customers the tariff was intended to help ended up paying fixed monthly charges higher than they would by using very little energy on a single rate energy tariff. At the same time, the tariff could not prevent some customers drawing currents near the limit of the supply for extended periods, resulting in high energy consumption with little diversity between the loads. The feeder voltages and losses were worse than expected and theft of service was difficult to identify. The pilot projects were converted to single rate energy supplies after a relatively short period.

When Eskom adopted the blanket (area coverage) approach to electrification, it introduced a 2.5 A tariff with a free connection, but energy at the same rate as for the 20 A capacity supply. This was the default level for connections. The capacity is sufficient to supply one or two lights, a radio and black/white television, but not a kettle or hotplate.

By paying a nominal connection fee (initially R40) customers could upgrade to a supply limited to 20 A. 20 A capacity is sufficient for a kettle, hotplate, TV and lights, etc. Most of Eskom's 3 million domestic customers are on supplies of 20 A capacity.

Large domestic customers can have 45 or 60 A supplies, sufficient for cooking, water heating and space heating, on payment of connection fees that vary between R1'000

and R4'500. The rate for energy is slightly higher than the rate for customers limited to 2.5 or 20 A.

6.4.3 Municipal domestic tariffs

At the start of the electrification programme most municipalities had two part tariffs for domestic customers, with a basic monthly charge depending on the capacity of supply (mostly 80 or 60 A, but some municipalities allowed customers to select ratings between 20 and 60 A), and an energy consumption charge. Larger, older municipalities with mature networks were able to charge domestic tariffs substantially below the Eskom tariffs, because the financial costs of much of the networks were already paid off and, in some cases, large non-domestic customers subsidised domestic customers. Smaller, newer municipalities without the benefits of mature networks and significant diversity between domestic and non-domestic customers had tariffs above the Eskom tariffs.

The municipalities modified their domestic tariffs when they introduced prepayment meters because the early meters could only accommodate a single energy rate. Some utilities maintained two part tariffs for conventional meters, partly to encourage customers to change over to the prepayment meters, but most eventually simplified their domestic tariffs to a common scale for all customers. Domestic customers in Cape Town choose between two tariffs, *“one for high consumption (more than 500 units per month) and one for low consumption (less than 500 units per month)”* [Cape Town, 2003].

Most municipalities applied full cost connection charges, but changed these to nominal connection fees when they implemented the Electricity-for-All programme or the National Electrification Programme. Durban Electricity provided new customers with electrical appliances as part of the connection, charging a connection fee of R142. This ensured that customers had the capability to use electricity for purposes other than lighting and helped to raise the average consumption above the national average [Borchers et al, 2001].

6.4.4 Connection fees for area coverage

The issues of affordability, subsidies and tariff equity are all affected by the blanket (or area coverage) approach to electrification. Giving access to all potential customers in a supply area, at no fee or for only a nominal fee, completely avoids the problem of connection fees that are too high for the poor. There is no need for micro-credit schemes to give poor households access to finance so that they can obtain access to electricity.

However, it might be argued that cost-reflective tariffs need to identify and realistically charge for the costs of the connection. This argument is weak on two practical points: it assumes that the costs can be correctly identified, whereas many elements of the costs are subject to errors of any allocation costing system; and it usually fails to recognise the savings achieved by excluding the administration of payments for every connection. More importantly, the argument lacks the ethical basis of making special provisions for those who most need assistance. Applying the principle of equal consideration of interests (see box 4) leads to the conclusion that the poor, who are least able to afford a connection, should be provided connections at lower cost than those who can easily afford them. The simplest way to build this into the tariff is to collect connection (or network investment) costs in the consumption charges. If all customers pay the same rate for energy, larger consumers will pay more for electricity than those who can only afford to consume so little that they do not reach the breakeven point of the tariff, and so do not contribute completely to the capital investment. Thus, the combination of a connection at no or nominal cost and a single energy rate creates a subsidy for the small customers. Of course, not all small consumers are poor, but the leakage of benefits to wealthy customers is limited to those with low consumption.

The next step to a consumption subsidy is a small one, in principle, but requires further attention to reducing the leakage of benefits.

6.4.5 Responsibility for deciding subsidies

The problem of subsidising development and achieving too low a return, leading to bankruptcy of utilities and countries, was described in section 5.2. It should be noted that collapse does not happen immediately an unsustainable economic and social policy is adopted, but only when the resources are exhausted. Thus, damage can already have been done before symptoms become obvious.

This leads to the question: Should electricity utilities make the decisions on electrification investment, when they have such substantial implications for the country? That is what happened in South Africa - the decisions about implementing the electrification programme were taken by business and the electricity utilities, with apparently little reference to central government. Later proposals for a basic electricity support tariff were made first by the Regulator, taken up by the politicians, and implemented before analysis was complete. The government could have blocked the initiatives, but did not, probably thereby indicating its approval.

In both cases, the initiatives were financed from funds outside the direct control of the government. Only in the later stages of the electrification programme were levies on Eskom sales transferred to municipal utilities, otherwise electrification subsidies and electricity support subsidies were taken from revenue from other customers.

The government has the main responsibility for determining the sources and targets of economic subsidies, which it does through taxes, budget allocations and regulations. The regulations direct the subsidies to the intended “target” and limit the leakages to those for whom the subsidies are not intended. Perfect subsidies are impossible because of practical limitations of defining the beneficiaries and their needs, and administering the processes of delivery.

Capital and operations subsidies distort resource allocation in different ways. A fixed subsidy per customer promotes new connections, energy subsidies (per kWh) promote emphasis on larger customers, and subsidised operation and maintenance (O&M) costs distort the allocation of work to O&M categories. While operating costs continue for the life of the system, subsidies in the form of capital investment grants have the advantage that project funding has a short life. However, adding asset replacement to operating costs diminishes the intended benefit of a capital subsidy.

6.4.6 Cross-subsidies

A problem commonly attributed to developing countries is that domestic and agricultural tariffs are heavily subsidised by business and industrial customers. In fact, subsidies exist in developed and developing countries. Domestic customers in some South African municipalities are subsidised by other customers, but Table 2.6 indicates that agricultural and domestic customers generally pay the highest tariffs.

Most national and regional tariffs subsidise the higher costs (per customer) of rural electrification. Averaging costs across urban and rural sectors may conceal subsidies, or they may be transparent, such as the Zimbabwe rural electrification fund's 1% levy on ZESA's sales revenue [Dube, 2001], later raised to 3% [ZESA, 2001] and 6%³¹. Subsidies of rural electricity costs distort comparisons with other rural energy for which distribution costs are not subsidised or differently subsidised, such as by exemption from VAT.

However, as shown in chapter 4, the capital cost of domestic electrification in rural areas need not be significantly more expensive than in urban areas, so cross-subsidies from urban to rural customers may not be substantial. A more important

31 Personal communication, 6 November 2002.

distinction may be between profitable and unprofitable customers arising from different consumption.

Factors affecting cross-subsidies include: the sizes of the group of beneficiaries and of their subsidy; the relative sizes of the groups supporting the subsidy (industry and business, or only other households); the administrative simplicity of uniform tariffs and the associated leakage of benefits; public perceptions of fairness and discrimination; and the difficulty for regulators to distinguish the real need for subsidies from the effects of bad management.

6.5 A subsidised tariff to meet social objectives

Adoption of national, regional and local tariffs has an underlying ethical-social basis.

- Completely cost-reflective tariffs produce a wide range of tariffs for large and small customers in urban and rural areas. The differences are difficult for most customers to understand. They are based on the ethical view that every customer must pay what it costs, having no support from other customers, irrespective of the benefits derived or the ability to pay. Cost-reflective tariffs support the principles of economic development, but not social development.
- A uniform tariff for each category of customers has those in areas costing the least to supply, subsidising customers in more costly areas. The justification is that no customers should be discriminated against for their location, and all customers should pay fairly according to their category. However, if the costs of electricity service are similar in all areas, but for different levels of service, then the uniform tariffs may indeed be without cross-subsidies. There may be perceptions of fair pricing, but also of unfair servicing, which may be acceptable if all are treated according to their needs.
- Subsidies re-allocate resources from one group to another. The justification for productive (commercial, industrial) customers subsidising domestic customers is that the productive sector benefits from the population resource in ways that are not included directly in their costs, and they can afford to make the subsidy. The contrary argument is that 'taxes' on the productive sector make it less viable, potentially harming the economy and employment.
- Tariffs in a privatised utility contain a "fair profit" component, dependent on the service provider's perception of risk. The greatest risk might be uncertainty regarding future government action, for it is by government action that a public utility is privatised anyway. Thus privatisation introduces a system where the economy starts valuing the risks of government, which it would not do if the government kept the utility as a public resource.

- Finally, the tariffs of eco-aware electricity utilities recognise the hidden costs of environmental pollution and resource depletion.

This analysis leads to specifications for a social tariff, presented in box 6.

Box 6: Specifications for a social tariff

A social tariff will be one in which a subsidy reduces the cost to customers of a fully cost-reflective tariff, including the profits of a privatised utility. The subsidy will not be so large as to damage the economy and will be derived from a source that can sustain it. Geographic uniformity will promote perceptions of fair pricing. The subsidised tariff may be restricted in terms of the service provided, but it should be substantial enough to make a difference in respect of the purpose for which it is intended. A social tariff must not put the beneficiaries into a poverty trap that restricts them to a limited benefit, nor reinforce long-term social dependency. Of course, the benefits should reach a clearly identified group of beneficiaries (the target group), with as little as possible leakage to those outside the group. A simple tariff structure will assist understanding and reduce the costs of implementing the tariff.

A social tariff, usually implemented as a low-priced, first block of energy and referred to as a lifeline rate, *"has to be carefully determined, to avoid subsidizing relatively well-off consumers; it should also be based on acceptable criteria for identifying "low-income" groups and reasonable estimates of their minimum consumption levels (eg sufficient to supply basic energy requirements for the household). ... This approach may be reinforced by an appropriate supply policy (eg subsidized house connections for electricity ...". And "for very poor consumers receiving a subsidized rate of electricity, a simple current limiting device may suffice, because the cost of even simple kWh metering may exceed the net benefit". [Munasinghe, 1990b]*

6.6 Proposed basic electricity support tariff for social development

During the elections in 1999 some politicians promised free electricity for the poor. In October 2001 the University of Cape Town was appointed by Eskom and the Department of Minerals and Energy to carry out research into the purpose, costs, benefits and processes of implementing a proposed tariff to subsidise the electricity consumption of poor customers, and to make recommendations. It was agreed that the research should exclude political, constitutional and legal aspects, accepting that the justification for the proposed tariff includes constitutional rights, the humanitarian need to alleviate the worst effects of poverty, and the responsibility of the government to balance its priorities in respect of public programmes and budgets.

A research team comprising 17 engineering, environmental, financial, institutional, medical and social specialists compiled a report outlining two options for a basic electricity support tariff (BEST)³², a broad-based approach and a self-targeted approach [UCT, 2002]. A smaller team then continued monitoring pilot implementation of the self-targeted approach and prepared a supplementary report on the proposed tariff [Gaunt et al, 2003].

The effectiveness of a tariff intended for poverty alleviation depends on whether it will reach those for whom it is intended (targeting), whether tariff subsidies alleviate the effects of poverty (impact), and how it is implemented.

6.6.1 Targeting

There are many measures of poverty, but the poor were identified for the purpose of the research as the households in the two lowest quintiles of income, that is the 40% of households with the lowest incomes.

Of the approximately 10 million households in South Africa in 2002 approximately 70% had access to electricity, but only 48% of poor households were electrified. Of those in rural areas, where two thirds of poor households are, 41% had electricity. In urban areas 61% of poor households had access to electricity. This represents a substantial improvement compared with 1990, when the corresponding figures for poor households with access to electricity were 10% in rural areas and 35% in urban areas, but still leaves many poor households unable to benefit from subsidised electricity tariffs. Projections indicate that by 2010 there will still be many poor households without electricity unless the connections rates increase significantly. Clearly, households without access to electricity cannot benefit from tariff subsidies, showing how important continuation of the electrification programme is for social development.

The political promise of free electricity inherently required the introduction of a two-block increasing block rate energy tariff, in which the first block is free or cheap (significantly below the cost of energy). This tariff represents a further subsidy beyond the already widely used single rate energy tariffs, which under-recover the fixed costs from customers consuming only a little energy, effectively subsidising them, but not to the extent that allows the very poor to use as much electricity as is considered a basic supply.

32 Government sources refer to Free Basic Electricity or Electricity Basic Service Support Tariff, but the research team recommended a simpler name that did not include the word 'free'. The recommended term has the acronym BEST, and has been used by the NER [Mkhwanazi, 2002].

The effective cost to customers of energy is illustrated in Figure 6-3, together with a two-part tariff (A) that is approximately cost-reflective, having a basic charge and energy charge. The vertical distance from (A) to the single rate energy tariff (B) or the two-block energy tariff (C) represents the subsidy received by a customer at any level of monthly consumption.

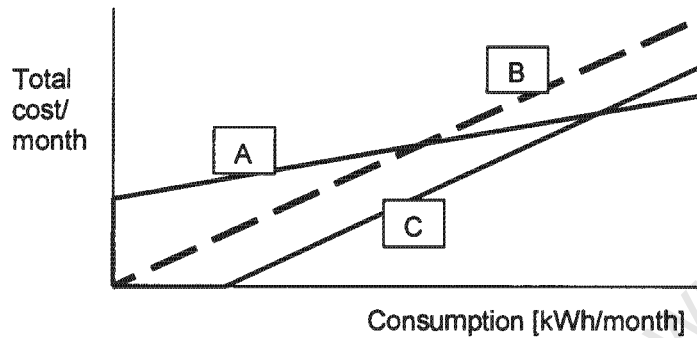


Figure 6-3: Cost-reflective, single rate and two block (with first block free) tariffs

The first block of a two-block tariff needs to supply about 35 to 60 kWh of energy per month for lighting, media access and limited cooking. The range arises from the different efficiencies of incandescent and compact fluorescent lamps. A smaller supply, or conditions excluding the application of the energy to cooking, would have correspondingly lower benefits for the households and communities. Lower capacity supplies have to be considered for non-grid electrification because it is not practical to supply more energy than about 10 kWh/month.

The target group of intended beneficiaries can be reached in three ways:

- Broad-based application of a common tariff to all customers gives the subsidy to all households, but recovers the costs from those outside the target group. A tax or levy on large consumers on the grounds that they are not poor still allows leakage of the benefits to small wealthy customers. This approach achieves the greatest coverage but, because it cannot reach households without access to electricity, it cannot correctly be termed “universal”. This is the form of the initially proposed tariff and was implemented in several municipal and Eskom pilot sites.
- Segmenting the population by income and giving the subsidy only to the target group reduces leakage, but incurs high administration fees for reliable and continuous assessment and is not appropriate for small social grants.
- Segmenting customers by the nature of service provided, such as by capacity limits or level of consumption, provides the benefit only to those willing to accept a restricted supply of electricity delivered on a subsidised tariff. This approach is referred to a self-targeted tariff.

The broad-based and self-targeted alternatives were considered in detail. Both can be implemented technically, financially and institutionally. The social impacts of the two alternative tariff structures on the poor will be similar, but are likely to be perceived differently, and are being tested further before a final decision is made. The balance of the characteristics of the two alternatives appears to favour the self-targeted tariff, but the choice between the two alternatives requires political consideration beyond the scope of the research.

6.6.2 Impact

Even limited quantities of free or low cost electricity will have significant impact on life in poor households. Electricity subsidies should allow use of electricity throughout the month, improve security by better lighting, and enable the basic use of appliances.

Indoor air pollution from the use of combustion fuels is a significant contributor to respiratory disease. The health and safety improvement achieved by using electricity is limited by the continued use of combustion fuels, confirming the importance of providing sufficient capacity for at least some cooking.

The benefits of electricity subsidies could be limited by a lack of appliances to use the electricity, and the targeted tariff identifies beneficiaries to whom an appliance assistance programme, such as energy efficient lighting, could be directed with greatest effect.

A shortage of information about the programme would also limit its benefits. The social impact research identified generally low levels of understanding of the proposed subsidy in communities where pilot schemes had already been implemented. A comprehensive communication and education campaign reaching the public, customers, local community leaders, vendors and the utilities' own staff will be needed for the subsidies to achieve the intended benefits.

The social research found that communities are aware that introducing consumption subsidies will increase the existing inequities between those with and without access to electricity, illustrating the social need to continue the electrification programme.

The research identified several indications that the basic electricity should not be provided free but for a small charge. They include avoiding reinforcement of an attitude of entitlement, recognising the social value in purchasing, regulating the demand for tokens at vendors at the start of the month, and maintaining flexibility for

fiscal management. However, the affordability of an even nominal payment could be an issue, and the perceptions of the public, particularly in respect of the commitments apparently made by politicians, may require that some electricity be provided for free.

Electricity consumption subsidies have negligible impact on greenhouse gas emissions. The impact on local vegetation will be mixed, according to whether fuel wood is being derived at present from indigenous or alien vegetation.

The implementation of the subsidy programme and its impact on the poor will need to be monitored and evaluated to assess whether it is making a real and felt impact on people's lives and on poverty alleviation. Despite the research, uncertainty remains regarding the impact of subsidising electricity consumption over a long period, and monitoring from the start will be useful to identify the trends. The responsibility for assessment needs to be established.

6.6.3 Implementation details

All existing prepayment meters are suitable for a single rate energy tariff, and with the newer (STS compliant) prepayment meters it is technically feasible to implement a two-block energy tariff. Not all the early proprietary meters can implement a two-block tariff, but many of them are already being replaced, and modifications can be made to the vending systems to overcome the limitations of the meters. Block rate tariffs with more than two blocks are difficult to implement with prepayment meters, and have little value as lifeline tariffs.

Data collected from the National Load Research project provided a base from which to evaluate the expected customers' load responses to tariff changes. In particular, it was found that customers using 50-60 kWh of energy per month seldom have a 5-minute demand exceeding 8 A. This is low compared with the current ratings in most households, typically between 20 and 60 A.

Estimates of demand associated with energy consumption were used to assess the additional generation and network capacity needed. Introducing electricity subsidies is likely to increase the electricity consumption of average rural customers to above the level for which recent rural networks have been designed. In some regions this increase could have a significant impact on the performance of the network, as described case study 10.

A self-targeted tariff can easily be linked to a reduction in the current limit of the prepayment meters, for example to 10 A. A 10 A rating has the advantage that it

allows individual use of commonly available kettles and hotplates rated up to 2 kW. Self-targeting with a higher current rating, such as the 20 A in wide use in Eskom, would not significantly constrain customer energy use and so would be less effective in reducing the leakage of benefits, and incur higher generation and network capacity costs.

Case study 10: Electrification load growth in Transkei

The loads in Transkei, a region approximately 300 x 200 km in the Eastern Cape, have historically been limited to the two main towns, Umtata and Butterworth, and a few rural centres. The main supply into the region was a single 132 kV line from the south, with distribution at 66 and 22 kV to the rural centres, and four small hydro power stations have a total capacity of 60 MW. The load grew from 30 MVA in 1980 to about 60 MVA in 1995/8. Over 100'000 new household connections were made between 1996 and 2001, but many of the households are extremely poor and average consumption is very low. A second 132 kV line was built from the north in 2001, but has limited capacity because of other loads along the route. By 2002 the demand in Transkei had grown to about 90 MVA and several incidents at periods of high system loading led to instability and loss of the network. Introduction of a basic electricity support tariff would significantly encourage consumption and the resulting load growth could push demand beyond the system's supply capacity, creating a need for urgent reinforcement.

Source: Own experience and personal communication with Eskom.

Analysis

- (1) Regions with risk of rapid load growth need to be identified and network performance monitored to identify reinforcement requirements in sufficient time. Building stronger feeders before their capacity is utilised is a more robust approach but potentially wastes scarce resources.
- (2) Not all regions will be affected by the new tariff in the same way, but where the proportion of newly electrified households is high the risk may be similar.
- (3) Demand side management initiatives, especially the distribution of energy efficient lamps, implemented with the new tariff may reduce the rate of load growth.

The details of the implementation of a BEST, in particular a policy regarding refunds for lost tokens, may require that the first block be issued as two tokens for a single transaction if there is a nominal charge for the first block. Energy used beyond this limit will be charged at the standard domestic tariff applied by each utility, and ensures the tariff is not a poverty trap.

Consideration was given to a severely current-limited supply, such as 1 A, equivalent to the energy capacity of PV systems used in non-grid electrification. However, such a limited supply (power rating 0.23 kW) would exclude the use of electricity for any form of heating, including kettles, cooking and ironing.

A subsidised supply of about 50 kWh/household will have a relatively small overall impact on the entire economy, on growth, investment and redistribution of wealth.

However, the programme will need to be balanced politically with other government priorities and the subsidy tariff may affect the attractiveness of the electricity sector for private investment.

There are only two realistic sources of funding, namely funding from nationally collected revenue (voted on the national budget) and a cross-subsidy or earmarked tax on domestic electricity consumption. The self-targeted tariff can easily be funded from the national budget, and central funding allows the government to benefit politically from giving support to the poor. The funding for a broad-based subsidy would be more complex, with earmarked taxes and equalisation funds to distribute surpluses and deficits between utilities with very different customer profiles. It would have a higher risk of error, misappropriation and unintended impacts, including greater leakage of benefits to higher income households and, also, would not be as clearly identified as coming from central government.

Implementation as subsidised electricity (instead of free electricity) makes the policy more flexible (to be managed or phased out). The compensation of the utilities for supplying subsidised energy to households must be determined to avoid under- or over-compensation. However, the details of these proposals still need to be established according to the policy adopted.

The cost of the self-targeted tariff is likely to be about R350 million/year in terms of 2002 values, although the estimates still vary. Expressed as a net present value using an economic discount rate of 8%, this is about R4 billion, or about 20% of the capital already invested and planned for electrification up to 2010. This approach makes and hides many assumptions about future load growth, load factors, tariffs, diversity between customers and national generation mix. Clearly, however, the support tariff will unlock, at relatively low cost, the social value of the funds spent on electrification that are not yet being used effectively in nearly 20% of households because so many people with access cannot afford to purchase useful quantities of electricity at the full cost.

The estimates of future costs could not have been made without information from the load research project. The substantial record of customer consumption related to household income allowed projections of future electricity consumption to be developed. Estimates could also be made of the accelerated network reinforcement needed to meet the increased demand associated with subsidised consumption.

6.6.4 Interpretation of a basic electricity support tariff

Comparison of the specifications for a social tariff (box 6 in section 6.5) indicates that a BEST complies with most of the provisions, as shown in Table 6.2.

Table 6.2: Comparison of a self-targeted BEST with social tariff concept

Specification	BEST
Subsidy reduces the cost to customers.	Achieved.
Subsidy will not be so large as to damage the economy and will be derived from a source that can sustain it.	Managed by the National Treasury. Broad based subsidy requires complex cross-subsidies and equalisation funds.
Geographic uniformity will promote perceptions of fair pricing.	Proposed uniform tariff throughout country.
Subsidised tariff may be restricted in terms of the service provided.	Self-targeted tariff limited to 10 A, allowing customers to use widely available appliances such as kettles.
Social tariff should be substantial enough to make a difference in respect of the purpose for which it is intended.	First block of energy sufficient for lighting, media and limited cooking.
Not put the beneficiaries into poverty trap that restricts them to a limited benefit.	Further energy at normal cost not limited.
Benefits should reach a clearly identified group of beneficiaries (the target group), with as little as possible leakage to those outside the group.	Coverage of self-targeted tariff limited by electrification and communication. Broad based subsidy has higher leakage to non-poor households.
Simple tariff structure will assist understanding and reduce the costs of implementing the tariff.	Simple two-block tariff, but extensive communication campaign recommended to improve understanding.

Some of the findings of the BEST research agree with findings of other researchers. Ballantyne [2002] reported that the broad based subsidy of 20 kWh per month implemented by the municipal utility in Cape Town has little effect on large customers: “... where the average monthly consumption is 600 to 700 units the 20 free units has had no effect on consumption levels.” Further, the total number of units claimed each month varies by nearly 10% partly, but not only, because: “the marked increase in December 2001 can be attributed to the many holiday dwellings where purchases are made only during holiday periods” indicating appreciable leakage to wealthy households.

Zomers [2001] states “the benefits of electrification for rural households are often limited to improved lighting and (a better) supply for audio and video appliances”. The BEST research considered the limitations of very restricted capacity supplies and recommended that for the subsidy to be an effective means of poverty alleviation it must supply enough energy for limited cooking. Of course, this would not be

possible with rural electrification from PV supplies, confirming the importance of grid electrification.

6.6.5 Estimating the costs of the subsidies

The cost to a utility of the subsidy depends on how it is calculated. If taken as the value of the revenue foregone, being the “free” units at average cost, the subsidy will cost a utility about:

35 c/kWh x 50 kWh/month x 1 million customers x 12 months = R210 million/year. In addition there are network reinforcement costs and possibly higher average costs for energy purchases.

However, there is a difference between the single rate tariff used to calculate foregone revenue and the cost reflective tariff. The subsidy will move many customers from using less than 50 kWh/month to a higher level of consumption. This is already evident from the preliminary data collected from the pilot sites, which will provide useful data for the assessment of price elasticity. The increased consumption of the very small consumers reduces the “loss” already factored into the existing tariffs. Therefore, for customers already connected, the first block incurs small marginal cost for the utility, but passes a bigger benefit to the customers. The difference arises from the subsidies that are already approved and incorporated in the single rate tariff.

The detailed calculation of the cost to all utilities of a support subsidy depends on their existing tariffs. Alternatively, a simple mechanism for compensation is possible if the recommendation for a single national self-targeted support tariff is accepted.

6.6.6 Implementation by municipalities

In an interesting political development, some local authorities acted before the central government reached a decision on the support tariff and implemented broad-based tariffs designed to support the poor within their own areas of supply (see Table 6.3 and case study 11). However, these tariffs made no provision for the fact that most of the country’s poorest people live in rural areas outside the municipalities, and that the municipal tariffs made little contribution to the poverty alleviation of the poorest sector.

Table 6.3: Municipal electricity support tariffs (as at February 2002)

Municipality	Domestic customers	Prepayment meters	Subsidy tariff
Cape Town	520 000	305 000	20 kWh a month free for all households
Durban	480 000	160 000	Planned: 50 free kWh a month for all households
Tshwane (and Acacia)	260 000	135 000	50 free kWh a month for all households
Port Elizabeth	150 000	110 000	Planned. Only to households with income <~R1200 a month.
Bloemfontein	130 000	90 000	30 kWh a month free for all households
East London	~100 000	~70 000	Planned: 20 kWh/month (probably to be means tested)
Pietermaritzburg	55 000	10 000	Council will wait for Government's policy decision
Polokwane	25 000	9 000	100 kWh pm @ 19 c/kWh, 33 c/kWh thereafter (+VAT) for all households since 1995, or 100 kWh pm free, 33 c/kWh thereafter (+VAT) since 1998 for households with an income of less than R800 pm. About 3000 households qualify and re-apply annually.
Robertson (part of Breede River and Winelands)		~ 10 000	20 kWh pm free where household income <R800 pm
Heilbron(part of Ngwathe)	6 800	5 200	15 kWh a month
Eshowe	3 500	1 500	Planned: 50 kWh a month from July 2002

Source: UCT, 2002

Case study 11: Subsidies implemented by municipalities

Six municipalities implemented a variety of tariffs, varying from 15 to 100 kWh/m free for all households or significantly subsidised. In some cases, means tests were used to identify qualifying households. Other municipalities had plans to implement a tariff or were waiting for guidance from central government.

The municipal sites where social tariffs had been implemented provided valuable input to the tariff research.

Source and further information: UCT, 2002.

Analysis

(1) Adopting a uniform basic electricity support tariff will require adjustments by most of the municipalities that have already implemented subsidies. For some customers the benefits will be increased, but for others the new subsidy will be a decreased benefit.

(2) Allowing local choice of the subsidy form and size will have implications for government policy, determining the costs of the subsidies and transfers between utilities, and EDI restructuring.

The domestic tariffs in Cape Town are illustrated in Figure 6-4.

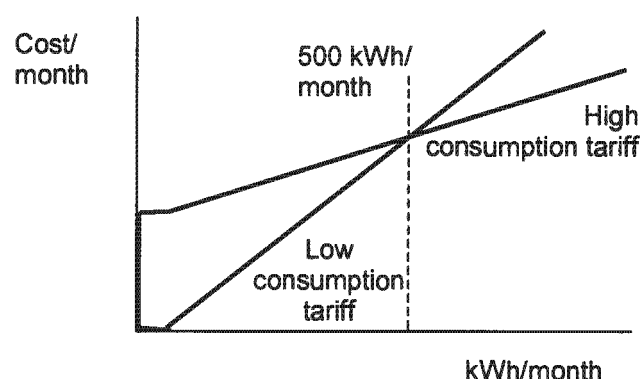


Figure 6-4: High and low-consumption tariffs in Cape Town

Since high consumption customers will not be using less than 20 kWh/month, their tariff is equivalent to a lower service charge and no free basic electricity, as indicated in Table 6.4.

Table 6.4: Effective domestic tariffs in Cape Town

<i>Tariff</i>	<i>Service charge</i>	<i>Free basic energy</i>	<i>Energy charge</i>
Low consumption	0	20 kWh	34.05 c/kWh
High consumption	R30	20 kWh	27.8 c/kWh
Equivalent high consumption	R24.44	0	27.8 c/kWh

Clearly, the subsidy is given to all customers having low consumption defined as being under 500 kWh/month, representing high leakage of the benefit to households that are not poor. The size of the block of free basic energy is constrained by the structure of the subsidy. A block of 50 kWh would increase the leakage to the low consumption customers and reduce the effective service charge for the high consumption customers to R16.10/month. Substantial tariff restructuring would be needed to provide a meaningful block of free basic energy to poor households.

The larger municipal utilities have capacity to fund a limited subsidy by relatively small increases for all customers. In the case of Cape Town, the cost of a broad-based 20 kWh allowance to all domestic users was funded by a 1.6% tariff increase. The tariff increase was not approved by the NER and provoked an as yet unresolved dispute³³.

³³ The dispute, declared in 2001, was expected to be heard in the Pretoria Supreme Court on 18 November 2002, and then proceed to the Constitutional Court, however the hearing was postponed. The focus of the dispute is the role and authority of the NER in respect of tariffs approval, but underlying questions relate to the roles, obligations and rights of local and national government in electricity supply.

The policy issues behind the dispute are unclear, because the NER apparently withheld approval because of the subsidy element, despite having decided “we accept a degree of cross subsidisation in electricity pricing between different categories of customers which is both necessary and inevitable” [NER, 1999a].

The outcome of the dispute could be very important to Eskom, because if the Government fails to implement central funding of a BEST, Eskom will be under pressure to implement the tariff without Treasury support, but, because of the high number of poor domestic customers electrified during the electrification programme, the costs will require a much larger tariff increase than needed by the Cape Town municipality. The smaller municipalities similarly do not have the large pool of larger customers to carry the cost of the subsidies.

As a result of the wide variety of tariffs applied at present by electricity utilities, and the small likelihood that tariffs will be rationalised during the next few years, it was recommended that a nationally uniform BEST be implemented by the government as a first step towards rationalisation, but with the flexibility to accommodate all the existing tariffs. Various ways of implementing a tariff that supplies about 50 kWh for a nominal price of R5 are indicated in Table 6.5.

Table 6.5: Alternative forms of a basic electricity support tariff

<i>BEST format</i>	<i>Energy at a 'typical' cost of 36 c/kWh</i>	<i>Effects</i>
50 kWh for free	Tariff is worth R18/month to households.	Provides 50 kWh 'free electricity' but potential for future problems is high.
50 kWh for R5	R5 buys 13.9 kWh and 36.1 kWh are free. Tariff is worth R13/month.	Provides substantially less than 50 kWh for free.
65 kWh for R5	R5 buys 13.9 kWh and 51.1 kWh are free. Tariff is worth R18.40/month	Provides approximately 50 kWh for free; but less in utilities where energy tariffs are low and more where tariffs are high.
Variable kWh for R5, depending on each utility's tariff	50 kWh free, R5 buys 13.9 kWh of additional energy, so total energy bought is 63.9 kWh.	All customers get 50 kWh for free, but the balance at rates that vary with each utility.

The advantages of a self-targeted tariff providing the same energy to all customers for a nominal fee (such as 65 kWh for R5) are:

- Everyone nationally receives the same energy for the same payment, independent of the different energy tariffs in the many utilities.
- The effective financial subsidy to customers supplied by utilities with high tariffs is greater than to customers where electricity tariffs are already lower. This moderates the effects of national variations in domestic tariffs.

- The tariff can be managed most effectively in the future, according to the funds available from the government and the benefits intended for the target customers.

The disadvantage of requiring a nominal payment to obtain the free portion of electricity is that some very poor households state that they cannot afford it, but supplying free electricity reinforces long-term social dependency. Addressing such poverty is beyond the capacity of an electricity utility's lifeline tariff.

6.7 Usefulness of the concept of social electrification

The analysis indicates the need for balance between urban and rural electrification for social objectives, and allows that the level of service provided for social electrification could be lower than for economic or socio-economic electrification. It also shows that area coverage is appropriate for social electrification, but would not be expected for socio-economic electrification.

Prepayment meter technology accommodates an increasing block rate tariff with two blocks, enabling the introduction of social subsidies in domestic tariffs for poverty alleviation. A self-targeted tariff with a demand (current) constraint on the level of service provides sufficient capacity for lighting, media and limited cooking, which meets the social needs without being susceptible to benefits leakage to those for whom the subsidy is not intended. The tariff is relatively inexpensive to administer, which is an important consideration in obtaining the greatest impact from the subsidy expenditure.

Drawing on his analysis of electrification in many countries and World Bank reports, Zomers concludes *"the electrification of rural areas in most countries needed financial support and government initiatives. ... There is thus considerable evidence in both industrialised and developing countries that rural electrification should not be seen as a 'commercial' activity and that utilities need targeted external support from the government or others."* The analysis of social needs in this chapter indicates instead that the support must be directed to alleviating poverty through targeted tariffs that are independent of geographic location. Distinguishing between socio-economic and social objectives clarifies the need and leads directly to possible solutions.

Some technological aspects are fundamental to the concept of social electrification described in this chapter. The load research programme, described in section 4.3.2, provided the data to distinguish between the electrical loads of the poor and the not-

poor. The distinction allows capital expenditure to be matched to customers' needs and reduces the leakage to others of the benefits of a special tariff intended to help poor households.

6.8 Onword

This chapter has considered the interaction between the technological, economic and social sub-systems and found strong support for a social development concept of electrification. Economic and financial studies are inadequate for assessing social development plans because of the long term of the development, the difficulty of expressing the benefits in economic values, and because viability is not a criterion for project approval. In practice lifeline tariff subsidies are widely applied for poverty alleviation. Analysis based on the social model leads to a specification for a social tariff, and research into a subsidy of electricity consumption for poor customers produced a tariff consistent with the specification. This novel proposal for a self-targeted tariff meeting the needs of poor customers is being tested in pilot sites at present.

However, the social and tariff subsidy analysis appears to have implications for institutional structures of the electricity distribution industry, which needs to be considered in the next chapter, although the topic was not initially identified in the hypothesis or literature survey.

Chapter 7

Electrification Institutions - Role, Regulation and Reporting

7.1 Introduction

Considering the performance of electricity utilities inevitably leads to proposals for reform. Widespread corruption in developing countries led Zomers [2001] to state, *"It is now accepted that structural changes such as corporatisation and privatisation of the organisations are needed to effectively remedy these ingrained institutional practices"*. The main sources of problems on World Bank financed projects in the electricity sector between 1980 and 1992 were identified as financial problems, lack of management autonomy and accountability, and unclear goals. Restructuring was proposed: *"efficiency and effectiveness of infrastructure provision derive not from general conditions of economic growth and development but from the institutional environment, which often varies across sectors in individual countries. This suggests that changes in the institutional environment can lead to improved performance, even when incomes are low"* [World Bank, 1994]. Zomers concludes, *"the question for the developing world could be what is the **minimum** reform that is appropriate to stop political interference and government intrusiveness and to enable utilities to buy power from, and co-operate with, independent generators including industries"*.

Parallel with the electrification programme, and stimulated by it, there has been almost continuous discussion of restructuring the electricity distribution industry in South Africa. This chapter reviews the roles of the various institutions involved in electrification, and aspects of the relationship between institutional structure and electrification. It is impossible to consider all aspects of reform, and attention is restricted to the relationships between structure, objectives and technology.

7.2 Components of the institutional system

Although written thirty years ago, before the present drive for industry restructuring, the following still summarises the position regarding the institutions of electrification:

"Electrification of developing countries includes some of the most complex and extensive problems to be faced. There is therefore the greatest need for

co-ordinating authorities. Such authorities could review the whole range of electrification problems and help establish a co-ordinated approach. Questions to be dealt with include power market surveys, over-all power system planning, and specific problems of power generation, transmission and distribution, as well as institutional matters such as the organisation and management of the electric power utilities, training of personnel, formulation of tariff policy and electric utility accounting procedures.” [UN, 1970]

More recently, in relation to renewables but relevant to electrification in general, broad institutional consideration is still needed: *“Especially in the context of market development and governmental rural energy supply programmes, it is important to consider other institutional and organisational levels, which strongly influence the success of the implementation of rural energy supply models.” [Reinmüller and Adib, 2002].*

The components of the institutional sub-system are described below.

7.2.1 Government

Berrie [1992] identifies the responsibilities of developing country governments in respect of electricity supply as defining policy because market forces give only limited signals, supporting utilities in obtaining capital for development, supplying standards and environmental guidelines, and being consistent to all utilities. Munasinghe [1987] similarly identifies a role for government in rural electrification in terms of *“policy initiatives, legislative support and financial assistance ... even in a relatively wealthy and industrialised market economy”*.

By contrast, the Electricity-for-All programme was initiated by the electricity utilities in response to business initiatives, rather than government policy, and the programme was already well underway before the new government adopted it in 1994.

One of the complexities of the electricity distribution industry in South Africa is that the Minister of Public Enterprises is responsible for Eskom, the Minister of Provincial and Local Government for the municipalities and their electricity utilities, and the Minister of Minerals and Energy for electricity policy, electrification and the National Electricity Regulator.

7.2.2 Electricity utilities

Two distinct groups carried out the electrification programme:

- The municipalities had a substantial existing base of customers supplied over networks that needed continued operation and maintenance. They had experience of technology developed for the mostly urban environment, and mature processes. They had to cope with the results of civil action that encouraged the non-payment of accounts for services, including electricity, and to overcome challenges of local government reorganisation with the emergence from apartheid.
- The Eskom Distributors had a relatively small base of domestic customers, but extensive rural MV networks. They needed to introduce relatively new technologies to meet the financial constraints of the programme, develop business processes suitable for the new activities, and broaden the experience of the staff. The burden of operations and maintenance was initially low, but grew quickly and will continue to grow as the customers' consumption of energy increases and the networks age or need to be reinforced.

Both groups are required to be market-driven and responsive to the needs of their customers, have the capability to introduce and operate advanced technologies appropriately to reduce costs, and support government objectives for economic and social development.

7.2.3 Regulator

The regulator is appointed by the government to objectively promote fairness between the government, utilities and customers, including:

- interpreting government policy,
- advising government on regulations needed to give effect to the policy,
- approving applications for licences to supply customers, defining the areas and conditions,
- approving tariff structures and levels, probably setting profitability limits, and
- protecting the interests of customers, particularly those with little political influence, such as the poor.

A fundamental issue in developing countries is whether the electricity distribution industry has adequate resources for regulation in competitive or adversarial structures.

One of the objectives of the NER since it was established in 1995 has been to rationalise the tariffs of the existing utilities, but the structures and levels are still very different [NER, 2002c]. The unresolved dispute with Cape Town Electricity, nominally over tariffs, indicates rationalisation will not be achieved until the political

issues have been decided. Similar tariffs will only be adopted if the utilities agree on the purposes of the tariffs, but there is still disagreement over the costs of implementing different tariffs (time-of-use, demand, capacity or consumption), and the revenue to be collected from different customer groups. The variety of existing tariffs was identified in the BEST research [UCT, 2002] as an issue affecting the introduction of a new tariff for poor households and the proposed industry restructuring.

Regulation is a political activity to distribute various benefits, where market mechanisms are excluded or fail, but regulation itself is not immune to failure³⁴. Failure may arise from a lack of understanding of the consequences of regulatory actions or, in the same way as for any other participant in the electricity sector, through bias or corruption. The effects of regulator failure may be more subtle but just as damaging as in other sectors. It is essential, for example, that the regulator understands the differences between conditions in developing countries and any developed countries to which it may turn for assistance or training, such as provided under aid agreements [NER, 2000].

7.2.4 Private sector

Many writers have identified the essential role of the private sector in electrification, for example Mehlwana [2001] stated in regard to the service delivery approach to PV systems in South Africa: *"governments alone cannot address the energy poverty issues. The need to involve the private sector and create public-private partnerships in service provision is widely recognised in this programme."* Eskom identified several possible joint venture distribution companies during the early years of the electrification programme (see case study 12), and three were established. However, the relatively insignificant contributions to electrification by PV service providers and joint venture companies as utilities do not validate Mehlwana's statement.

Private sector contributions are generally restricted to contracts for construction services and materials. Some utilities are reluctant to use private companies because they are outside their direct control or are perceived as making unreasonable profits. The private sector and market forces will not contribute materially to the electrification of the poor without sufficient incentives, and subsidies for social electrification will contribute to private companies' profits. The regulator, no doubt, would try to limit the profit, but would have difficulty in an imperfect market. Therefore, an increased contribution by private companies to electrification in

34 The NER was officially criticised for mismanagement and restructured in 1998 [NER, 1999a] and the financial and compliance audit reports were qualified in 1999/2000 [NER, 2000].

developing countries appears unlikely unless the public sector breaks down, as has happened in some countries.

Case study 12: Lwandle Joint Venture

Eskom initiated several negotiations during 1992-1993 around the establishment of joint venture (JV) companies to electrify townships under the authority of local councils that lacked the resources to undertake electrification. One of the projects negotiated was for the electrification of Lwandle, a township in the Western Cape. The local council had arranged funding from the Provincial Administration and project planning and design by consulting engineers was almost complete. The JV model projected household consumption commencing at 200 kWh/month and growing quickly to 300 kWh/month. An installation of high standards would be provided, the project was financially viable and Eskom undertook to fund it on condition the supply rights were transferred and the Provincial Administration provided certain guarantees. The proposal appeared favourable to all parties. The consulting engineers, however, had recently carried out research on household incomes and energy expenditure for a similar township in the region. The consumption projections arising from that research were significantly lower than in the JV model. The more pessimistic forecast resulted in substantial losses that would be recovered from the guarantees. No agreement could be reached for the establishment of the JV and the project proceeded as originally planned. The revenue during the early years of the project was close to the forecast, and significantly below the JV model projections.

Source: Own experience.

Analysis

- (1) The results of the financial model of the JV operations were sensitive to the consumption projections. Any projections could be justified by analysis of the possibilities in the absence of reliable data. Only recently acquired information from a similar community avoided a situation in which the project would have "under-delivered".
- (2) Favourable financial projections were used to justify changes to the structure of the distribution utility. The errors in the assumptions could have led to results that were not acceptable to some participants in the proposed restructuring.

7.2.5 International associations

The institutional structure extends across national boundaries, and there are several important electricity associations in the Southern African region. The Southern African Power Pool (SAPP) provides for energy trading between countries, mostly at voltages exceeding 132 kV. More importantly for distribution, the Power Institute for East and Southern Africa (PIESA) has working groups on low cost electrification, standardisation, reduction of non-technical losses, incident investigations and power systems analysis.

7.3 Restructuring in South Africa

7.3.1 Justification for restructuring

Some proposals for restructuring are based on the supposition that it is needed for achieving objectives, as illustrated by the following examples.

"With the present structure of the electricity supply industry, it is highly improbable that these goals [accelerated national electrification] will be achieved. Consequently three main interventions are required: restructuring of the electricity supply industry; rationalisation of tariffs; and establishment of financing mechanisms and an electrification fund. ...the structure of the industry needs to be rationalised into a smaller number of distributors (from one to ten)" [Van Horen and Eberhard, 1994]. However, electrification targets were achieved without restructuring, tariff rationalisation or an electrification fund.

A reduction of political influence is also offered as a justification of restructuring. *"While it is probably true that innovative approaches to electrification have partially been a result of the current industry structure, it is becoming increasingly clear that the objective of 'sustainable electrification' is not achievable for many small local authority distributors. Despite the capital subsidy for service connections, operational losses are a severe constraint to many municipalities continuing with electrification. Attempts to reduce the level of non-technical losses will, in many cases, continue to be futile until the industry is placed at 'arms length' from political influence. This will only be achieved through the industry restructuring."* [SALGA, 2001b]

Other justifications are based on perceptions of size, costs, and efficiency. Eberhard and van Horen [1995] state *"While it may achieve the target connection rates for several years in the mid-1990s it is inevitable that the programme will founder once most urban townships have been connected and the focus begins to shift to the more costly rural areas. ... The unfavourable position in rural areas occurs for two main reasons: first, capital connection costs in rural areas are generally higher because of greater distances from the grid, and second, electricity consumption levels are lower because of low levels of affordability together with the availability of cheap or free alternative sources of energy such as fuelwood."* Chapter 4 showed that this argument is modified if rural supplies are planned and designed for the identified lower consumption and Chapter 6 discussed the sources of subsidies.

Sometimes restructuring is justified by a need for market competition. Eberhard, a member of the Board of the NER, felt restructuring of the distribution industry was needed so that electricity retailers could compete *"with other retailers to offer the*

most competitive electricity service of choice for individual customers” and “a competitive electricity market will greatly simplify regulatory requirements” [Eberhard, 1999]. However, the Regulator has indicated that competition is not foreseen. “The wires component of distribution, as a natural monopoly, will always be subject to regulation... The retail or supply business will be regulated while there is no retail competition and be subject to competitive market forces when retail competition is eventually introduced; this is not foreseen in the medium to long term.” [NER, 2002c].

7.3.2 Progress

As described in Chapter 2, Eskom was created in 1923 to take over the private companies, but not the municipal electricity utilities. Thereafter, the electricity function was entirely owned by national and local government. There were no shares, and the assets were funded by revenue from customers and loans. The municipalities’ customers had representation through the elected local government, and representatives of major customer groups were appointed to Eskom’s governing body.

During the 1980s, Eskom announced its intention of unifying the distribution industry, but this was dropped in the face of intense resistance from the municipalities. Restructuring to support electrification was debated widely in the early 1990s, but the greater need was probably a political one for visible changes reflecting the change of government in 1994. After several reports³⁵, consultants were appointed in 2000 to prepare proposals for restructuring, generally in accordance with van Horen and Eberhard’s proposals for less than ten distributors [DME, 1999]. Implementation of the recommended six regional electricity distributors (REDs) is unlikely before the next elections in 2004.

Delays in the restructuring of distribution led to proposals to restructure generation and transmission and sell Eskom. The Eskom Amendment Act of 1997 and Eskom Conversion Act of 2001, provided for a competence-based board of directors to replace the stakeholder-representative Electricity Council, and clarified that the government owns the assets of Eskom. The changes were made to “*prepare Eskom for ESI reform*” [Maroga, 2002]. Since the duty of care of directors is to the shareholders, the new board is responsible for ensuring the government’s objectives are met, in strong contrast to the previous responsibility towards stakeholders. Under the present structures, therefore, Eskom is a company owned by central government, while the municipal utilities are responsible through the local government councils to the inhabitants, most of whom are customers.

35 National Electrification Forum, Electricity Working Group, Electricity Restructuring Interdepartmental Committee, DME cabinet memorandum [DME, 1999 and FFC, 2002]

7.3.3 Difficulties of restructuring

Eskom and the municipal utilities are in different stages of institutional maturity and have different customer profiles. So amalgamating and re-dividing the EDI into six REDs must be expected to be complex, with relatively high risk. At this stage, it is not clear how confidently the benefits are expected, in the context of the justifications for change ten years ago and the subsequent performance of the industry.

7.4 A different structure

Restructuring is proposed on the basis that:

- the existing structure will prevent attainment of the objectives, or
- an alternative structure will be more effective in achieving the objectives.

7.4.1 Structure did not prevent attainment of objectives

The electrification programme's goals were met. Initially costs exceeded the estimates, but adopting lower capacity technologies and suitable processes reduced infrastructure costs below the initial budgets in real terms.

The consumption of the poorer customers did not reach the levels expected by some at the start of the programme, but other forecasts turned out to be more realistic. Higher average consumption, and more viable financial performance, would have been achieved by adopting policies of selective electrification, but initial investment costs per connection would have been higher. Blanket electrification does not discriminate against poor households, as selective electrification does. If selective electrification had been widely implemented it would not now be possible to reach the poorest households with support tariffs for poverty alleviation.

The evaluation of the National Electrification Programme showed that it did not meet levels of financial and economic viability expected of economic development. However, this objective was not defined at the beginning of the programme. Indeed, the opposite expectation was true: *"The NEP has never had an objective of achieving 'economic development' per se. The main objective was surely to improve the quality of life for households that previously have not had access to a supply of electrical energy."* [SALGA, 2001b]

It must be concluded that the structure did not prevent attainment of the electrification goals, but the possibility exists that performance might have been even better if alternative structures had been adopted.

7.4.2 Alternative structures

Worldwide, the electricity supply industry is being restructured, although for different reasons in different regions. Karekezi and Kimani [2002] described the situation in Africa as follows:

"Traditionally, power utilities in Africa have enjoyed a monopolistic hold over their national electricity industry. There is growing consensus that the monopoly has contributed to the undeniable under-performance in the delivery of electricity services. Power sector institutions are mainly characterised by unreliability of power supply, low capacity utilisation and availability factor, deficient maintenance, poor procurement of spare parts, and, high transmission and distribution losses among other problems. ... The power utilities in Africa have failed to provide adequate levels of electricity services to the majority of the region's population, especially to rural communities and the rural poor. ... The need to reform the electricity sector arose from the dissatisfaction over its poor performance."

Two aspects arise from their analysis. First, the EDI in South Africa does not appear to exhibit the failings justifying reform in other parts of Africa. Secondly, reform being considered and implemented in Africa, often with advisors from developed countries, is similar to that in the developed countries, on the apparent assumption that the developed-country solutions provide a better industry structure. However, reform in Africa is not proposed for the same reasons as reform in Europe and North America.

For example, unbundling of the small Uganda Electricity Board into entities "for generation, transmission, system operator, bulk supply, export/import, distribution (network services) and retail supply" commenced with a new Electricity Act in 1999 [Government of Uganda, 2000]. However, "The Uganda Electricity Board openly acknowledges that it does not want to be in the business of rural electrification" and political pressures to extend the grid and the constraints on tariffs "hinder the UEB's economic viability." [ESMAP, 1999b] The reform does not appear compatible with the electrification objectives and it is unclear how the donor investment intended to support privatised rural electrification will improve conditions that could not be rectified within the existing structures. A different problem with objectives and implementation exists in Zimbabwe (see case study 13), but with similar effects.

Case study 13: Zimbabwe Electricity Supply Authority's strategic objectives

After several strategic planning exercises, ZESA adopted objectives of being innovative, providing product and service quality to customers, attracting and retaining skills, and operating profitably and with liquidity. It also retained its objective of total electrification.

Although some improvements have been made, technical losses are increasing, plant availability is low, and financial ratios do not meet targets. The failure to meet many of the objectives can be ascribed to the corporate governance: "the existing electricity legislation was designed along the strong state control socialist ideology ...the performance of the ZESA reflects the performance of the Minister in charge". Ignoring the market forces prevents ZESA and the government from achieving the socially inspired objectives.

Source: Mangwengwende [2002]

Analysis

- (1) Most of the objectives are politically correct, but several lack measurable targets.
- (2) Tariff and power sector reforms must be compatible with macroeconomic policy.

An alternative to restructuring is the establishment of a completely separate authority for electrification, as in Zimbabwe [ZESA, 2001]. There are many disadvantages of adopting the approach in South Africa. The new organisation would draw its engineers and managers mostly from the established utilities and they would have to give substantial attention to developing new support systems that already exist in existing utilities. There would be substantial overlapping of geographical areas of activity, requiring duplication of facilities. Finally, once access to electricity was provided, the customers and infrastructure would be transferred to the existing utilities or another, in this case parallel, organisation would be added to the already diverse structure. A new utility working in areas that are already partly electrified would contradict the natural monopoly of the wires business of electricity distribution. It appears that new electrification organisations can only be justified where large regions are unelectrified or only sparsely electrified.

7.4.3 Rearrangement for improved performance

Could a different structure have achieved the economic and financial viability that was not achieved? Proposals for restructuring into larger utilities for greater efficiency are based on the perception that efficiency increases with size. With about one million customers each, growing to an average of 1.5 million as electrification is completed, the six REDs proposed in South Africa will have similar numbers of domestic customers as distribution utilities in England. By contrast, the average size of a rural co-operative in the USA is about 18000 customers (median is about 11500) [NRECA, 2002]. There does not appear to be conclusive research that shows large distributors perform more effectively or efficiently than smaller ones. Instead the

benefits of proposed structures appear to depend on the backgrounds of the proponents - see box 7.

Box 7: Similarity of restructuring proposals

Why do so many proposals for electricity industry restructuring appear similar? Needs may be similar, but the backgrounds in the various countries are usually quite different. Assessment of some of the changes in Southern Africa and discussions at industry meetings like CIRED and Cigré indicate that reform proposals tend to be similar because:

- ✓ Financial power is concentrated in a small group of countries, with worldwide influence through finance institutions and political connections.
- ✓ Utility managers, government officials and regulators meet regularly in international conferences, sharing ideas from which they tend to develop common viewpoints, even where their backgrounds differ.
- ✓ It is uncomfortable and even risky to take a path of action significantly different from other participants, while compliance with the “general wisdom” of the industry is easy to justify and reduces criticism when things do not turn out as planned.
- ✓ Large organisations promote changes from which they could benefit.
- ✓ Giving advice on restructuring is a low cost, low risk form of aid from developed countries to developing countries that usually replicates the experience of the advising organisation.

Further, the effects of restructuring appear unpredictable. An analysis of restructuring in Europe reported, *“Rather unexpectedly, the opening to competition of the electricity distribution sector has not resulted in convergence with respect to process, economic performance or productivity”* [Gilbert, 2000]. The restructuring in Europe specifically introduced competition, and no retail competition is foreseen in South Africa, but it appears uncertain that restructuring into a small number of REDs under one holding company will produce the anticipated performance.

A smaller number of distributors may have made inclusion and numerical consensus easier in developing the BEST proposals. *“Areas in which significant delays might be introduced are reaching agreement on the crucial issue of “free or subsidised”, agreeing policies and regulations defining the tariff as a nationally consistent programme instead of allowing local choice, and preparing the financial management systems to meet the needs of so many customers.”* [UCT, 2002] However, preference for alternatives could be as strong or stronger, so rearrangement into REDs may not have eased agreement on a tariff for social development.

7.4.4 Rearrangement could make performance worse

Early experience of distribution network planning complementing integrated regional development was found to be expensive. The approach possibly leads to better

electrification for economic or socio-economic objectives, but close integration with other development activities is much less important where the objective is universal electrification. In the same way, the structure of the electricity utility should be appropriate for its context.

Utilities operating in established urban areas are integrated usefully with other departments supplying related services to the same customers. Separation from the municipalities could increase the cost of electrification by more than the saving achieved by apparent 'economies of scale' of discipline-specific utilities.

Experience in other developing countries also indicates that consolidation of electricity utilities may not be entirely successful. Electrification in Brazil during the 1980s was accompanied by utility restructuring, but during the 1990s moves were made to break up the utilities and introduce privatisation. In Zimbabwe, the consolidated ZESA was unable to meet the electrification objectives and a separate organisation has been established specifically for electrification. Karekezi and Kimani [2002] have reported experience in other countries that indicates restructuring is not a sufficient strategy for performance improvement.

Frequent changes in structure are costly in terms of resources and diversion of management attention from other activities. During change it is necessary to expend effort and resources on management and regulation to ensure utilities do not neglect important activities, like meeting the needs of certain sectors and innovation, which is unprofitable in the short term.

One of the requirements of the EDI is that it be able to obtain the capital needed for expansion and network reinforcement. Khatib [1997] identifies three conditions for attracting private capital: government guarantees of the financial independence of the electricity utilities; financially and economically viable performance by the utilities; and expectations that they will be able to repatriate good returns on their investments. Since the availability of capital was not been a problem in the electrification programme, and the government now provides capital subsidies, requirement for capital does not appear to be an issue justifying restructuring. On the other hand, restructuring that conceals inherently poor financial and economic viability of electrification programmes could have long-term detrimental effects.

Restructuring at this stage could have serious consequences for maintaining the quality of supply of the system. The possible under-design of the rural systems, with the hindsight of actual load growth, was identified in section 4.4.6. Rearrangement of the utilities requires preservation and access to the planning and construction records, which has been demonstrated to be a problem in several take-overs and

amalgamations by Eskom and municipal utilities. *“Recent studies suggest that the continual transformation of the institutional landscape in South Africa has reduced the capacity of most government bodies to implement new reforms effectively. Compounding this, the new demarcation has forced several previously independent departments to amalgamate and in some instances entirely new departments have little previous experience or information on service delivery in their new areas.”* [UCT, 2002]

Therefore, experience indicates that rearrangement of distribution utilities could have disadvantages similar to or greater than the advantages.

7.4.5 Adoption of different objectives in a rearranged structure

In South Africa, rearrangement of the utilities would have reduced the industry's diversity, which appears to have been a source of innovative experimentation with technology and competition by comparison [Borchers et al, 2001]. It is therefore reasonable to consider that a unified industry during the late 1980s may not have accepted the challenge of electrification, preferring instead to remain with the status quo until forced by political events to change, or that rearrangement at the start of electrification would not have made the high costs of implementation as visible as they were in 1995. Loss of institutional diversity, then, could possibly have led to the adoption of different objectives by the distribution industry.

Where a new organisation is established specifically for electrification, it becomes the justification for its existence and will define the main objectives [ZESA, 2001]. However, it also creates a situation in which the basis for deciding to create the organisation might overshadow a realistic assessment of the possibilities. Having a singular reason for existence does not guarantee the capabilities to carry out the responsibilities, especially where detrimentally affected by corruption, incompetence or a lack of resources.

7.5 Structure and social development

Several authors have identified the problems that characterise many electricity utilities in developing countries, for example *“weak planning, inefficient operation and inadequate maintenance, high technical and non-technical losses, low quality of supply and frequent power failures, inability to raise prices to meet revenue requirements, poor management, excessive staffing and low salaries, poor staff morale and performance, undue government interference, and so on”* [Munasinghe et al, 1989], and more recent publications each add a few more items to the list.

Some of these are the result of the political requirement to have the utilities carry out social functions in addition to their primary purpose of supplying electricity. Others are symptoms of not having transferred technological capability into the institution, considered later.

7.5.1 Finance and structure

Leach [1999] proposes that a diverse array of technical and institutional approaches is needed to support electrification. These include having a greater diversity of institutions and interests, such that the previously large centralised financing “*is giving way to millions of individual energy users and small entrepreneurs who typically need credit financing that is several orders of magnitude lower*”. He states that good financial policies need to be adapted to the conditions of each country, but his and many similar proposals do not appear to recognise that most financial arrangements in developed countries are based on a concept of security of property. Property rights are strongly enforced and provide guarantees or remedies for credit financing and loans. Conversely, in most of Africa, property rights are only weakly recognised and in some countries are overturned by government regulation or directives. The denial of property rights in Zimbabwe, and nationalisation of businesses in other countries with minimal compensation, completely undermine the conventional (developed country) approaches to financing. While large loans for energy projects are guaranteed by national governments, similar guarantees for small-scale credit are impractical. The conditions relating to property rights may be more important than the “*weakness of Africa’s energy policy making and planning capabilities*” identified by Leach.

Many developing country utilities depend on government grants, foreign loans and aid grants. The limited alternatives force the utilities to comply with the financiers’ conditions. From the financiers’ points of view, the conditions are imposed to reduce the risk of losses or to ensure that their objectives, such as economic development or poverty alleviation, are met. The developing countries “*have reasons to assess their operations and in this respect they are encouraged, and occasionally ‘obliged’, by lending institutions*” [Zomers, 2001].

Where utilities are directly involved in social action, as with the BEST, development must be regulated because grants, subsidies and aid for social energy lack the forces of a market. Looking to the future “*The tariff should be implemented on a national basis, without allowing “freedom of choice” by the electricity supply utilities. Future changes to the structure of the electricity distribution industry, by the implementation of the REDs or by any other process, will have significant complications if the BEST has to be modified whenever utilities change.*” [UCT, 2002]

7.5.2 Privatisation

Recent changes in developed countries have been towards the privatisation of the public utilities. If this change is perceived as beneficial, what was the justification of the nationalisation of most of them in the first place? Have the objectives and values of the governments changed? What is the nature of the change?

In the developing countries, the public utilities are seen to be in the national interest, contributing broadly to development, and effectively reinvesting any profits in the country and further development, without having to produce returns for shareholders. Unless these conditions have changed or a more important objective has been identified, changes in the ownership will introduce new objectives that are likely to conflict with the existing objectives.

The key differences between public and private utilities are:

- private sector utilities have to recover a surplus or profit sufficiently above the full costs to compensate for the investment risks, whereas public sector utilities are considered to be 'safe' financial investments, and
- the relationships between private sector utilities and government are defined by two-sided contracts, instead of by unilateral government decisions.

The World Bank [1996] proposes that *"By strengthening the finances and managerial position of the industry, the reforms now taking place to put it on a more commercial footing provide a new opportunity for electricity services to be more widely and efficiently provided. They will, however, need to be complemented by some form of public leadership."* It appears ironic that restructuring is needed to reduce the interference from and inefficiency of the public sector, but that it needs public leadership to moderate the tendency of privatisation to *"concentrate on investments in generation and the more lucrative, higher growth, and higher-income end of urban markets"* [World Bank, 1996].

One of the alternatives for greater private sector involvement is management contracting such as was attempted in Guinea Bissau. *"Introducing a five-person management team under a foreign management contract improved the performance of Guinea Bissau's national electric utility"*, however, by 1994 *"serious problems became evident"* [World Bank, 1994]. Problems included non-payment by government departments and illegal connections by consumers. By 1997, the conditions had deteriorated to being as bad as before the management contract was placed and, although neither the government nor the management contractor wanted

to continue, there was no-one interested or in a position to take over the utility management³⁶.

Zomers [2001] concludes, *"neither the privatisation of utilities nor competition are solutions for the electrification of rural areas. It would be very difficult to find private enterprises that would be prepared to electrify rural areas, accept a very low rate of return and charge affordable tariffs, even monopoly-based ones let alone those with competition."*

7.5.3 Competition

Competition requires a market with sufficient players to allow comparisons to be made. *"Generally it takes many competitors, none of which has a large market share, to produce perfect competition in the economic sense."* [Stoft, 2002]

The EDI in SA does not have direct competition within the licensed areas of supply, but there are several forms of competition that are less evident. For example, there is competition in household energy from other energy suppliers, especially paraffin, which is zero rated for VAT, while VAT is added to electricity.

In the electrification programme, competition existed between the costs of supply reported by various authorities, culminating in the NER awarding the same grants per connection to all the municipalities in 2001 (see Table 2.6). Thus the municipalities that could not achieve the common performance standards had to find their own supplementary funding.

Indirect competition between the municipal utilities and Eskom is evident in technological standards and tariffs. Although both Eskom and the municipalities participate in the establishment of common standards (NRS), Eskom does not itself use them. Tariffs are visible to customers, especially at the boundaries of supply areas where comparisons are made easily. Eskom criticises the municipalities for subsidising domestic tariffs, but the costs of supply operation and the maturity of the municipal systems in urban areas reduce the real costs of many municipalities.

Eskom's statement of intent of unifying the industry led to some conflict with the municipal utilities and stimulated the debate on restructuring. Threatened restructuring is a virtual competitor, as good performance is the best argument against making changes. This may have been a strong factor in the success of the NEP, with the municipal utilities significantly exceeding their targets.

³⁶ Personal discussions with government, utility and management officials in Bissau.

In the extreme, non-performing utilities are taken over by other utilities, so that some consolidation takes place naturally over long periods. Durban Municipality supplies towns beyond the metropolitan boundary, and some small towns have transferred their supply rights to Eskom.

7.5.4 Efficiency and effectiveness of meeting social objectives

The level of reform reached in the electricity sector in sub-Saharan Africa is lower than for any other region [ESMAP, 1999a]. Access to electricity makes an important contribution to both socio-economic development and poverty alleviation, so there is a need for the electricity utilities to implement electrification. They have to find a balance between being social welfare institutions and commercial, profit-making organisations. Utilities in now developed economies, like Ireland and the rural United States, achieved this dual objective, but many years ago.

The problem for the African utilities is that the worldwide environment has changed, and they are not in positions of technological, economic and organisational leadership. Finding a strategy for efficient utility management and electrification is a significant challenge for Africa, and the solution is not clearly evident. Munasinghe et al [1989] recommends *"setting more realistic targets for physical and financial performance and clearer identification of constraints on meeting those targets"*. Privatisation is an unlikely route to improvement because of the low economic potential in the region under these conditions. Restructuring is also unlikely to bring success as it often avoids the fundamental problems causing functional failure or inefficiency, introduces new uncertainty, and should only be adopted as a last resort.

Another factor to be considered is that a single monopolistic structure has potential for serious problems if "things go wrong". Bad management, corruption and lack of accountability are typical problems reported from the utilities, government and regulators in developing countries. Diversity of organisations of different size and character reduces the risk in the same way as in a portfolio and allows comparisons between organisations to draw attention to situations where defects exist. Diversity is not only important in a negative sense. It allows different management styles to be adopted, and provides parallel paths for training, from which the best staff can be recruited to the various organisations as needs develop. The existence of different utilities also allows staff to move between them to meet their personal needs without having to leave the country, and at the same time carrying good ideas from one to another. A further benefit of diversity is that there is almost automatic "benchmarking" between the utilities, through reporting to the NER and applications for project funds, stimulating virtual competition in meeting the industry objectives.

7.5.5 Structure and politics

Statements to the effect that utilities should be protected from government “interference” probably arise from a lack of understanding of the conditions. A public utility’s top managers, by the nature of their appointment, will mostly be government supporters, but are still responsible for managing the utility. *“An electricity utility cannot evade the political implications of its activities. To attempt to do so is an indication that the utility’s objectives have not been identified properly. Without a thorough analysis of the environment, including the political aspects, a utility’s management cannot formulate a realistic strategy and cannot be effective.”* [Gaunt, 1980]

Similarly, Zomers [2001] writes *“provided the utilities have sufficient authority, the “government-ruled” structure is appropriate when the electricity supply infrastructure is expanding and efforts have to be directed at making electricity available to the whole population.”*

Earlier comments to the effect that the national electrification was initiated by the utilities separately from government ignore the possibility that the managers in utilities responsible to national and local government were effectively executing their political role.

7.6 Structure and technology

Worldwide, the drivers of change and innovation in electricity supply appear to be customer and public demand for cheaper, high quality supply and environmental sustainability, enabled by technological changes that erode the economic advantages of scale in the electricity utilities and increase the importance of electricity in the total energy mix. The pressures on utilities in developing countries further include:

- increasing demand for electricity
- shortage of funds and skilled personnel
- aging, poorly maintained infrastructure and
- out of date tariffs, especially where inflation is high.

Generally, the responses appear to be:

- re-regulation and restructuring of public utilities to allow and encourage competition, and
- the development of energy market mechanisms for competition to operate.

In addition, but not generally evident from reports, it was shown in Chapter 4 that a technology response can have substantial impact on both physical and financial performance.

7.6.1 Long-linked technology and change

It is useful to consider the organisation characteristics relevant to the success of meeting electrification goals. Neither the Eskom Distributors nor the municipal utilities are characterised by flexibility, but tend to be functionally (or process) oriented (planning, construction, operations, finance, sales) and highly centralised. Thompson [1967] calls these “*long-linked technologies*”, and organisations are characterised by vertical integration and relying “*primarily on standardised responses or rules for adaptation*”. By most theories, these characteristics should have been a hindrance to the effective implementation of electrification, which required supplying new services to new customers. However, the utilities were implementing their core technologies, albeit with some adaptation, and the functional structure promoted efficiency in pursuing the simplistic goals set in terms of connection numbers. Both Eskom and the municipal utilities were able to adapt their processes and standards to meet the new needs of electrification.

The potential existed for the overall objectives to be obscured by other constraints and goals concurrently driving the organisations, including race and gender equalisation, financial constraints and political pressures from government and labour. A lesson from this is that simple goals, carefully monitored and adjusted as needed, can convey a clear signal to the organisation, with the result that objectives can be achieved, even at risk of sub-optimisation.

In this case, the focus of performance was a technological function (connecting customers using a ‘blanket’ approach in most cases, so that boundary-spanning sales and customer interaction was not a key activity). Based on this experience, it can be suggested that a functional hierarchical organisation structure can be appropriate where conditions are relatively stable, as characterised by:

- steady achievement of the connection targets in a steady market over ten years and continuing into the future.
- relatively slow technological change, except in response to internal financial constraints.
- protection of the utilities by legislation and regulations.
- generally mature organisations, not attempting re-organisation at the same time as trying to meet the external needs.
- steady markets.

7.6.2 Technology and business models

Some business models separate the technological management of the wires (or solar PV system) from the supply of energy, as in retailing or energy service companies. The concept of energy services is based on competition in the retailing sector, while the wires or hardware may be owned and managed by the same or another company. Such models place management at the centre of the organisation, and consider technology as a boundary-spanning activity. They are valid and appropriate where the emphasis is on financial performance.

A more suitable model for electricity utilities in developing countries is one having "at the core of the business a technology or process that delivers efficiently and effectively something the customers want. A solid understanding is needed of that core business. Surrounding and supporting the core there are units addressing the financial, human resources and regulatory requirements of business. All the activities are co-ordinated by management. The advantage of this model is that without a core, the other units have no function, but the core cannot stand alone." [Gaunt, 2002b].

Munasinghe [1987] recommends, *"if the national rural electrification effort is entrusted to an existing agency that also has other responsibilities, then the centralized functions associated with design, operation and maintenance, and financial aspects of rural electrification must be clearly identified and assigned to the staff implementing the rural electrification program. As the rural electrification efforts develop and experience is gained, the focus might be shifted gradually towards more decentralized and localized operations and maintenance type functions."*

The recommendation is partially supported by the experience of Eskom. The Distribution Technology (DT) section was established at corporate level within Eskom to develop standards and techniques for application by the Eskom Distributors, the regional operating units. DT's development work helped to shape the technology adopted for the NEP. However, proposals also arose from the Distributors, which had the independence to try alternatives. The mixture of a central group and limited independence encouraged innovation and provided a measure for comparison and a process for disseminating new ideas. Indeed, as the experience increased, a greater degree of decentralisation was achieved and DT's role tended towards integration, support and development. It is anticipated that a similar strong technical core might be established if the proposed REDs are established.

As shown in Chapter 4, the scope for cost reduction through technological improvement is significant despite the apparent maturity of the electricity supply

industry. By comparison, it appears that the scope for significant cost reduction through restructuring is relatively small. This indicates that electrification will derive greater benefit from developing the technology core of the distribution industry, rather than rearranging it. A possible constraint is that suitable technologically trained people appear to be a scarcer or less influential resource than managers.

7.6.3 Technology transfer

There is no doubt that there are capable people within African utilities, even those described as failing to meet their objectives. There are many possibilities for failure: unrealistic objectives (from inadequate assessment of the situation and resources, or imposed from outside); conflict between various objectives, some economic and some social, which management cannot meet without distinguishing between them; or lack of understanding of how to organise to reach the objectives adopted.

Training can be achieved through formal courses for specific skills, workshops for addressing selected topics, and individual training in knowledge areas. However, successful transfer requires opportunities to practice the skills. *"Teaching such skills in a vacuum usually has little impact"* [Miller et al, 1995].

Mbewe [1992] recommends *"Technology transfer between African countries should be encouraged. There should be frequent interactions between experts from different countries to share ideas and experiences"*. In fact, PIESA was established for this purpose.

7.6.4 Reporting as an initiator of change

Importing relevant information to those who can initiate change is an important stage of the adaptive-coping cycle of effective organisations [Schein, 1970]. The high costs of rural connections during the early years of the electrification programme were identified in section 2.4. The middle management of the utilities and the funding organisations, including DBSA, knew that the costs were significantly above the expected expenditure. However, the internal culture in several organisations was directed to perceptions of success and did not easily accept bad news. As a result, the focus of reporting was on the numbers of connections made, by which measure the programme was very successful. This delayed useful action being taken to reduce costs. A similar cultural pressure may be responsible for the low visibility of high non-technical losses, identified in the evaluation of the National Electrification Programme [Borchers et al, 2001]. Without awareness of a problem, change is unlikely.

7.6.5 Regulation and technology

Regulation is not limited to tariffs and supply area licensing, but also addresses quality and other aspects of importance to customers. *"Arising from the finding that operators' perceptions of the quality of line performance correspond well with outage frequency and duration, it is recommended that regulators establish quantitative performance measures for distribution systems. ...and serve as an indicator of the need to take steps to improve performance."* [Gaunt, 1994]

This requires that the Regulator needs to interpret policy, but the responsibility for formulating supply quality policy is unclear. Customers and utilities need to be involved, but the government, or Regulator on its behalf, should lead. In practice, quality of supply and service standards have been prepared by the distribution industry through the NRS system [NRS 047, NRS 048].

7.6.6 Non-grid technology

The behaviour of the grid utility affects the viability of any non-grid electricity provider. Because of the apparent superiority of the grid in respect of supplies over 10 kWh/month, network extension to the most profitable rural development nodes pushes the non-grid options into progressively deeper rural areas, which are more difficult and expensive to service. Therefore competitive (predatory) behaviour by the utility must be expected and either tolerated, because of its natural emergence, or regulated to mitigate its effects on the electrification programme as a whole.

7.6.7 Impact of technology on effectiveness

The analysis in Chapter 4 identified the significant reduction in capital costs of electrification achieved by adopting different technological standards. Clearly, the structure of the industry allowed the adoption of the changed standards. The restrictions on capital availability provided the impetus for change.

Further electrification will be funded from the Department of Minerals and Energy, instead of from internal Eskom funds and, for the municipalities, grants from levies on Eskom generation. The possibility exists, therefore, that the pressures within the utilities to reduce capital expenditure will change. They could argue in future, as in the past, that the "developers", now the government, must meet the costs of electrification to the technical standards of the utilities.

Clearly, the structure of the electrification organisations, source of funding, technology and objectives of electrification are all closely related.

7.7 Significance of structure

The basis of government policy on electricity industry structure, from the early days to the latest experiences with electrification, is that structure will be determined by the current *perceptions* of the public interest. The perceived preferred structure may change in response to external conditions, even if there has been little change in the key aspects of the industry such as customer needs and technology. In fact the needs in Southern Africa would appear to indicate the desirability of changes in a different direction from the restructuring followed in developed countries.

Technology has reduced the economies of scale in distribution, and markets have directed attention to the customers' price and quality of supply needs, indicating that smaller utilities may be suitable. While distributors in some countries have been, or are proposed to be, restructured to consolidate them into larger organisations, in others the past consolidation is being reversed!

Similarly, in some countries electrification was carried out by existing national or provincial organisations, but in others smaller co-operatives or new utilities created specifically for electrification are identified as contributing to success. An evaluation of the National Electrification Programme in South Africa found that the electrification objectives were met by both large and small utilities and, while both showed weaknesses in some respects, there appeared to be strength in diversity.

The size and fragmentation of the distribution industry has several implications. Fragmentation into a large number of utilities, presently just over 200, appears to introduce high costs of management. However, many of these are departments of municipalities, and the management already exists for other services. The service and financial aspects of the electricity utilities are not significantly different from those of other municipal services, although the engineering technology is different. Therefore the costs of management may not be significant in many cases. Fewer, larger electricity distributors might benefit from some economies of technical scale, but the extra boundary-spanning functions in urban and rural areas would probably be more costly. Top-level management and control becomes more complex as more customers and diverse needs must be met.

For nearly a hundred years, it was commonly accepted that geographic monopoly was efficient and in the public's interest. For the wires business, the basis of electrification, this has not changed. The early justification of EDI restructuring to introduce competition between distributors has disappeared.

An industry structure with different types of utilities, as exists in South Africa at present, appears to offer robustness in the face of potential problems. However, the

government has spent substantial sums in terms of time and resources, and decisions have been taken at cabinet level more than once. Therefore, restructuring will probably occur at some stage because it would be too difficult for too many people to retract the proposals unless radically new information becomes available.

In the face of the mixed evidence of success being related to particular industry structures, key success factors other than the institutional structure need to be identified for electrification. The experience of the electrification in South Africa indicates these might be related to having simple goals and a fundamental core of technological expertise.

In general in Africa, since restructuring appears neither sufficient nor necessary to improve performance, the inefficiency, incompetent activities, bad management and lack of transparency ascribed to power sector institutions should be identified and addressed directly.

7.8 Onword

Experience and the substantial reports on the role of institutional structure in electrification indicate that structure is relatively unimportant to success, as long as a few basic requirements are met, including having:

- a clear understanding of objectives that are realistic,
- a technological core that can meet the needs to develop and maintain networks at minimum cost, and
- political awareness in the utilities, and government acceptance of the utilities' objectives and activities, to the extent that interference is unnecessary.

It also appears that efforts and expenditure on restructuring may not show much benefit in the long run, and in the short term could damage the efforts for electrification. Further, there may be significant value in having or retaining diversity of utility structures and sizes, but that direct competition and privatisation of the electricity distributors could have risks for the implementation of electrification for social development in developing countries.

Electricity utilities have been widely used for socio-economic and social interventions, and in developing countries this is not an unexpected role for them. However, social development responsibilities complicate the utilities' obvious goals of delivering electricity efficiently and profitably. Aspects of planning and evaluating electrification under conditions of social development responsibility are considered in the next chapter.

Chapter 8

Planning and evaluating electrification

8.1 Introduction

This thesis has considered several aspects of electrification, including the technologies, ethics underlying electrification for social development, relationships between electrification and society, suitable tariffs to make electrification more effective in alleviating poverty, and the influence of institutional structures on electrification. Throughout this research, it has been assumed instinctively that there is successful and unsuccessful electrification. However, success only exists in terms of achieving the outputs, outcomes or impacts adopted as objectives before the activity started.

Electrification in South Africa appears to have been adopted as an objective in itself, without formally identifying the broader expectations of the programme. Perhaps this is common to electrification in many countries. Without objectives beyond implementation, any progress could be judged successful, but with hindsight something better might have been achieved.

Concepts of economic, socio-economic and social development assist the formulation of goals to guide the planning and implementation of electrification, and those goals become the standard against which achievements are evaluated. This chapter shows how applying the hypothesis of this research could help to make electrification more successful.

8.2 Identifying the objective

Chapter 1 introduced different reasons for implementing electrification. Mkhwanazi spoke of the *"country's agenda for socio-economic upliftment"* and according to Mbewe the objectives of electrification are *"to improve the living standards of the low-income (rural) population through economic growth, and to make their development*

process self-sustaining in the long term". These objectives are representative of economic, socio-economic and social development.

In chapter 3 a lack of resources, other than labour, was identified as a characteristic of poverty. As a result, access to electricity alone is insufficient for development. In effect, if the target community does not have sufficient capacity to benefit from the electrification, then the objective of electrification cannot be economic development and is, rather, improvement of the living standards or quality of life (QOL) through poverty alleviation. The relationship between these two objectives of electrification and a community's capacity to benefit from electrification is illustrated conceptually in Figure 8-1. Electrification of a community having all the other resources needed for economic development but lacking electricity will contribute to objectives defined in economic terms. However, where a community lacks all the other factors of economic development, electrification can only contribute to poverty alleviation. The balance of the contribution of electrification is to socio-economic development, which contributes to long-term economic development with returns from investment that are too insignificant or too long-term to be classed as economic.

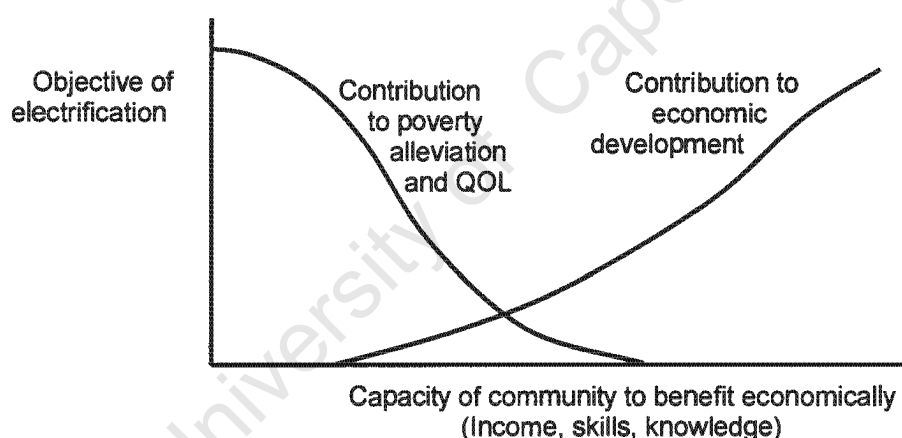


Figure 8-1: Contribution of electrification to development in terms of community capacity to benefit economically

Without understanding the overall objectives and therefore the differences between economic, socio-economic and social development, achieving increased access is perceived as progress and the activity of investing in electrification itself becomes a symbol of success.

8.3 Planning electrification

The planning of electrification is the activity of making choices based on limited information. The following sections indicate how planning decisions depend on the anticipated development.

8.3.1 Community consultation

In the early stages of an electrification programme, community consultation helps to gain an understanding of a community's capacity to use and pay for electricity, and the likely load growth. This should provide the planners with information about the effective objective of implementing electrification in that community. Consultation also provides for transferring information about electricity to people who have not previously had access to it, and are not aware of the alternatives and constraints. As women make many of the decisions about household energy consumption, communication with only the elders of the community may not be sufficient.

Sometimes, during the electrification programme, communities treated consultation as opportunities for expressing grievances and demands. This may have been because they had an inadequate understanding of electricity and electrification, or could have been political or derived from attitudes of entitlement.

It is generally reported that community consultation became easier as electrification progressed, to the extent that it sometimes became superficial or did not happen at all. This is partly because communities gained information from others who had already received electricity, and confidence was established by the reputation of the programme. Although the importance of consultation diminished for the community (perhaps they had other issues they felt were more important), the need for the utility to educate the potential customers about electricity probably did not. The limited understanding of electricity and electrification became evident during the research into the options for the BEST [UCT, 2002].

8.3.2 Blanket or selective electrification

As discussed in chapter 6, blanket electrification is appropriate for social development, but selective electrification where the objective is economic or socio-economic development. The difference also affects the setting of priorities for implementation.

The priority of communities for electrification can be determined according to distance from the existing network, settlement density, potential for economic

activity, public facilities and other parameters, as used, for example, in Zimbabwe [ZESA, 2001]. These factors are important in economic or socio-economic development. However, most have low significance when blanket electrification is being implemented for social development.

Much effort was directed to identifying objective criteria for priority ranking of communities, on the basis that electricity should be separated from politics. This indicates a failure to recognise that there will be political lobbying in a social or socio-economic programme of electrification. In fact, it would be contradictory to expect no political interference in essentially social programmes, so defining objective criteria for priority will always be difficult. A successful tactic of the Eskom programme was to identify a mix of projects that met the target number of connections within the annual budget and make meaningful progress in reducing the electrification backlog in all nine provinces. This approach to objectivity provided negotiating leverage to reduce political interference to levels that were not disruptive.

8.3.3 *Integrated development planning*

Integrated regional development requires co-operation between the many sectors being integrated. It incurs a high cost because it causes delays and adds to the administrative burden, and this becomes especially evident when the planning specialists, professionals, officials and other participants working in the economic sector are paid differently from the poor and under-served communities being “developed”. The cost of integration may be reduced where the development is administered by a central government department, rather than relying on co-operation between different disciplines or institutions. However, a loss of input from the specialists may occur because of the centralisation of decision-making.

Lenders and donors may impose conditions requiring integration of electrification with other development programmes. This could be based on a belief that the increase in benefits exceeds the cost of integration, or it could be required to help those agencies present their aid programmes to supporters with other objectives. In practice, the formal integration of plans and programmes also requires greater political participation, sometimes perceived as political interference.

Integration is a characteristic of the logframe. If the participants understand the desired impacts of electrification and the processes or linkages needed to reach the desired outcomes, then the need for central integration or co-operation will be much smaller. Having a better understanding of development helps planners in each discipline to make better judgements and fewer expensive mistakes.

8.3.4 Optimum investment

Figure 8-2 illustrates the concept of optimum planning and the penalties of incorrectly forecasting the needs of a supply system. Increasing the load taken by the customers can solve the problem of the high cost of excess capacity when the planning is too robust, but may not be practical. On the other hand, simply increasing the capacity solves the problems of inadequate design capacity (under-design) that incurs high costs of losses, costs arising from driving equipment beyond its rated limits and costs of reinforcement, for loads that exist already [Gaunt, 1998].

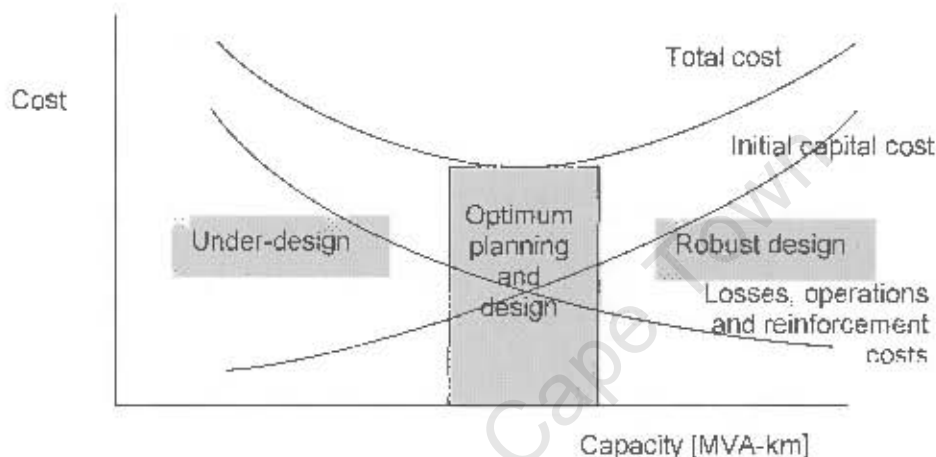


Figure 8-2: Variation of cost with capacity

If the electricity distribution system is supplying economic customers, the costs of loss of supply arising from rationing or black-outs caused by under-design will be high. An electrification system implemented for social objectives will have a lower penalty associated with under-design. Obviously, the optimum capacity is that which is just right, but under-design will be preferred to over-design where the costs of under-performance are relatively low. This analysis reinforces the finding that minimum cost solutions are needed for socially directed electrification.

8.3.5 Product-market strategy

The hypothesis in this research is that there are different objectives for electrification of different customers. A product-market matrix differentiated by the objectives of development for two basic distribution utility activities is shown in Table 8.1. Ansoff [1968] identifies that the start of strategic analysis is "to make explicit and/or to review the objectives of the firm", and also "perception of need is a major issue in strategic decision-making." Profitably supplying economic customers is normal business for utilities, but the product-market matrix identifies other segments for which other, more appropriate strategies may be needed. It appears in practice that

either these differences have not been appreciated by the utilities, or electrification for social, poverty alleviation objectives may have been undertaken as a defensive strategy against take-overs or restructuring.

Table 8.1: Product-market matrix for electricity distributor

		<i>Product</i>	
		<i>Wires</i>	<i>Retailing</i>
Non-domestic	Producers	Premium quality networks	Key economic customers
	Institutions: clinics, schools, public	Reliable networks	Socio-economic customers, low margins
	Service companies	Network performance defined by service level agreements	Bulk supplies, retailing by others
Domestic	High consumption customers	Financially viable networks	Economic (profitable) electrification
	Marginal customers	Economically viable networks	Socio-economic: doubtful viability
	Poor customers: poverty alleviation	Networks not viable	No viable market without subsidy; political value only.

With EDI restructuring now appearing more likely, and poor customers having little financial and economic benefit for the utilities, a strategic re-assessment of their actual and potential political value to utilities appears necessary. From the perspective of the government and the NER, the proposals to merge the various market segments into the activities of six similar REDs raises special challenges in identifying suitable support strategies and regulating performance of utilities concentrating on financial viability. Otherwise, the recent investments in social objectives will be wasted.

8.3.6 Estimates and assumptions

The following aspects need to be addressed by electrification programme planners:

- Have the best technological alternatives been considered?
- Is the programme financially viable? If not, is it economically justifiable?
- Is it sustainable: institutionally, socially, culturally, technologically (operations and maintenance) and environmentally?
- Is it locally replicable; that is, can it be built and operated as planned in the specific circumstances, irrespective of apparent successes elsewhere under possibly different conditions?

In practice, these assessments are reduced to meeting defined hurdles for releasing the funds. As discussed in chapter 3, the planners know the investment decision hurdles, and everyone knows the targets to be reached, and the target costs for that

year and region. However, the planners also make the assumptions about energy use, growth rates and other factors in the computer algorithms that calculate whether projects are acceptable. Therefore, superficially acceptable numbers for a project may obscure the unsuitability of a selected technology.

Awareness that costs in South Africa were significantly and systematically exceeding the investment estimates only became an issue in the mid-1990s, well after starting electrification. As with the integrated planning, better understanding of the objectives and linkages of electrification, and better feedback from the projects to the planners and managers, would have improved decision-making.

8.4 Assessing electrification

Electricity systems are large, with complex interrelationships between the elements. Changes in one part cause changes in other parts. Many relationships are changing at any time, because of the system's size and its many points of contact with the economy and community. Therefore, it is difficult to define in terms of specifications and regulations the best sub-systems or the most effective processes. However, modern political economics has identified that in at least some parts of the system there is scope for improved financial efficiency derived from segmenting it into different parts. This concept gives rise to the modern trends of restructuring by "unbundling" the large complex systems, to simplify the assessment of sub-systems that are more easily measured than the whole.

Financial and economic methods of evaluation are appropriate for financially viable electrification and economic development. However, the objectives of socio-economic and social development are more difficult to define in measurable parameters. Unbundling the industry has the advantage that greater attention may be given to specifying the overall objectives of electrification, and identifying the parameters to monitor.

One aspect of assessment is that the measured parameters are used as indicators of the success of an electrification programme. When inappropriate parameters are used, being chosen for their ease of measurement and simplicity of reporting rather than as valid indicators of the long-term performance or impacts, they can become false targets guiding the behaviour of the participants. Activities are managed in the short-term to meet the targets, instead of to achieve the real objectives. This is particularly evident where construction management indicators are used to define programme success, for example in achieving the annual targets for connections and budgets in the electrification programme, or making cost reductions, as

described in chapter 4. The difficulty of managing the short-term for long-term results may be a significant reason for not meeting overall objectives:

"It is clear that the possible benefits of electrification are numerous and diverse. Numerous studies have been conducted to try and assess the extent to which these benefits have been realised, and under what conditions. It should be noted that the results have more often than not, been less than encouraging." [Dutkiewicz, 1998]

The evaluation of the National Electrification Programme undertaken during 2001 [DME, 2001] made a substantial attempt to assess the achievements in relation to the development objectives, in preparation for defining the objectives for further electrification. Unfortunately the budget and time available were significant constraints on the evaluation. Despite the constraints, a broad review was made of the programme inputs, outputs and outcomes, including the social, economic, financial, and technical aspects.

8.4.1 Assessing outputs

Outputs are generally measured as part of the project management: on time, within budget and conforming to specification. The desired outputs are usually identified before project implementation starts, because they are used in the process of approving the capital expenditure.

In general, the outputs of the electrification projects were acceptable to those responsible for them. Despite occasional projects with quality problems, which were rectified, the overall work was approved within the normal procedures of the industry. Table 2.6 shows that costs fell steadily as more attention was given to reducing the cost of the overall programme, but the individual project costs were monitored at each stage of planning, preliminary design, contract award and completion, even in the early years. As shown in Table 2.5, connections significantly exceeded the annual target of 450'000 during the early years of the project, and the total number of connections exceeded the overall target.

8.4.2 Assessing outcomes

The outcome of electrification is determined by the operations of the utilities and households. Many aspects define this intermediate stage between outputs and impacts, so many measurements are needed for representative assessment.

Utility performance is measured by the financial and technical performance. The revenues from electricity sales should cover the costs of investment and operations,

but in a review of eight projects only one was financially viable for the utilities [DME, 2001]. The technical performance can be measured in terms of the quality of supply, but this was not possible from the data available. Losses are also a good indicator of technical performance, and it was found that the level of losses was extremely high in several projects, arising from theft of service. In one project, less than 40% of the energy sent into the network was accounted for by sales revenue. Obviously, high non-technical losses have significant implications for the financial performance of the projects and the sustainability of the National Electrification Programme.

The 'success' of completing more connections than the target needs to be reconsidered in terms of the findings regarding viability. As an output, it illustrated that the industry overcame the problems of building up a sustained programme of new connections, and the processes of planning, procurement, manufacturing and construction. This achievement of exceeding what were expected to be challenging targets was 'success' at the project level. However, on the basis that the projects are not financially and economically viable, the extra connections indicate a situation in which the commitment of resources to uneconomic investment exceeded the planned level. As an outcome, then, the achievement of more connections than planned may not be an indicator of success, depending on the overall objectives.

It is more difficult to assess the social effects of electrification than the operations of the utilities. There is less agreement about the factors that characterise social development and how to measure the changes, and the social data equivalent to financial viability and technical performance is not routinely collected. The relationships between electrification and human factors like health, nutrition, access to information and satisfaction are complex and not fully understood. Instead, measurements are made of changes in access to electricity, how much is consumed, the habits of using it, and perceptions of well-being. These are taken as indicators of the contributions to the overall objectives of poverty alleviation and improved quality of life.

Methods of measurement include quantitative and qualitative questions in household interviews, focus group discussions, and meetings with community leaders and other groups, both before and after electrification. As habits change slowly, more than one subsequent visit is needed to assess changes. Meticulous data collection and analysis is time consuming, so the costs of such measurement are high compared with assessments of technical and financial performance. It appears that there is scope to formalise social measurement, depending on the objectives being monitored, but this will not be possible until those objectives are better understood.

Staff of the Energy and Development Research Centre (EDRC) at UCT have carried out the most complete surveys of household use of electricity and the social impact of electrification in South Africa³⁷. The experience contributed significantly to the social research that formed part of the National Electrification Programme evaluation [Borchers et al, 2001] and the BEST research [UCT, 2002]. Some of the findings are particularly relevant to the objectives of social electrification. For example, high levels of unemployment restrict the capacity of households to pay connection fees, buy electricity tokens, and buy or repair appliances, thus restricting the benefits of having access to electricity [Qase et al, 2001b].

Complications in assessing the effects of electricity on households arise from a variety of factors, including illiteracy and low levels of customer understanding of the relationships between energy consumption, cost and the use of the energy. For example, *"The evaluation team could not establish whether the customers find these booklets (customer aids on the consumption costs of typical appliances) helpful and user friendly, considering that a significant number of the target population may be functionally illiterate. From the beneficiary interviews it was found that some people do not fully understand their electricity expenditure. While some of them understood that TVs, radios and refrigerators are better on energy consumption compared with electric stoves, others did not, and complained that R5 worth of electricity used to last three days while R20 now does not last even a week."* [Qase et al, 2001b]

The low level of understanding of relative energy costs is also illustrated by the continued use of candles and paraffin lamps for lighting in other rooms, instead of using an extension cord from the socket outlet on the ready board [Qase et al, 2001a]. The overall cost would be lower and the quality of lighting much higher.

The research into the social impact of electricity subsidies, leading to the proposals for a BEST, appear to be the most comprehensive undertaken in South Africa so far. The research had to review the additional impact of subsidised energy above the usual benefits of electrification. The following comments are derived mostly from that research report³⁸ [UCT, 2002].

Most households in newly electrified communities attach great value to electric lighting, some reporting that a 'bright house', with all rooms lit, has become part of their 'culture'. The ability to have lighting throughout the night is valued for a feeling of improved safety. With street lighting there is less need for lighting at individual houses, but there is no public lighting in most rural areas.

37 The results of 45 reports are summarised in *Rural electrification in South Africa*, EDRC, 1998.

38 The social research on the BEST research was headed by G Prasad.

Dependence on electricity for lighting increases with years of availability, but is affected by the reliability of supply and the ability to afford electricity for most of the month. Communities' perceptions about the quality of supply change as they become accustomed to using electricity. Reports of interruptions of up to a week indicate dissatisfaction.

Households using less than 25 kWh per month typically use electricity only for lighting and radios, and don't use lights throughout the night. Most people listen to TV or radio or both, for national and local news and entertainment.

Electrical appliances are considered to be more convenient and cleaner than appliances using combustion fuels. Electricity reduces the time and effort spent by women on domestic activities such as cooking, water heating and ironing. The small savings for each task are more difficult to quantify than the time required for firewood collection, but the beneficiaries consider it significant.

Women express the desire to cook with electricity, but not all households with hotplates use them regularly, because there are problems with repairing defective appliances, and the costs of cooking traditional foods with long preparation times are perceived as high. Similarly, not all households with refrigerators or freezers keep them switched on all the time, depending on when they have perishable foods.

Female-headed households use only about half the energy used in male-headed households. Considering their lower use under present conditions, it is probable that they will be most affected by a BEST, so the subsidy will have an identifiable gender impact.

The load research project has identified clear trends of consumption increasing over the period for which a household has had access to electricity [Dekenah and Gaunt, 1998]. This is partly due to the time taken to accumulate appliances, but it also reflects a slow habit change in switching to electricity from other sources.

In surveys specifically aimed at assessing the impact of a BEST, most households expected they would be able to use electricity for the whole month, buy more electric appliances, and spend more money on food. The question of poverty alleviation emerged in all the focus group discussions, with a wide variety of responses from happiness to doubt whether free electricity would make a difference. However, there are broader issues than electricity alone: *'We cannot buy electricity if we do not have money. We cannot get money from the stones. The government should help us with employment...Otherwise Eskom would run at a loss because we are going to demand free electricity...'* [interview reported in UCT, 2002]

Further research is needed to determine whether subsidised electricity will replace other energy use, especially wood, coal and paraffin; under what conditions it supports economic activity in households; and how it will affect usage above the consumption level of the subsidy.

The attitudes to electricity theft are interestingly different between communities. In some, theft is apparently a minor problem and blamed on the *“rich and those who are trained technicians and people who work for electricity contractors”* [interview reported in UCT, 2002]. Free or subsidised electricity is not sufficient to reduce theft, but could be used as part of a package of measures. The impact of writing off debt for some communities and not others still needs to be established.

One of the aspects needing to be addressed in the present situation is the value of charging a nominal fee for the subsidised electricity. Some people believe that a service given for free is appreciated less and has negative social impact, compared with one where there is at least a nominal charge and recipients feel they are purchasing the service. At the same time, a small charge, of R5 for example, assists in scheduling electricity purchases from vendors at the beginning of a new month, allows management flexibility of the subsidy in the future (both energy and price can be varied), and provides an audit control on the vendors (important for the control of vendor compensation). However, making a charge contradicts the politicians' promises of free electricity. This matter is not yet resolved.

A limitation of the outcomes assessment of electrification, until recently, has been the lack of comparison between the social measurement and the electrical measurement of actual electricity usage. The benefit of using the measured load data to refine energy modelling for policy analysis was illustrated by collaboration with the UCT Energy Research Institute [Howells et al, 2002]. The combination of load research data and social impact research also provided useful and novel information for the BEST research project. A second limitation of outcomes assessment is that most social research is carried out without the benefit of control groups, because of the high cost. The technically-based Load Research Project includes control groups at a much lower cost than in the social impact research, by comparing measured energy use in communities defined by household surveys.

Most of the outcomes identified above, and particularly those in the BEST research, relate to social objectives. The evaluation of the National Electrification Programme, in contrast, was directed more to the economic and socio-economic objectives defined in the government's Energy White Paper. That research identified activities stimulated by electrification, but the findings were restricted to anecdotal descriptions

and largely omitted the social effects in households. Unless the economic, socio-economic and social objectives of electrification are defined unambiguously, the outcomes assessment may not be related to the overall programme's objectives.

8.4.3 Assessing impacts

The above discussion indicates the practical difficulties in assessing outcomes in the context of the overall objectives for development. Obviously, assessing the impacts is even more difficult, because there are so many more factors that affect the linkages between outputs and impacts.

Stimulating economic growth and improving the quality of life, especially poverty alleviation, are basic development objectives. Sometimes the provision of infrastructure is assessed as contributing to economic development. This misleading argument uses the activity of project implementation as a direct measure of successful development. Similarly, employment in the electricity distribution industry is not a contribution to economic development, or even to social development through temporary employment, but is only an enabling activity.

Difficulty in assessing impacts may lead to the adoption of strategies that are only weakly associated with the overall objectives. For example, interventions may be justified for their contribution to economic development, even if the association is not valid, and some inappropriate interventions may be adopted. Or, where it is difficult to assess social or socio-economic return, an approach may be to favour a least-cost solution, approximating the impact with an outcome.

The difficulty in assessing the attainment of overall objectives obscures the contribution of technology to reaching them. However, the technology of electricity delivery is the core of the distribution business, and as discussed in chapter 4, the choice between suitable and unsuitable technologies has significant impact on cost and technical performance, as well on the social benefits delivered and, ultimately, on the achievement of the overall objectives.

8.5 Identifying factors contributing to success

Project and programme assessments are not made only in the context of inputs, outputs and impacts. The NEP evaluation [DME, 2001] identified five lessons that relate to the linkages between activities and programmes. Briefly, three related to financial viability and the need for subsidies, the effect of institutional structure on the capacity to meet the connection targets, and the setting of simple connection targets.

The other two lessons were that reducing the cost of electrification requires the application of a wide range of technical alternatives and that successful electrification requires as much focus on meeting community welfare needs as on technical and financial issues. These latter two findings, developed from a practical assessment of the electrification programme, indicate support for the theme of this thesis, although developed from a different starting point.

It appears that the national electrification was initiated at a particularly suitable time. Eskom had spare generating capacity and manpower because of the sudden reduction in the power station building programme, the private sector had initiated the scenario planning that gave prominence to the electrification programme proposals, and political conditions worldwide and in South Africa were changing. The programme was initiated from outside the central government sector, but Eskom (a statutory corporation) and the local government electricity utilities participated. Electrification was already in full progress by the time the new government was formed in 1994. The absence of political initiatives and interference may have been an important success factor. Not until 1998 was the control of the electrification programme brought fully under the DME and the NER, and even then with staff seconded by the utilities to the Electrification Programme Coordinating Committee.

Continued policy support and resources commitment will be required if electrification is to be completed by 2012, but appears uncertain. Utilities and other stakeholders appear to be reviewing, informally and even unconsciously, their product-market intentions. They need to decide whether it is appropriate or necessary to take on responsibilities of social welfare, which are incompatible with the government's stated intentions for restructuring and its objectives for the electricity distribution industry. The same institutional commitment that achieved successful outputs during the electrification programme may no longer be evident in future.

The role for technology also requires consideration. Politicians, financiers and senior executives generally do not get involved in assessing the details of the technology for electricity supply and electrification, because they assume that their engineering specialists can make responsible decisions. However, if the engineers do not have adequate specifications, in terms that are relevant to them, they cannot give the most effective advice and make the best decisions.

Technology decisions are made in the context of the electrification and its overall objectives. Experience from this programme indicates the context is usually not conveyed formally to the planners and designers, nor to their managers, and their performance goals may even discourage planning and design decisions directed to obtaining the objectives intended. Therefore, it is essential to communicate the

objectives, constraints and possibilities across the gaps that divide the engineers and technologists from the other participants in electrification.

The widely held belief that integration of electrification in overall development schemes is of significant advantage does not appear to have been supported by experience in electrification projects in Southern Africa that have shown that the costs of integration can be high and the benefits small. Integration has to be carried out by relatively senior people, and the broad scope of interactions is time-consuming. In a large-scale electrification programme such as that implemented by Eskom as part of the NEP, it was more effective to clearly state the intentions regarding electrification so that other potential participants could be informed. It was found that matters of potential conflict and any omissions were quickly brought to the attention of developers and planners. The affected communities, in fact, provided at low cost much of the integration that is proposed for incorporation into "integrated development schemes". Of course, there will be incidents where important components are missing from a scheme, but in most cases the cost of the omission will be substantially less than the costs of integration to "ensure" that such incidents don't occur.

8.6 Planning and assessment in the absence of defined objectives

The evaluation of the National Electrification Plan required a retrospective formulation of the logframe, because the technique had not been used to develop the programme objectives prior to implementation. The logframe was based on the policy of the Energy White Paper, interpreted for the topic of electrification. This approach is evident in the "missing goal" of "securing supply through diversity of alternatives" in the logframe created for the evaluation [DME, 2001].

The emphasis of the evaluation was on the economic and socio-economic impacts of electrification, as illustrated by the significance attached to small business development. Because of the terms of reference and the cost constraints on the evaluation, most assessments of outcomes were based on short meetings with parts of the community, using qualitative descriptions of the business opportunities created by electrification. Quantitative analysis was not attempted.

In contrast, the research into a Basic Electricity Support Tariff required the research team to interpret the scope and objectives of the proposed tariff relative to poverty:

"The Government of South Africa has committed itself to providing free electricity in 2002 to the poorest sector of the population to aid poverty alleviation. The costs, benefits and processes of achieving the objective are

not yet fully understood, as they will depend on the responses of people to new conditions. Many important aspects of the implementation plan have not been decided, therefore the present situation represents a potential risk to the Government and to the national economy.

The immediate requirement for the research was to inform a Cabinet discussion of the proposals for implementing the EBSST in the financial year 2002/3, but the full implications have a much longer term." [UCT, 2002]

Comparison between the two recent research projects, carried out in similar communities and based on the same electrification programme, demonstrates that the results of assessments and development research are constrained by the scope of the research. The research into the support tariff required a greater emphasis on social aspects of electrification, with the result that the relationship was much more intensively researched than in the evaluation of the electrification programme. It is clearly important that the objectives of any project being assessed are understood and defined in economic, socio-economic or social terms, so that the research can be directed to investigate relevant elements of the overall system of electrification.

8.7 Applications of the concept to planning and evaluation

The application of the concepts for planning and evaluation can be demonstrated in a simplified example of an electrification project.

8.7.1 Capital investment for electrification

Assume that the average consumption of the households connected during an electrification project grows from about 50 kWh/month in the first year after connection, to a projected value of about 350 kWh/month in 20 years. Reaching the level of 350 kWh/month more quickly, say within eight instead of 20 years, makes the supply financially viable [NER, 1999]. A pessimistic projection of slow growth could be that consumption will increase only to 300 kWh/month in 20 years. The different growth rates are illustrated in Figure 8-3.

Further assume a tariff of 35 c/kWh, a cost of energy of 15 c/kWh, a distribution network operating and maintenance cost of R170/year and a net discount rate of 12% pa.

It is quickly evident that unless the increases in tariff exceed the inflation rate, or the rate of energy consumption growth exceeds the net discount rate, the present value of annual revenue falls with time. Further, the capital investment available for the

distribution network, allowing the project to be viable, depends on the rate of consumption growth, as shown in Table 8.2.

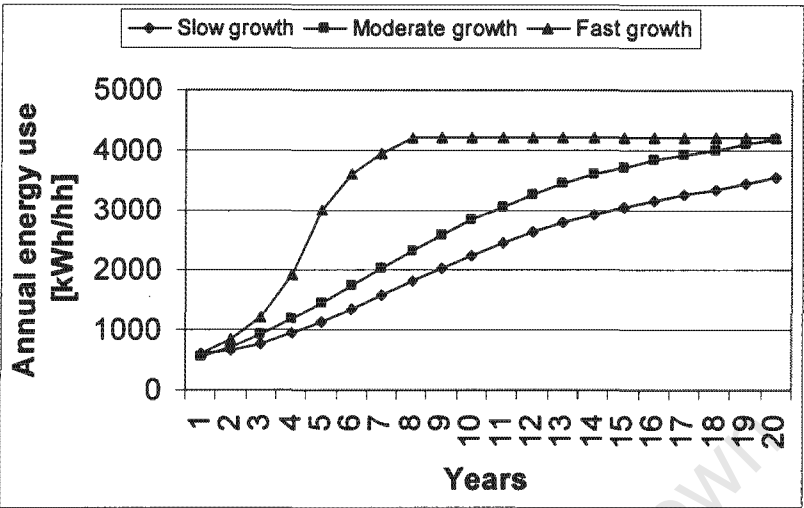


Figure 8-3: Projections of energy consumption for model

Table 8.2: Capital available for model electrification network to be viable

	Rate of consumption growth		
	Slow	Moderate	Fast
Capital expenditure for electrification [R]	1225	1807	3240

It should be clear that a planner, knowing the implementation cost will be about R3220/connection, must use a 'fast' projection of consumption growth to obtain approval of the project. Also, if the probable growth rate is really closer to the 'moderate' or 'slow' projection, then a subsidy of about R1400 or R2000/connection respectively is needed by the utility for its electrification activities to be financially viable.

8.7.2 Planning and evaluation logframe

The correct identification of the 'problem' being addressed by the planned interventions identifies the overall objectives for a programme. The traditional view is that electrification contributes to economic or socio-economic development by replacing other less efficient or scarce energy. Social electrification is implemented to alleviate poverty or meet political commitments. Two logframes for electrification directed to reaching different objectives are presented in Table 8.3. They illustrate that inputs-outputs-outcomes-impacts and assumptions about the relationships between them depend on the objectives for which the electrification is being implemented.

Table 8.3: Comparison of logframes for socio-economic and social electrification

	<i>Economic and socio-economic electrification</i>	<i>Social electrification</i>
<i>Impacts</i>	Households in modern energy economy. Improved quality of life. Improved regional economy.	Poverty alleviation. Political demonstration of service delivery.
<i>Assimilation and change</i>	Stimulated business development. Increase in economic activities. Health and education improves.	Better lighting supports education. Less indoor pollution promotes better health.
<i>Outcomes</i>	Lower household energy costs. New businesses. Viable utilities.	Basic use of electricity in homes. Environmental improvement. Sustainable utilities.
<i>Operation and use</i>	Appliance purchasing and use. Revenue collection. Efficient, profitable utility operation. Regulate financial performance.	Give basic electricity support tariff. Electricity sales. Poor households use electricity. Utilities supply adequate quality. Regulate social performance.
<i>Outputs</i>	Households and businesses connected for acceptable cost.	Numbers of households connected. Completion within budget.
<i>Activities</i>	Selective electrification based on IRR and ERR viability. Cost-reflective tariffs.	Blanket coverage. Implement capital subsidies, minimum capital investment.
<i>Inputs</i>	Investment, materials, skills, integrated development plans.	Grants, materials, expertise.

During and subsequent to the implementation of the projects or programme, the appropriate logframe would determine the parameters needing to be measured for evaluating the achievements.

8.8 Confounding factors

The planning and assessment of electrification assumes that the relationships between elements of the logframe can be defined. However, in practice, there are many factors that confuse the situation. High rates of change and changes in new directions cause uncertainty in both planning and assessment. Three examples of fundamental changes illustrate the diversity of aspects that can affect the future of electrification.

8.8.1 Communications technology

Changes in communication technology will affect the way the utilities operate. Call centre technology and organisation can create virtual offices quite different from physical regional headquarters, so that marketing, fault response systems, real time control and metering, and distribution automation will contribute to networks and support systems that should be more efficient and effective, but will change the cost

structure of distribution. Relatively little research has been reported in this area in respect of developing countries.

8.8.2 Disease

HIV/AIDS will have significant impact on the need for electricity and the capacity to afford it. Infection rates in most Southern African countries already exceed 20% of the population, concentrated among the most sexually active who are most likely to be involved in economic and productive activities. Output and productivity in both the formal economic sector and the subsistence sector are detrimentally affected by higher-than-normal rates of illness and death. Households in which both parents have already died and grandparents or oldest siblings are bringing up the family, or households caring for the very ill, will possibly have different electricity usage patterns in ten years, compared with the present. Load research and social impact analysis must identify whether these potential changes are occurring.

8.8.3 Government policy

A large housing programme, on the same numerical scale as electrification but at a cost an order of magnitude higher, would have a greater impact than electrification on the economy. The housing programme during 2001 numerically exceeded electrification, resulting in a decrease in the percentage of households electrified. Government poverty alleviation and socio-economic development policy regarding housing may need to be re-assessed in the same way as followed in this research into electricity. Suitable project constraints will be needed in addition to simple numerical targets, and it may be found that only the provision of basic services without house structures is affordable. Such policies influence electrification by affecting the number of households to be supplied and the attitudes of the recipients of the services.

A second aspect of government policy affecting electrification is the level of understanding of the relationships between electrification and social or economic development. It is already clear from this research that most people do not distinguish between different overall objectives of expenditure on electrification. As greater understanding develops, policy itself may change. The effects may include different emphasis on rural and urban electrification, allocation of subsidies to the proposed support tariff, a greater effort to supply other enabling factor inputs where socio-economic development appears most feasible, and possibly a reassessment of distribution industry restructuring in the light of problems being reported from other countries and the results of this research.

8.9 Onword

The activities of an electrification programme exist in the context of its purpose, whether or not the objectives are formally defined and the assumptions recognised. This chapter has reviewed some of the effects of a lack of understanding in terms of economic, socio-economic and social objectives on the planning and assessment of electrification projects. Applying the concepts to two major investigations of the electrification programme and a support tariff, as well as to a simple example, shows that the understanding of electrification shapes the objectives, plans, and evaluations of achievements. Further, recognising different development objectives for electrification allows weaknesses in programmes to be easily identified, offering potential for more efficient and effective allocation of resources in future.

All the decision-makers in the process of electrification need to be aware of the differences. Non-technical people need to understand the contributions that different technologies can make to meeting their objectives, and technical people need to be aware that different outcomes are required in different circumstances, and that the technologies must be correctly selected and applied.

Chapter 9

Lessons Learned

9.1 Introduction

The preceding analysis has covered a broad range. Electrification in Southern Africa has been considered in the context of its history of achievements. Diverse aspects of the ethics of development, the impact of society and economics, and the institutions of electricity supply all affect the technologies and processes of electrification, leading to a critical assessment of the planning and evaluation of electrification.

However, this research started with a specific hypothesis; that a better understanding of the objectives of electrification would improve its implementation. This chapter collects the answers to the research questions and reviews the hypothesis in order to identify the lessons derived from the research. It considers the present position in terms of the findings and, finally, it concludes with the implications of the research for further electrification in Southern Africa.

9.2 Key factors of successful electrification

Many factors have been identified as being important to the success of electrification programmes. This section summarises their importance in the context of electrification in Southern Africa.

9.2.1 Technological factors

The experience of the electrification in South Africa is that the engineering of the supplies was adjusted to meet the financial resources and the needs or capacity of the customers to use electricity. In general, rural supplies are thought of as being more expensive to install than urban supplies. However, rural households, especially in Africa, are generally poorer than urban households and use energy differently, so that the energy supplied from a grid electricity system can be much

smaller than in an urban environment where households are mostly, but not all, less poor. As a result, the cost of connection of rural households is very similar to that of urban households. In effect, the energy delivery system can be engineered to supply the identified needs at an appropriate cost. These are significant findings compared with conventional wisdom. They also have significant implications for the development of solar home or PV supplies, which are often justified financially by comparison with high capacity, high cost grid connections.

Much lower capacity supplies cost less and are very competitive with other sources such as PV systems. The energy delivery capability of even a low capacity supply from the network substantially exceeds that from a similar cost PV system, and the network connection does not represent the poverty trap of forever-limited energy capacity. Clearly, though, a grid connection would not be justified for remote loads that can only use 10 kWh/month.

The concept that the distribution network represents about a third of the total cost of supply and that the balance of the cost is fixed, so that engineers can do little to reduce total cost, is misleading because it fails to take into account that the distribution system can be designed to limit the impact of customer loads on generation capacity and operating expenses. Technologies such as demand side management and load limiting can make substantial differences to the total cost of supply, especially in weak rural networks. As a result, the cost of bulk power, while important, is not necessarily a key factor in the success of rural electrification.

However, the existence of suitable network technologies does not imply that they are automatically adopted by electricity utilities. Engineers and officials who perceive less expensive systems as being of lower quality, even when they meet the customers' needs, are reluctant to adopt the cheaper technologies. The process of technology transfer and adaptation, so that innovation and novel techniques are brought to the status of standard practice, is a key success factor in a dynamic situation such as implementing an electrification programme.

The understanding of existing technology and implementation processes influences the formulation of objectives by technical, financial and political decision makers. Technology research and development can create systems that allow alternative objectives to be adopted. For example, changes in electrification design parameters made during the electrification programme, based on information gathered in a load research project that commenced even before the programme started, had significant financial impact. The potential for financial improvement through technology and processes probably exceeds that from industry restructuring.

The technical energy losses in most distribution systems should be less than 10%, and in urban systems even lower. Higher losses in a distribution network are a good indicator of the need for management attention: either loss reduction by network reinforcement or better control of non-technical losses. Alternatively, acceptance of high non-technical losses possibly indicates that there is a strong social component in the support of electrification, under which conditions restructuring towards economic organisations is unlikely to be effective.

9.2.2 Social factors

The main electrification network in South Africa was established to meet economic needs. Socio-economic development followed, supporting agriculture and rural centres, and extending the grid even where it was not financially viable. This created an infrastructure from which social development could be undertaken, even to the extent of supplying households with limited electricity at nominal cost.

Where customers are willing to pay enough for electricity to fully cover the cost of supply, decisions are simply economic, and system requirements are defined by the needs. By contrast, the cost of supplying electricity for poverty alleviation exceeds the price the customers can pay, even if their needs are small (although possibly exceeding the capacity of PV systems). Meeting socio-economic needs is an intermediate position. Decisions about network investment to meet socio-economic and social objectives should involve more parties than the customers and suppliers.

Providing suitable infrastructure for social supplies requires knowledge of the customers' needs, both as electrical loads and as households using energy to meet their social needs. Therefore, load measurement, customer surveys, communication and education are important components of electrification. Communication with customers is more important in the early days of an electrification programme and when introducing innovations, but becomes less important as communities gain greater knowledge of and trust in the programme.

Substantial research has been carried out into the possibility of subsidising electricity consumption for poor households. Defining poverty is very difficult, and identifying the poor by simple administrative measures is unreliable. It is more effective to let the poor define themselves, by selecting a subsidised tariff that meets their needs. This is not a "poverty" tariff, in that it is only available to poor people, but its characteristics make it more attractive to poor households than wealthier ones, so it reduces the leakage of benefits to those for whom the subsidy is not intended. The tariff that has been proposed does not constitute a poverty trap as it allows more electricity to be used when it can be afforded. Also, in terms of fairness for general

social policy, there should not be a “something for nothing” element, as that intervention should only be made directly by government and not perceived as coming from services utilities.

9.2.3 Institutional factors

Obviously electrification utilities must have the technological and financial resources needed to carry out their tasks. In addition, though, they need a clear understanding of the objectives and a commitment to achieving them. This need for understanding and commitment extends also to the supporting institutions, such as central and local government and the electricity regulator. However, support from all the government sectors responsible for development may not be a prerequisite for success.

Electrification in South Africa demonstrates a transition in electricity supply development. At the start of electricity supply, many years ago, private sector companies undertook the development on an economic basis. They were replaced by government owned utilities that also acted on economic grounds, but introduced socio-economic activities, mostly in response to pressure from groups of customers. More recently, with the increased political power of deprived communities, the social aspects of electrification activities have received attention.

Similar transition occurred in the household electrification programme. The proposals for large-scale electrification evolved from a scenario-study exercise in the private sector with strong lobby strength. The objective setting took the programme outside the formal structures of the government, into informal structures like the National Electrification Forum. Eskom and the municipal utilities carried out implementation of the electrification programme for the first ten years. Eventually the government took control of the funding and direction, and introduced the concept of social tariffs. It is unclear whether the same process of objective setting could happen now, given that the political conditions then were in a state of flux, but have since stabilised. It is also uncertain whether the present structure could be as effective in defining the objectives and gaining the support of the participants.

The leadership in socio-economic and social electrification came not from the government, but from lobby groups in the private sector and from the implementing utilities. Zomers [2001] identified similar processes and lobby power in the electrification of the developed countries, but found, in many cases, that special institutions were required for implementation.

The strong regional or national institutional structure that some felt was necessary for electrification in South Africa turned out not to be required. There were some utilities

that were not able to carry out electrification, and they sometimes lost control and had to be incorporated in other utilities: Electrification is a small burden to an efficient utility with adequate financial and human resources, but an impossible burden to a utility already unprofitable, inefficient and lacking clear direction because of external interference. However, in general, the diversity between electricity utilities may have been a significant advantage. A variety of organisations provides an environment for diverse technology and skills development, encourages training, creates a system from which new managers can be recruited from outside with relevant skills (avoiding in-house stagnation) and spreads the risk for financial investors. The differences between organisations probably also stimulated virtual competition and an awareness of the potential and need for changes.

Power sector reform by assigning distribution to for-profit private companies could not have achieved the same progress in socio-economic and social electrification, without direct funding from the government. The public sector utilities in South Africa do not appear to be characterised by the poor management, corruption and political interference that have damaged other utilities in Africa. It is probable, then, that the actual costs of achieving the electrification in South Africa were very economical. It is not clear that private organisations, with a focus on financial efficiency, would be more effective than the present electricity utilities. Public (non-profit) organisations, such as government and municipal utilities may be better aligned to maximise the public benefit of electrification in developing countries.

Negotiations about the restructuring of the electricity distribution industry in South Africa will continue. However, the objectives have been blurred by the successful electrification that restructuring was intended to enable. Restructuring often avoids addressing the fundamental problems underlying functional failure or inefficiency. Major restructuring also introduces new risks of institutional and regulatory instability, and should only be adopted in the last resort. Clearly, though, there are some aspects still needing to be improved in South Africa, in particular tariffs.

9.2.4 Financial factors

Electrification success needs attention to capital expenditure, operating expenditure and affordability. However, the financial and economic viability may not be the principal objectives, nor even obvious constraints on an electrification decision.

Concern about not subsidising operating costs may not be significant. Instead, a greater understanding of cost structure indicates that allocation of subsidies and aid to capital, operations or allowance for future replacement are all nominal, and depend on the financing policy. The targets for return on assets also depend on the

policy. If electrification serves economic objectives, profit is a method of sharing the financial benefit of the economic activity between the customers and the utility that supports their endeavours. Socio-economic electrification implies that a subsidy is being provided, at least in the medium term, so any profit expected for or by the utility only adds to the subsidy requirement. (If short-term subsidies are repaid in the long-term, then development is economic.) Electrification for social or poverty-alleviation, for example lifeline rates, must be subsidised in the medium term, and possibly long-term. Recognising this condition prompts decisions that will reduce the cost of the subsidy as much as possible, while still retaining a minimum benefit, and have substantial impact on the technology adopted.

Technology change appears to require financial pressure. Financial constraints provide the signals that initiate the coping and adaptive mechanisms of change. External aid can suppress change by reducing the financial signals of the needs.

The objectives and values associated with financial aid may be incompatible with some development aims. Aid that supports the broad spectrum of sustainable technological, social, economic, political and institutional objectives of governments and utilities is more likely to gain complete commitment. At the same time, governments and utilities need to demonstrate to aid agencies that the organisations and managers of electrification comprehend and support clearly defined objectives, such as the alleviation of poverty or economic development.

The electrification in South Africa gave customers access to electricity without requiring them to make significant financial contributions. Therefore, special customer credit schemes were unnecessary. Clearly identified funding for electrification was provided by and to the electricity utilities. The long term vision and financial commitment provided the financial stability for the National Electrification Programme to be completed successfully. The change of funding at the end of the Programme immediately resulted in a reduction of households connected annually.

The capacity for poverty alleviation subsidies and electrification depends on the financial and economic strength of the country. Affordability for the country should be considered not just in absolute terms, but also relative to other "social" expenditure.

9.2.5 Objectives and goals

It was determined that electrification is a high investment activity, not defined in the same way everywhere, characterised by complexity and a possibility that optimisation cannot be applied to the overall system. The complexity has been

confirmed by consideration of the technological, social, institutional and financial factors involved.

Electrification for economic, socio-economic and social objectives requires different policy formulation, technology application and tariff development.

The failures of electrification programmes can be explained where the objectives of the electrification were not clearly understood or defined, and the misunderstanding leads to dysfunctional decisions or actions.

If the electrification programme implemented in South Africa is to be replicated in another country, goal setting needs to be implemented less simplistically, supported by more effective evaluation techniques, and avoiding the implementation delays that could characterise development planning. The goals need to take into account the political and social strategies, and adopt organisation and business approaches consistent with the best technologies available. All the institutions involved in electrification must find a suitable balance between the management autonomy of the utilities and the political guidance of the local and national government.

9.3 Answering the research questions

Several questions were identified in chapter 1. Preliminary answers were developed in the survey of electrification in South Africa and of published literature. Having completed an analysis based on the electrification in Southern Africa, a better understanding has been developed, and is summarised below.

What can African countries embarking on new or expanding electrification programmes expect to derive from the apparent confusion of previous programmes?

The experience of other electrification programmes offers a wide range of apparent lessons for future programmes. However, because the circumstances of each programme differ from other programmes, it is often difficult to establish what aspects are relevant and likely to be reproducible in another situation.

Early electrification in South Africa followed processes similar to those in other African countries. However, the recent household electrification programme has been quite different, and different also from programmes in other countries. This research has been directed at identifying some of the aspects of difference, particularly those that appear to have significance in Africa, such as the need to

address poverty alleviation and an approach to meeting that need. It is evident that new programmes in Africa must develop an understanding of the conditions and relationships affecting electricity supply in the particular region. Simplistic replication of approaches, technologies or institutions from other environments is unlikely to achieve the desired objectives.

What is the purpose of electrification?

Electrification is usually implemented to contribute to economic development and to improve the quality of life. However, the linkages between proposed electrification projects and these benefits are not always defined. Clearly identifying the purpose of electrification as being for economic, socio-economic or social objectives will probably improve decision-making and the probability of success.

The perceptions of various people and institutions can be identified by consideration of the values they use to justify electrification. Apparent contradictions, such as between stated economic objectives and acceptance of high non-technical losses or support of increasing block-rate tariffs, help to identify the dominant purpose of electrification.

Is electrification viable?

Many studies show that many electrification projects have not been financially or economically viable, but the outcomes depend on a wide range of variables, including the application to which electricity is put and the technology of supplying it.

In some cases, the main objective of electrification is not economic but social. Decisions to implement electrification to meet social objectives are based on religious, philosophical or pragmatic grounds. Electrification that meets social objectives at minimum cost may still be viable in an overall sense, even if not financially and economically.

How can the viability of electrification be improved?

The experience in South Africa shows that the cost of electrification can be engineered to lower levels by adopting suitable technologies and processes, and that following minimum capital investment strategies improves the financial and economic viability of electrification. These approaches require that the objectives be clearly defined and the customers' needs properly understood.

What is electrification, and how does the definition relate to grid and non-grid technologies and identify target customer sectors?

Electrification is the process of giving people access to electricity. A limited definition considers access only for economic production units and institutions; a broader definition includes households of ordinary people who need access to modern energy for the impact it has on their lives. Early electrification in South Africa was to meet the economic needs of mining, industry and commerce. Later, the electricity networks were extended to rural towns, farms and community centres. Intensive household electrification only occurred after 1991.

Electrification has been implemented in both urban and rural areas, by a variety of municipal electricity undertakings, Eskom (and its predecessor, Escom), and private companies. Electrification is independent of the supply technology, but the largest proportion of customers, including households, is connected to a central network.

Non-grid electrification is generally more expensive than grid electrification implemented with suitable technologies and processes, except where remote loads have very low energy requirements.

Who are the stakeholders in electrification, and how are their objectives incorporated into the purpose for which electrification is implemented?

Stakeholders include:

- National and local government responsible for economic and social development of their communities, and for establishing the framework within which all other stakeholders operate;
- Electricity utilities;
- Customers who will benefit from the supplies of energy;
- Equipment suppliers and services contractors wanting to do business;
- Politicians, business people and financiers with individual objectives; and
- International aid agencies interested in extending their influence and assistance.

These various stakeholders negotiate positions or actions that benefit themselves, but they have different degrees of influence and power. Economic or social objectives of electrification may make significant differences to their participation.

***How are decisions taken, targets set and programmes planned and evaluated?
How do decision-makers compare the benefits of electrification with the costs
(in both short and long term)?***

The targets for the electrification programme in South Africa developed slowly by interaction between various stakeholders. The concepts of what numbers of connections were feasible were mostly based on comparisons with programmes in other countries. Government only came into the programme at a relatively late stage, by which time the targets for connections and costs were already established.

As shown in chapter 1, politicians and officials make statements (usually expressing their decisions) that indicate a lack of appreciation of the differences between economic, socio-economic and social objectives of electrification. Similarly, where rate of return calculations are used, input values may be selected to give outputs acceptable to project approval committees, on the basis that a project is 'known to be needed'. Electrification is so complex that broad assumptions are made about many of its aspects, and decisions are taken without rigorous comparisons of costs and benefits. However, better understanding of the different objectives should improve the decision-making regarding electrification.

What are the characteristic economics of electrification - capital, operations, revenue/tariffs, and viability?

The capital cost of network extension depends on the loads to be supplied and the technologies adopted. The associated cost of generation or the bulk supply of electricity also depends on the power capacity of the customers. Operating and maintenance costs depend on the extent and complexity of the networks.

Revenue depends on tariffs approved by regulatory authorities, based on expectations of revenues and costs. The anticipated household consumption of 300 kWh/customer/month, used in planning models, was not achieved within the 'expected' five years for most electrification projects; in fact, average consumption only reached levels about one third of that. An evaluation of the National Electrification Programme indicated that the household electrification undertaken since 1990 was not financially viable.

Plans to implement a special tariff for poverty alleviation will further affect the viability of electrification. Subsidies paid by the government will increase the affordability of electricity in poor households and increase the revenue received by the utilities. However, if the nature of the electricity support tariff were to increase the costs to larger customers, the price elasticity of consumption could reduce the overall viability

of electricity supply for the utilities. At the same time, subsidies are only a redirection of funds from other potential applications, so the economic impact affects more than electricity.

What changes have occurred in the technology of electrification? What drives technological change and how do the changes affect an electrification programme - including methods, implementation process, components, planning, and standards?

Pressure to reduce costs drove technological change towards less robust supply systems, closely matched to customers' needs identified by load research. Single phase, SWER and bi-phase systems were adopted to reduce line costs. Prepayment metering was introduced to reduce revenue losses, but was not completely successful. Blanket electrification (area coverage) was adopted to meet numerical targets and reduce the cost per connection. Cost pressures led to the introduction of turnkey projects, but design control was a problem. Standards needed to change with technology development.

The results of the technology and process changes are evident in significantly reduced capital costs per connection, to the extent that rural electrification is no longer more expensive than urban electrification. However, simple cost comparisons between technologies can be misleading, especially where costs structures, for example the ratio of initial to long-term costs, are different for each technology.

How does information develop and "transfer of technology" take place in respect of electrification?

New ideas were mostly from decentralised sources, and shared at workshops, conferences, through academia, and by product development. The industry structure created opportunities and incentives to test various technologies, but standards were developed through co-operation.

Some new technologies were adopted quickly, but others took much longer to be incorporated. There appears to be scope for further investigation of the process and duration of technology transfer and adoption, particularly in organisations like utilities that are not subject to commercial competition.

How do social, institutional, political and ethical factors affect electrification? In particular, what are the effects on the structure, management and social culture of the electricity distribution industry (EDI)?

Applying the systems approach to electrification identifies a large and complex problem of dynamic interrelationships between many elements. Electrification can be assessed from several perspectives and at different levels of project, programme and policy. Religious, philosophical or pragmatic ethics provide the justification for electrification to meet social objectives. The culture, management and structure of the EDI differs according to the unique combination of the many elements having an influence.

In South Africa, the opportunities for electrification appear to have been identified by engineers and utilities, supported by business, and driven by diverse perceptions of obligations towards those without access to electricity. The diversity of the utilities encouraged competition by comparison, and stimulated development of technologies and processes to meet simply defined challenges of connection numbers and, subsequently, costs. Politics was mostly in the background during the early years of the programme, but successful implementation attracted political support from 1994.

How do decision-makers compare the benefits of electrification with the costs? (short and long term)

Most proposals were presented as financially or economically viable projects, although sometimes by assuming optimistic numbers. The models of financial and economic rates of return do not appear to provide useful answers for projects of social development. Impact studies only commenced relatively late in the programme.

What lessons can be drawn from electrification experience to apply to future electrification? Are they relevant in other countries and in what context could the lessons be applied?

The proposed classification of electrification for economic, socio-economic and social objectives appears to be useful for making decisions about the technologies to be applied. It also provides for more effective assessment of alternatives and the better evaluation of projects. Lessons learned from the electrification programme include:

- Lack of understanding of the social objectives of household electrification initially led to the use of inappropriate technologies and cost over-runs on projects.

- Lack of understanding of the differences between economic and social objectives leads to apparently confused policy statements.
- Ambiguous statements of the extent of electrification are a result of lack of understanding of the differences between programmes, or, in comparisons of electrification in various countries, deliberate representation of a situation as being better than it is.
- Understanding the importance of first cost in meeting the electrification objectives encouraged a new approach to electrification technology.
- Lack of understanding of the relationships between the many elements of the electricity supply system leads to proposals for reform that are unlikely to achieve improvements and, possibly, will be worse than the original.

The conditions applying to these lessons from electrification do not appear to be restricted to South Africa, so it is likely that the lessons can be applied in other countries also.

9.4 Assessing the hypothesis

Review of the electrification programme implemented in South Africa during the 1990s shows that it was very successful in meeting the numerical targets for household connections, but the costs incurred exceeded the expected levels, especially in the early years, and a subsequent evaluation of the programme found it to be not financially or economically viable. Official statements alluding to the economic benefits of electrification indicate that the programme will continue to receive government support, but this appears to be based on an un-stated recognition that the programme meets social objectives.

During the initial stages of implementation of the programme, the technological standards and processes were the same as had already been in use for several years. However, the high costs forced a subsequent adoption of different standards and processes, in particular adopting design parameters more appropriate for the customers being supplied, using single-phase systems instead of three-phase, and adopting blanket electrification (area coverage) without connection fees. These approaches reduced the initial costs per connection by about 40% in real terms over seven years.

Capital expenditure committees reviewed proposals for network extension projects, using indicators of financial return, even where the projects were implemented for their social impact. While projects were funded internally by the electricity utilities, unrealistic assumptions were made in the financial models so that the hurdle values

were attained and projects could proceed. Now that the government is providing the funds for electrification, such approaches to getting project approval are no longer necessary.

Proposals have been made to introduce a basic electricity support tariff to alleviate poverty in poor households. Such a tariff has purely social objectives. It will assist households that are too poor to benefit even from the access to electricity provided by a free connection. However, to be effective, the social tariff must be complemented with continued network expansion to reach the many poor households that have not yet been connected.

The hypothesis for this research was that:

Classification of electrification as being for economic, socio-economic or social (for poverty alleviation) objectives provides a concept system which allows for better decision-making and allocation of resources, making the attainment of the objective of electrification more likely.

The experience of electrification in South Africa indicates that:

- The programme was successful, but could have been improved by planning, implementation and control based on better understanding of the objectives.
- At the time of conceiving the national electrification programme, the justification was a socio-economic one. The programme would benefit from the overcapacity then existing in generation, stimulate the economy and contribute to the development of those communities without access to electricity.
- There has been a generally poor understanding of the economic and social objectives of implementing widespread household electrification. Even in 2001, the National Electrification Programme was evaluated in terms of financial and economic viability, although the purpose of the programme, with hindsight, was predominantly social.
- The electricity sales in the electrification projects did not meet the official projections of the planners, although hindsight shows that other estimates at the time had been better informed. The lower-than-forecast revenues contribute to the 'poor' financial and economic viability in the subsequent evaluations. The economic and socio-economic analysis in the early years was confused by statements about improving the quality of life by making electricity available, without recognising the social limits in very poor communities.
- There was slow acceptance of technological change. Financial constraints and sharing of information about technology alternatives eventually led to changes in policy and standards more appropriate for the objectives.

However, more realistic revenue projections and better control of expenditure at the start of the programme would have led to the earlier introduction of appropriate processes and technological standards. Understanding the effects of the differences between socio-economic and social objectives on technology and process selection could have produced earlier savings.

- The National Electricity Regulator proposed immediate implementation of a social tariff for electricity in 1998, but it has taken several years to develop an understanding of the implications. Implementing a basic electricity support tariff will be consistent with social objectives now associated with electrification and unlock the benefits in the under-utilised electricity infrastructure.
- Better understanding of the overall 'electrification system' contributes to improved decision-making, demonstrated by the policy and technology changes that have occurred since the programme was conceived in the late 1980s.

Clearly, the lack of understanding of the differences between economic, socio-economic and social objectives caused some inappropriate decisions to be made, including the levels of acceptable capital expenditure per connection in the early years of the programme. Subsequent changes were made, but based on practical restrictions more than an understanding of the nature of the objectives.

The analysis of this research identifies the different approaches needed in response to different development objectives, for example the low initial capital investment needed for social supplies, or the current-limiting of a self-targeted basic electricity support tariff. Thus the better understanding of the objectives would enable decisions to be based on the understanding, and lead to the attainment of the objectives with minimum commitment of resources, instead of decisions only being made in response to limitations as they become evident.

Therefore, it is concluded that the hypothesis is valid: distinguishing between economic, socio-economic and social objectives will guide decision-making and assist electrification to be more successful.

9.5 This research in context - a backward glance

This thesis opened with the questions "Will the expected benefits of electrification investment in South Africa be achieved and was the optimum system implemented?"

In summary, the 'expected benefits' are unlikely to be achieved quickly, because they were expressed in terms of economic and socio-economic objectives. However, substantial benefits are derived from the electrification programme through its contribution to social and poverty alleviation objectives. Hindsight indicates that the confusion of objectives prevented the optimum systems being implemented at the start of the programme, but financial constraints and changes in development thinking have led to the adoption of more appropriate technologies and processes.

This research has incorporated some novel aspects. For example,

- The analysis drew on the experience of large-scale electrification within an African context and culture in a developing country, and made findings that could have broader application.
- Despite the initial justification of electrification for economic and socio-economic objectives, the approach introduces poverty alleviation and social development as primary objectives of electrification, and identified parameters for it within that context.
- The scope for grid based electrification to meet economic, socio-economic and social objectives was identified, showing how objectives and constraints need to be clearly defined for useful comparisons to be made between grid-based and non-grid electrification. The analysis indicates that grid-based electricity can be competitive with and more effective than PV systems in many instances of social electrification. This could have significant impact on future policies for PV electrification.
- Subsidised self-targeted tariffs were developed to meet poverty alleviation objectives. This approach could be applied in other countries where electrification has social objectives.
- The research clarified the purpose and objectives of electrification that appear to be poorly understood by many people involved in preparing and assessing electrification plans, and implementing and evaluating projects and programmes.

9.6 The present position

There is debate over whether electrification is necessary for or leads to development. However, several studies indicate that the prospect of development in the absence of roads, water and electricity is small, so the extension of electrification is important. The nature of the development may be economic, socio-economic or social (poverty alleviation), but electrification is apparently needed for all three, though it is not alone sufficient for any of them.

Economic electrification is mature and easily understood, planned and implemented. The period of the financial viability analysis of socio-economic and social development is very long, increasing uncertainty about the relationships and projections. The uncertainty should influence the technology, operation and structure of electricity utilities, but evidence indicates the effects have not been recognised. This research (in this thesis) indicates that electrification programmes with social objectives must be defined in terms of:

- adoption of minimum capital investment technologies, even under-designing rather than implementing over-designed projects that waste scarce resources by under-utilisation;
- appropriate operational management with attention (measurement, reporting and corrective action) to efficiency (including losses), service and supply quality, and financial control; and
- an industry structure with short lines of communication and management, recognising and meeting the characteristic needs of the customers, and allowing competition between distribution utilities (at least by comparison with each other, as natural geographical monopolies are too strong for artificially regulated direct competition to overcome).

Social electrification does not consist only of providing physical access to electricity, though that is of course necessary. The poor also need help in using the electricity, through low-cost or free connections and subsidised consumption tariffs. The tariffs must be targeted and carefully managed to prevent leakage of benefits to those who are not poor, and to limit corruption.

Poverty in Africa exists on such a large scale that electrification for social or poverty alleviation objectives must use only the minimum resources within technological constraints, so that economic and socio-economic development potential is not compromised. If politicians, government officials, financiers and engineers do not incorporate the above concepts in their understanding of electrification, their allocations of resources are unlikely to be sustainable. Further, even in economic and socio-economic development, adequate, low cost technological systems can contribute to infrastructure development.

Governments and electricity utilities must ensure that, where aid is offered, an aid agency's objectives are consistent with appropriate approaches to electrification.

9.7 Scope for future research

The concept of social objectives as distinct from economic and socio-economic objectives opens many potential areas of further research. They include:

- defining better the relationships between electrification (output), the social results of using electricity in poor households (outcomes), and the human factors of poverty alleviation and quality of life (impact), and formalising social measurement and assessment of the outcomes and impacts of electrification programmes;
- improving the understanding of the environmental impact of electrification, especially in social development;
- improving the awareness of and overcoming factors limiting the benefits of access to electricity;
- load research of electricity customers in different social conditions, such as the use of electricity with increasing incomes, or resulting from new or increased subsidies, or in other countries;
- identifying further ways of matching the technical capacity of networks to the needs of poor customers at low cost, including appropriate technologies and planning methods;
- determining the effect of the history of access to electricity and the ability to afford it on perceptions of the quality of supply, and developing appropriate responses to not meeting existing quality of supply standards;
- determining the effect of subsidised electricity on other energy use, on economic activity in households, on consumption above the level of subsidy and on writing off unpaid debts for electricity in some communities;
- evaluating the charging nominal fees for services, including electricity, to avoid reinforcing patterns of dependency on free goods and services; and
- developing decision-making approaches, such as multi-criteria methods, suitable for assessing electrification projects with social objectives.

9.8 Looking forward - electrifying Africa

The South African electrification programme is unlikely to be replicated exactly in other countries because

- it was based on spare generation capacity that created a relatively slack manpower and capital resource;
- the initiative did not come from the central government but from the economic sector identifying a strategy that utilities could adopt quite easily;

- political change in the country created an opportunity for politicians to embrace the policy of electrification; and
- the expenditure on electrification was not substantial compared with expenditure on other social programmes.

These conditions do not apply in most developing countries. Summing up the South African experience, the strategy was appropriate for the particular circumstances. The lesson for other countries is to assess the circumstances, and plan and act accordingly. Directly adopting targets, processes or technologies from a programme implemented in a different environment could be risky.

Despite the limitations of replicating the South African electrification, the distinction between electrification for social and socio-economic objectives is valid for all developing countries, and affects the technological, social, institutional and financial decision-making. The success of the South African programme, if not the programme itself, could be replicated with a better understanding of the differences between economic, socio-economic and social objectives, and the impact on policy.

The analysis in this research appears to indicate that most South African utilities were already functioning effectively, and the distribution industry had experienced manpower available to undertake the electrification programme. By contrast, electricity distribution utilities that are already experiencing massive problems with inefficiency, financial losses, poor quality of supply and service, a backlog of network maintenance and rehabilitation, and inadequate staffing cannot be expected to undertake system expansion effectively, without making the existing conditions even worse and incurring high economic costs for a country as a whole. Under such conditions, the priority should be on improving the existing institutional, financial and technological approaches to electricity supply. However, privatisation by selling the utilities will significantly reduce the scope for undertaking future socio-economic and social development. Instead, governments should adopt stricter management procedures for the electricity utilities, probably without direct political interference, to establish a foundation for future social and socio-economic action.

The management procedures should include following least cost solutions, including the application of appropriate technological standards, refurbishment and rehabilitation of existing networks with minimum capital expenditure, loss reduction, and the adoption of realistic, measurable targets. Improved staff capabilities will be required, so technological and management training will be needed.

Such activities will be unattractive to many equipment suppliers and some aid donors, but there will be opportunities for niche products and effective aid programmes that meet the real needs.

Some confounding factors - HIV/AIDS, poverty, political aspirations and unrest - form part of the environment for electrification, and the problems will only be overcome by appropriate action based on a valid understanding of the objectives. Without wise and carefully managed investment, it is fairly certain that the negative outcomes and impacts will be severe for developing countries in Africa. Carefully planned and implemented electrification programmes could make positive contributions to development.

9.9 Conclusion

This research was an input; the thesis is an output. Electrification should develop more favourable outcomes as the lessons are implemented and, in time, desirable impacts of economic and social development may be achieved.

The 'experiment' of electrification described here will continue. Electricity supplies will be extended to more households in South Africa, and probably in other African countries. Restructuring of the electricity distribution industry into regional electricity distributors is planned for 2005, but might be modified by local constraints and international developments in the industry. Some form of basic electricity support tariff is expected to be implemented during 2003, even if it is not based on the recommendations of the recent research.

Electricity in Africa will continue to have both economic and social impacts. Understanding the differences, and applying them to the planning and evaluation of electrification and electricity supply should contribute to better decision-making and greater effectiveness.

Nkosi Sikilel' iAfrica.

Summary

The thesis identifies differences between electrification carried out to meet economic, socio-economic or social objectives, evident from the history of electricity supply in South Africa, a recent evaluation of the National Electrification Programme and subsequent research into options for a basic electricity support tariff. Examination of the ethics underlying development intervention and international aid shows that social objectives are a justifiable part of electricity supply in developing countries, although they are seldom taken into account in formal project and programme assessment. Recognising the social objectives has many implications for decisions regarding electrification technology development, capital investment, the structure and regulation of the electricity distribution industry, and the planning and evaluation of electrification programmes.

The huge cost of electrification programmes and their operation justifies research into improving their performance. Electrification is characterised by complexity and possibly by the adoption of sub-optimal solutions to the various problems. The substantial electrification activities in Southern Africa provide a special opportunity for investigation. It is proposed that better decision-making and resource allocation will result from an improved understanding of the economic, socio-economic and social (poverty alleviation) objectives of electrification. The research includes technological, financial, institutional and ethical aspects.

Electrification in South Africa started for economic reasons, to reduce the costs of the mining industry, other industries and the railways. The convenience of electricity for lighting induced the municipalities to adopt it for public and private supplies, and the government recognised the importance of controlling and owning this economic function.

The most significant socio-economic electrification in South Africa took place during the 1970s and 1980s when, spurred by political pressures, Escom (which later became Eskom) extended subsidised supplies to the farms in rural areas. Even so,

many farms were too far from the grid to be able to afford supplies at the high costs associated with the technologies and tariffs then in use.

The establishment of several new townships near the cities during the 1980s, associated with the influx of people from the rural areas, emphasised the issue of whether electricity should and could be supplied to poor families. In many cases where electricity was available, the viability of the distribution was challenged by expensive technical standards, uneconomic tariffs and bad debt.

A business strategy process in the late 1980s identified the possibility of deriving significant socio-economic benefit from a national electrification programme. The "Electricity-for-All" programme commenced at the same time that South Africa started going through political change from apartheid to a broadly democratic government. Targets defined by the National Electrification Forum were adopted by the new government as the National Electrification Programme in 1994.

It became evident that many people were too poor to benefit substantially from access to electricity, and the voter appeal of promising free services was recognised. Proposals for "poverty" tariffs and promises of free electricity identified another reason for electrification, one that does not have socio-economic, but purely social objectives of poverty alleviation and political support.

Three different objectives can be identified then for the electrification in South Africa: initially economic, later socio-economic and recently social. Basic theory indicates that the "solutions" for different objectives are usually different, so the thesis explores the solutions to the electrification programmes in these three phases, and the differences that did, should or might support them.

The viability of economically driven electrification is a simple business case. The analysis of electrification for socio-economic development is widely researched and reported. Despite differences in some details, it appears generally assumed that electrification benefits development by contributing to improved education and health and supplying the services that bring customers into the formal economy through improved production. Extensive literature shows that organisation structures, tariffs and technology have been developed on the basis that they should support the identified socio-economic objectives. However, the implementation of projects does not always meet all the objectives expected of electrification because, possibly, those various objectives are not differentiated.

There is little evidence in published literature of electrification undertaken for purely social reasons, that is, with the primary objective of poverty alleviation. The concept

that social development or poverty alleviation can be a driver for electrification is demonstrated by examining the electrification progress and decision-making in Southern Africa in greater detail. Practical examples provide a basis for the theory underlying electrification programmes.

The achievements of the national electrification in South Africa from 1991 virtually doubled the number of domestic customers in 10 years. The electrification was characterised by a continuous and substantial change of technological standards. The changes included the greater application of single-phase instead of the traditional three-phase distribution, the adoption of new technologies in line design and feeder conductor selection, the broad application of prepayment metering, and revised industry standards and implementation procedures. The result was lower electrification connection costs.

The adoption of new technologies was enabled by innovative research and development in the private sector and universities, which already had close relationships with the utilities and received their financial support for research. However, a change from the approach of meeting numerical targets for connections was largely driven by recognition of the high costs of the existing standards and methods.

The development may be viewed as an engineering approach to problem solving. As the challenges changed, so the staff of the electricity distribution industry responded with better technology.

The scale of the change was such that it challenged several conventional ideas of electrification. It was generally accepted that capital investment costs per customer in rural electrification are high, but the experience shows that appropriately planned rural systems may not be more expensive than urban systems. Further, the financial constraints and customer needs that forced down the costs of electrification also challenge the standards, technologies and approaches to non-grid electrification so widely supported by some development assistance agencies.

Technology improvement is not unique to South Africa. Its importance in the context of this research is that it was stimulated by an awareness of costs that was symptomatic of new needs in distribution and electrification, even if the nature of the change was not clearly understood. The technological achievements of the electrification programme also created opportunities to extend further the benefits of electrification.

Analysis of the ethics supporting electrification identified religious obligations to help the needy, the philosophical principle of giving equal consideration to the interests of all, and political or pragmatic reasons to help the poor. It also examined the deficiencies and effectiveness of aid and the contribution that electrification makes to improving safety and the environment. From all perspectives, electrification to alleviate poverty is justifiable and even desirable.

It is not that the world lacks the resources for social development and poverty alleviation through electrification, but that the mechanisms for using the resources are insufficient. African countries, particularly, do not have a good reputation for efficiency and integrity. Financiers and supporters need to have confidence in the institutions and processes for using funds and technology, first in identifying acceptable objectives and then in management to reach them, without resource waste and benefit leakage through corruption and inefficiency. There is still a need and a role for aid and subsidies, but they must be designed to achieve the objectives with minimum disadvantages.

Analysis of the relationships between the technological, economic and social sub-systems found strong support for a social development concept of electrification. However, economic and financial studies are inappropriate for assessing social development plans because of the long term of the development and the difficulty of expressing the benefits in economic values. A social model leads to a specification for a social tariff, and research into a subsidy of electricity consumption for poor customers produced a tariff consistent with the specification. This novel proposal for a self-targeted tariff meeting the needs of poor customers is being tested in pilot sites at present.

The social and tariff subsidy analysis has implications for the institutional structures of the electricity distribution industry. Experience and the substantial reports on the role of institutional structure in electrification indicate that structure is relatively unimportant to success, as long as a few basic requirements are met, including having:

- a clear understanding of objectives that are realistic,
- a technological core that can meet the needs to develop and maintain networks at minimum cost, and
- political awareness in the utilities, and government acceptance of the utilities' objectives and activities, to the extent that interference is unnecessary.

It also appears that efforts and expenditure on restructuring may not show much benefit in the long run, and in the short term could damage the efforts for electrification. Further, there may be significant value in having or retaining diversity

of utility structures and sizes, but that direct competition and privatisation of the electricity distributors could have risks for the implementation of electrification for social development in developing countries.

Electricity utilities have been widely used for socio-economic and social interventions, and in developing countries this is not an unexpected role for them. However, social development responsibilities complicate the utilities' obvious goals of delivering electricity efficiently and profitably.

The activities of an electrification programme exist in the context of its purpose, whether or not the objectives are formally defined and the assumptions recognised. Applying the concepts of economic, socio-economic and social objectives to investigations of the electrification programme, a basic electricity support tariff, and a simplified example, shows that the understanding of electrification shapes the objectives, plans, and evaluations of achievements. Recognising different development objectives for electrification allows weaknesses in programmes to be easily identified, offering potential for more efficient and effective allocation of resources.

All the decision-makers in the process of electrification need to be aware of the differences. Non-technical people need to understand the contributions that different technologies can make to meeting their objectives, and technical people need to be aware that different outcomes are required in different circumstances, and that the technologies must be correctly selected and applied.

The benefits expected of electrification investment in South Africa are unlikely to be achieved quickly, because they were expressed in terms of economic and socio-economic objectives. However, substantial benefits are derived from the electrification programme through its contribution to social and poverty alleviation objectives. Hindsight indicates that the confusion of objectives prevented the optimum systems being implemented at the start of the programme, but financial constraints and changes in development thinking have led to the adoption of more appropriate technologies and processes.

This research incorporated some novel aspects.

- The analysis drew on the experience of large-scale electrification within an African context and culture in a developing country, and made findings that could have broader application.
- Despite the initial justification of electrification for economic and socio-economic objectives, the approach introduces poverty alleviation and

social development as primary objectives of electrification, and identified parameters for it within that context.

- The scope for grid based electrification to meet economic, socio-economic and social objectives was identified, showing how objectives and constraints need to be clearly defined for useful comparisons to be made between grid-based and non-grid electrification. The analysis indicates that grid-based electricity can be competitive with and more effective than PV systems in many instances of social electrification. This could have significant impact on future policies for PV electrification.
- Subsidised self-targeted tariffs were developed to meet poverty alleviation objectives. This approach could be applied in other countries where electrification has social objectives.
- The research clarified the purpose and objectives of electrification that appear to be poorly understood by many people involved in preparing and assessing electrification plans, and implementing and evaluating projects and programmes.

Electricity in Africa will continue to have both economic and social impacts. Understanding the differences, and applying them to the planning and evaluation of electrification and electricity supply should contribute to better decision-making and greater effectiveness.

Glossary

A few terms are explained to clarify some aspects of electricity supply.

Abbreviations most commonly employed to indicate multiples of the units used in electricity supply are:

k for kilo, meaning one thousand: 1 000

M for mega, meaning one million: 1 000 000

G for giga, meaning 1 000 million: 1 000 000 000.

Energy and electricity

Energy: The capacity to do work, typically measured as kilowatt-hours [kWh] for electricity or Joules [J, or MJ] in many other applications. The principle of conservation of energy defines the relation between chemical energy of coal, thermodynamic energy of steam and the electrical energy delivered to customers. The energy used by electricity customers is often referred to as consumption, and the kWh measured in the customers' meters are colloquially referred to as "units" of electricity.

Power: The rate of producing, transferring or consuming electrical energy is measured in Watts [or kW, MW or GW] over a specific period (for example 5, 30 or 60 minutes). For customers' loads the power is often referred to as demand. In some cases reference is made to apparent power, measured in volt-amperes [VA, kVA or MVA], which is related to power by a power factor.

After diversity maximum demand: The notional demand of an average customer, calculated from the maximum demand on the system divided by the number of customers. It is usually expressed in kVA, but for domestic customers is better modelled as a current at the nominal voltage, such as 230 V.

Current: The rate of flow of electric charge in a conductor. The unit of measurement is the ampere [A].

Voltage: The electrical force that drives energy through the network or load is measured in volts [V]. Voltages of 11 to 33 kV are referred to as medium voltage. The standard voltage of the low voltage (LV) system in South Africa is 400 V between the phases of a three-phase system, giving 230 (or 231) V between a phase and neutral.

Technical losses: Loss of energy from the transmission and distribution system caused by the resistance heating of current in conductors (most significant), magnetic losses in transformers, energy used to operate equipment including meters, and leakage of current out of the system over polluted and wet insulators (usually insignificant).

Non-technical losses: Apparent losses that arise because of administrative errors, such as incorrect meter reading, having no records of some customers, or not accounting properly for revenue from sales. Apparent losses can also arise from metering inaccuracy, particularly where purchase meters read high and sales meters read low, especially those meters that are not working. The term is also used to describe theft of electricity by illegal connections to the network, meter tampering and bypassing, and fraud.

Alternative energy: A term usually referring to any energy other than electricity derived from a network or grid. It includes electricity from photovoltaic panels, mini- and micro-hydro, wind generators and even diesel generators, as well as non-electrical energy like coal, paraffin (an alternative name for kerosene), fuelwood, biomass, etc. Not all alternative energy is renewable energy.

Renewable energy: Energy derived from resources that are replaced in a short period, for example hydro-electricity and sustainable exploitation of fuelwood, or conversion of natural energy like solar energy, wind pumps or generators, and wave energy that makes little discernable difference to the physical environment. Renewable energy usually excludes sources with long cycle times, like coal and oil, as well as nuclear energy, which accelerates the natural fission process.

Infrastructure

Generation: Process of producing electrical energy from heat (burning coal) or light (photovoltaic cell). Also refers to the facilities (power stations) where generation occurs.

Transmission: Transfer of electrical energy at high voltages through transformers and overhead lines to the centres of load. Also refers to the transmission systems, which operate at voltages above 132 kV (132'000 V).

Distribution: All the processes related to the transfer of electrical energy from the sources of generation or the transmission systems to the places where the energy is used. Also refers to that part of the network operating at voltages of

132 kV and below. (In some countries 132 kV would be considered a transmission voltage and distribution would refer to voltage levels of 66 kV or lower.) Distribution is also referred to as reticulation in South Africa where it relates to the final stages of the distribution system at medium voltage (11 and 22 kV) and low voltage.

Substation: An arrangement of switches and transformers where the voltage is transformed from one level to another and from which the incoming energy is distributed by several feeders.

Feeders: The connections between substations and loads.

Network: The transmission and distribution lines and substations that together form a system (a network of branches and nodes) for the transfer of energy from power stations to loads. Networks are usually meshed, with several branches between many nodes, or radial with serial connection of nodes. Most distribution feeders are radial. Networks are also called "the grid".

System planning: The process of conceiving, evaluating and selecting alternatives for additions and changes to the power stations, transmission and distribution networks making up the power system.

Utility, undertaking: A business that is either part of the public sector or operates under licence to supply a service to meet a general need, particularly electricity or water supply.

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