The financial impacts of rural electrification

Mark Davis

Draft report

EDRC
April 1996

1. Introduction

This report forms part of a broader study into the financial impacts of electrification on the electricity supply industry and accompanies an earlier document entitled `The financial impacts of electrification on the electricity distribution industry' (Davis 1996). The purpose of this additional report is to focus specifically on questions relating to the rural component of the electrification programme. In particular the report aims to quantify, as far as possible, the financial consequences of rural electrification, and to identify the impacts on rural electrification of other policy decisions relating to institutional arrangements and subsidy policies.

This report is based on a detailed financial analysis of the electrification programme. Although details of this analysis are contained in Davis (1996), a brief summary of the scope and nature of the analysis will be presented here. The study comprised three parts: (1) the quantification of capital costs based on certain electrification scenarios; (2) a cash-flow analysis of distribution agencies under these scenarios; and (3) the quantification of the impact of electrification on the total net income of these distribution agencies. The last component of the study included an investigation into the extent of tariff increases and subsidies which might be required to meet losses incurred in the electrification programme.

1.1 Methodology

Capital costs were estimated using a model developed by Distribution Technologies at Eskom.[1] This model combines demographic information from the NELF[2]/Eskom demand-side database, with information describing the location and capacity of existing networks. Capital costs are calculated for electrification in each magisterial district by estimating the costs of distribution lines and transformers, as well as the costs of reticulation and service connection. Given a set of required household connection targets, settlements are prioritised on the basis of least capital cost. In this way a profile of electrified settlements and capital costs can be built up, on an annual basis, for the time period under consideration. The model allows different technologies to be incorporated, with their associated costs, based on the capacity of supply to each household (for example, 60A, 20A or 2.5A limited supplies).

Using this cost data, and combining it with information and assumptions on refurbishment, consumption, tariffs, supply costs and support costs, it is possible to project a cash flow for the distribution agency undertaking the electrification programme. The most contentious assumptions relate to the estimation of consumption growth, as it is a key determinant of revenue, and sensitivity analyses must be used to track the effects of variations in the underlying assumptions. Other variables used in the sensitivity analysis are the discount rate, revenue losses, and capital costs.

The cash flow analysis of electrification provides details on financing requirements, and allows an examination of the net effect on the implementing institution's finances. Assuming that sufficient capital can be raised from equity sources and capital markets, there are further concerns about meeting annual costs, including finance charges. Insufficient revenue from electricity sales means that, in order to prevent a debt-trap from occurring, annual losses must be met from other revenues. This can either be from existing surpluses in the industry, or from general tariff increases. The third stage of the methodology examines the size of these subsidies.

Detailed assumptions used in the study are presented in the appendix.

---

1 The assistance of J Roux from Eskom in this part of the analysis is gratefully acknowledged.

2 NELF: National Electrification Forum.

1.2 Scenarios examined

A set of scenarios were constructed which looked at institutional arrangements in the industry, electrification targets and supply technology options.

Institutional arrangements included: (1) the continuation of the *status quo* – that is, municipal distributors supplying urban areas, with Eskom supplying the rest of the country; (2) the establishment of a national electrification distributor; and (3) the establishment of regional electricity distributors, based on provincial boundaries. Electrification targets are based on the NEES[3] mid-range scenario, broken down into provincial totals as described by Els (1994). Lastly, technology options include either the continuation of the use of a 60A supply with prepayment meter, or the introduction of capacity differentiated supplies, allowing customers the choice of 60A, 20A or 2.5A load-limited supplies. For this latter option, assumptions were made concerning the proportion of households adopting each supply type.

1.3 Rural electrification

The full analysis covered electrification in all areas of the country and it is difficult to isolate the 'rural' component of this. Although it is evident that the Eastern Cape, Northern Province and KwaZulu/Natal contain the bulk of the rural population (mostly located in the former homeland areas of the country), it is difficult to construct an adequate definition of 'rural' which can successfully be used in conjunction with available demographic data. For this reason, the analysis has taken a fairly broad definition, and taken 'rural' to mean all areas currently outside the main metropolitan areas and existing municipal supply authorities' areas of supply. Within these remaining areas there is a wide range in settlement densities, and it was possible to make a rough distinction between 'dense' and 'dispersed' settlements.

The scope and pace of rural electrification is determined by two factors: the size of national targets and their distribution among the provinces; and the rights of access which distribution agencies have to unelectrified areas of the country. In the present system, where Eskom does not have supply rights to many municipal areas, Eskom's electrification projects are largely (although not exclusively) confined to rural areas of the country. If institutional arrangements are reformed, either towards a national or regional distribution authorities, then there will be a tendency to concentrate on the lower cost urban areas, leaving more remote rural locations for later in the programme.

This report will look first at consumption growth, and the nature of the effect of assumptions on the financial results. Secondly, there will be a presentation of the key results, including the results of the sensitivity analysis. Thirdly, there will be a discussion of the cost savings of using load-limited supplies compared with conventional supply technologies. This will be followed by a description of the effects of industry restructuring on rural electrification, specifically the effects of reordered project selection priorities under a rationalised industry. Lastly, there will be a look at the scale of subsidies required for rural electrification, and a brief comparison of urban and non-urban electrification.

2. Consumption growth in rural areas

Pricing policy for the electrification programme has incorporated two important features. Firstly, connection charges are nominal, so all capital costs must be recovered through the tariff or subsidies. Secondly, there is no fixed monthly charge, so all revenue is linked to consumption rates. This means that all fixed costs and capital redemption must be met through the unit energy charge.

This pricing policy is progressive in two ways. Firstly, it removes the hurdle of high connection fees which in many countries has prevented low-income households from connecting to the grid. Secondly, there is an implicit subsidy from

---

3 NEES: National Economics of Electrification Study, commissioned by NELF.

high-consumption (and presumably high-income) to low-consumption (and low-income) households. Households which use electricity for the bare minimum – usually lights and possibly radio or television – are heavily subsidised. In this way, the tariff structure implicitly includes a 'life-line' element for low-income households.

However, for the same reasons that the tariff is attractive to low-income households, it is risky for the utility. If average consumption levels fail to meet the break-even point, the utility will suffer financial losses. Figure 1 shows a rough calculation of the net present value (NPV) for a single household over a 15-year period for different consumption rates. Given the assumptions listed, it can be seen that a consumption level of over 300 kWh/month is required to obtain an acceptable rate of return (indicated by a NPV greater than zero).

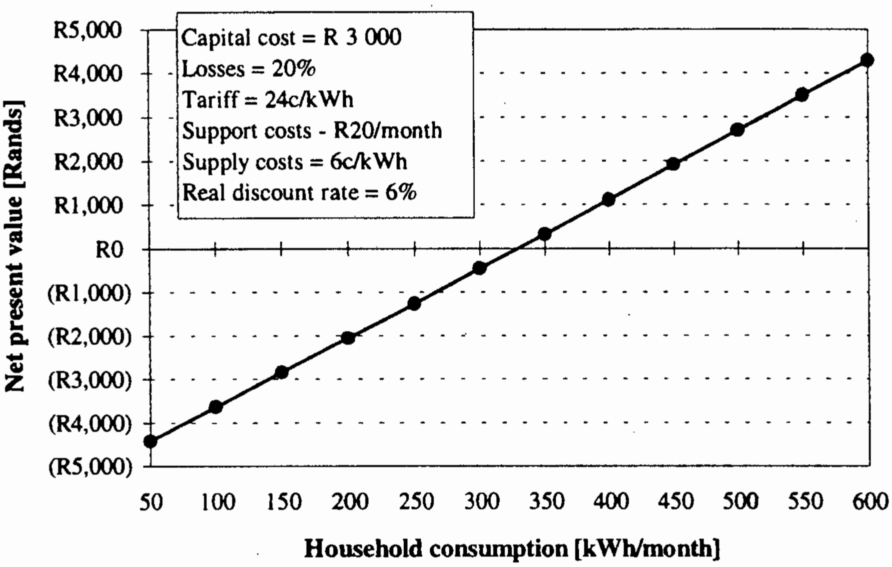


Figure 1: Approximation of the net present value per household for different consumption levels

Experience in the electrification programme to date has been that consumption levels are low and revenue losses are high. Average revenue losses for the entire country during 1995 have been in the region of 34% (Bezuidenhout 1995). These losses are in addition to technical losses and represent a substantial loss of revenue in the electrification programme.

Table 1 shows the average sales levels of Eskom's electrification customers since the start of the electrification programme. With the exception of the Cape Town distributor, sales (which are lower than consumption due to revenue losses) have been below 100 kWh/month. Sales within the former Pretoria distributor's area, which mostly covers only rural electrification projects, have been particularly low.

Eskom distributor[1]	1992 (Dec)[2]	1993	1994	1995 (to July)
Bloemfontein	138	76	79	78
Cape Town	201	137	123	124
Durban	105	73	88	83
Johannesburg	53	70	67	83
Pretoria	32	51	55	59
Total	**96**	**75**	**80**	**83**

1 Following restructuring within Eskom, these distributors no longer exist.

2 Figures for 1992 are for December only, not averaged across the entire year. Since there is usually a December peak in sales, the 1992 figures may over estimate the annual averages.

Table 1: Sales levels since 1992 [kWh/month]
Sources: Eskom 1992; Eskom 1993; Eskom 1994; Eskom 1995

An analysis of changes in consumption over time shows that growth rates can be quite high – in the region of 10% to 20% per annum, although this is off a low base. Electrification projects in the Eastern Cape have had bulk supply meters installed since the earliest projects were implemented. This allows actual consumption, rather than sales, to be tracked. All electrification projects with a history of 18 months or more were selected from this region, and their consumption growth examined. Table 2 summarises the results, with settlements grouped into consumption bands. As much as 70% of settlements recorded average consumption levels of less than 100 kWh/month, and growth rates for the entire sample were 14% per annum. For most settlements, this is equivalent to an average annual increase in consumption of between 5 and 10 kWh/month.

These consumption figures are based on settlements which are, by and large, fairly urban in nature. With a few exceptions, they are either residential areas of small Eastern Cape towns, or settlements close to some of the larger urban centres in the province. It is possible that as electrification reaches more remote and isolated areas, consumption levels in new projects, at least initially, will be even lower.

Ave consumption kWh/month	**Percentage of sample** %	**Growth rate** % per year	kWh per year
150	7	25	38
100 - 150	24	16	15
75 - 100	22	9	10
50 - 75	38	14	7
0 - 50	9	14	4.5
All	**Ave consumption = 90 kWh**	**14%**	**10**

Table 2: Consumption growth rates – electrification projects in the Eastern Cape
Source: Davis 1995a

Although these consumption levels indicate that any utility undertaking electrification is likely to sustain financial losses, it can be difficult to quantify the extent of these losses. Even though consumption is low, growth rates are relatively high, and there is no certainty, at this early stage, regarding the 'plateau' which average consumption will tend to. The determinants of consumption growth are difficult to identify, although it is generally accepted that income levels will affect consumption directly, and indirectly through access to appliances. However, there is likely to be a range of other important factors, such as climate, access to other fuels (particularly wood), as well as the nature of control over household expenditure decisions.

At best it is possible to propose scenarios for consumption growth. The financial analysis performed for this study made base-case projections and conducted a sensitivity analysis on these projections. Table 3 shows the underlying assumptions used. For each consumer category, consumption growth was characterised by an initial consumption, a final ('plateau') consumption, and time period to reach this maximum (i.e. the growth rate). Given that load-limited supplies affect the type and number of appliances that can be used, different assumptions were used for different types of supply, as well as for low or high density locations.

	Low density areas			***High density areas***		
	2.5A	*20A*[1]	*60A*	*2.5A*	*20A*[1]	*60A*
Minimum	*50*	*50*	*100*	*50*	*50*	*100*
Maximum	*100*	*200*	*300*	*150*	*250*	*350*
Reaches max in year	*5*	*9*	*8*	*7*	*10*	*8*

1 When capacity differentiated supplies are not offered, the consumption growth profile for 20A consumers is used

Table 3: Assumptions regarding consumption growth

The consumption growth profile presented in Table 3 tends to err on the conservative side. Although users with a 60A limit are assumed to reach average consumption levels of 300 to 350 kWh/month, this applies to only 13% of all customers.

Actual consumption growth is affected by these assumptions as well as losses and the rate of connection of new consumers. As new consumers are connected to the system, their low levels of consumption will depress the average. Figure 2 shows the actual averages which result from the set of assumptions used.

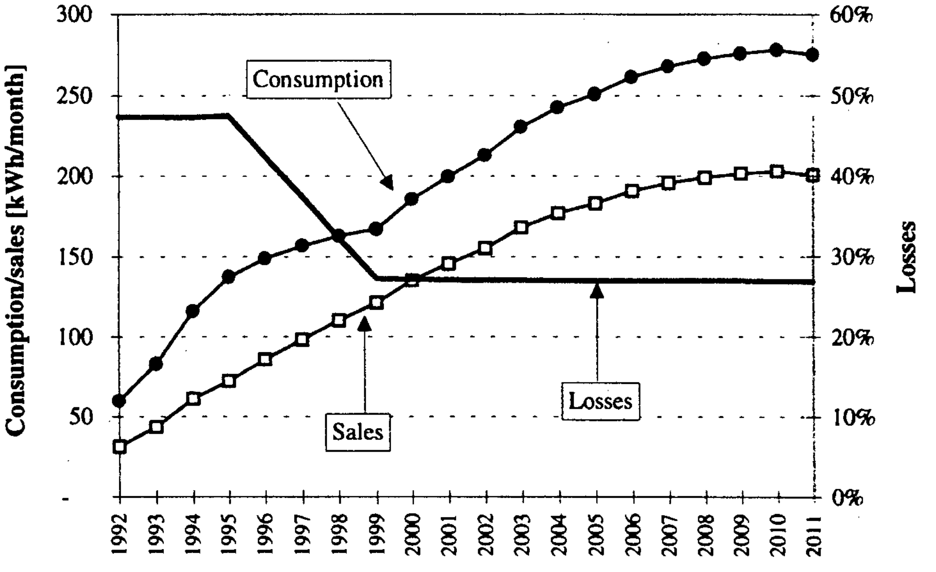


Figure 2: Average household sales, consumption and losses
(losses include both revenue and technical losses)

3. Results

This section will report the principal financial results for electrification of non-urban areas of the country. The connection targets for these areas correspond to Eskom's current set of targets, broken down for each province. Figure 3 shows the annual connection targets, together with the projected increase in access to electricity. These results are based on an existing rural population of four million households (in 1994), with an annual household formation rate of 2%. The figures show a fairly rapid rise in access to electricity, climbing to 50% by the year 2000. However, it should be noted that this is based on a fairly broad definition of the term `rural', and that actual connection levels in remote rural locations will be much lower. In addition, it is plausible that a percentage of these connection targets may be shifted to urban areas in order to keep costs down. This will have the effect of lowering projected access rates.

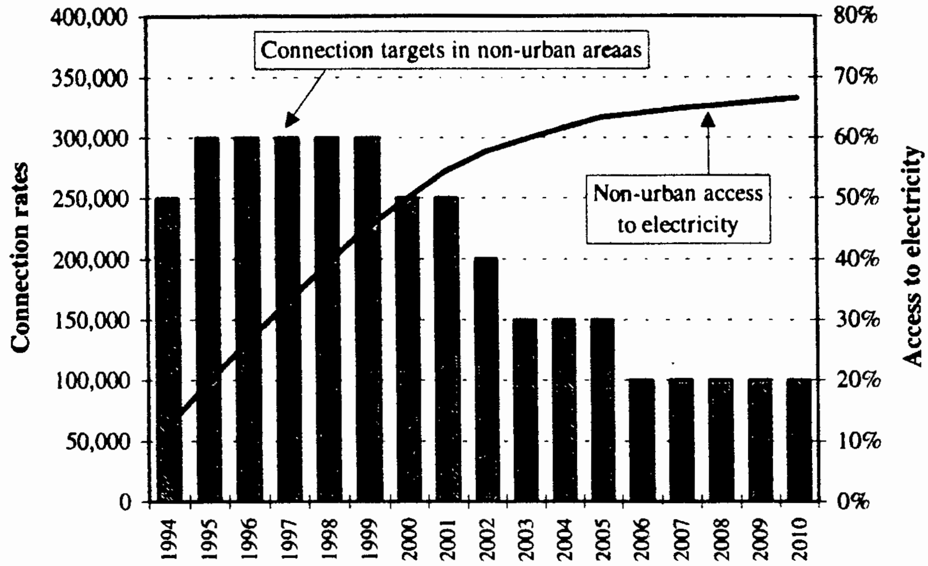


Figure 3: Connections rates and access to electricity

3.1 Capital costs

The capital cost of connection is an important financial parameter for three reasons. Firstly, capital costs determine the extent of financing required to implement the programme. Secondly, electrification is capital-intensive and it is capital costs which drive the overall results of the financial analysis. Thirdly, unit capital costs can be used to determine whether off-grid technologies, in particular photovoltaic systems, have a substantial role to play.

The capital costs presented here are based on the assumption that capacity differentiated supplies are offered in rural areas, and that 60% of households in scattered rural settlements opt for a 2.5A supply, and the remaining 40% choose a 20A supply. In densely populated areas, 80% of households are assumed to use a 20A supply, and 20% choose a 60A supply. Projected ADMDs[4] with these limited supplies are then used to calculate the capacity of required distribution lines and transformer capacities.

It can be seen in Figure 4 that unit capital costs start at around R4 000 per connection, and climb steadily until they start to fluctuate between R6 000 and R9 000 per connection. This is a consequence of the fact that the modelling chooses lower-cost areas earlier in the programme, probably a fairly realistic assumption. As the programme reaches more remote areas, unit costs are likely to increase, even if capacity differentiated supplies are used. Overall, average capital costs in non-urban areas were found to be R4 740 per connection.

Figure 4 also shows the total capital requirements on an annual basis. It can be seen that capital requirements for non-urban electrification peak at around R1.4 billion in the first half of the programme, and taper off as connection targets decrease.

---

[4] ADMD: After diversity maximum demand.

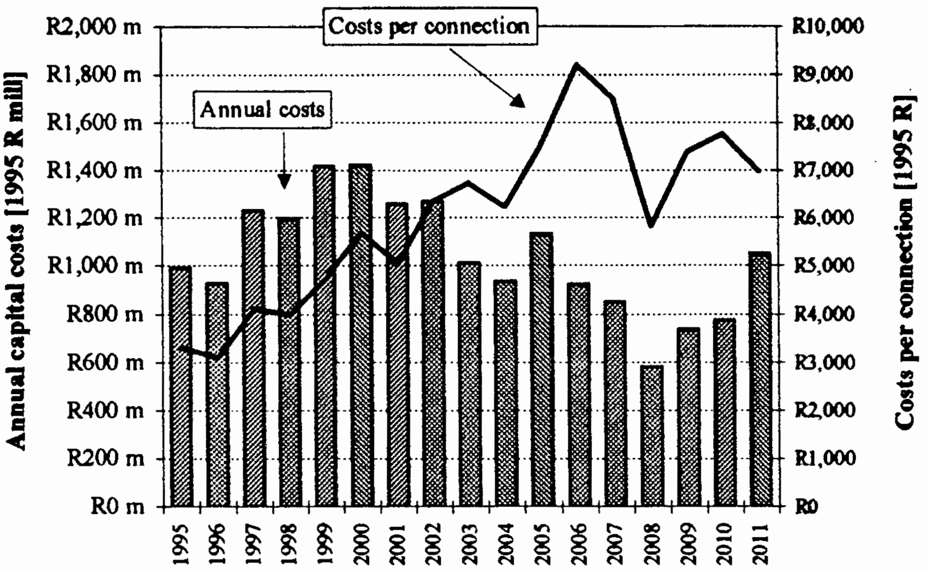


Figure 4: Capital costs for non-urban electrification

Household photovoltaic systems supply an electricity source that is capable of powering lights, television and radio. Although a 2.5A supply is likely to be able to power a slightly wider range of appliances and for longer periods in a day, photovoltaic systems and 2.5A supplies are broadly comparable. Since commercial enterprises were selling photovoltaic systems for around R4 000 in 1994 (Davis 1995), it is clear that, even on average, photovoltaic systems represent a lower cost option. However, there are other benefits associated with bringing the grid to an area, which are absent if rural electrification is based on photovoltaic systems. For example, the grid allows higher-powered appliances (such as water pumps, power tools, freezers) to be used, and some houses and shops will opt to choose a full 60A supply, powering a wide range of appliances. If photovoltaic systems are offered, higher-power applications are excluded, unless powered by diesel generators.

3.2 Net present value of the programme

The NPV is the discounted cash flow over the entire lifetime of the programme. It takes into account the cost of capital (reflected in the discount rate), the capital and refurbishment costs as well as all operating costs and revenues. The cash flow is taken over a sufficiently long period to ensure that all capital investment is matched to associated cost and revenue cash flow.

A wide range of assumptions are required to calculate the results, relating to all elements of costs and revenues. These assumptions are attached in the appendix. There are two different ways of calculating the recurrent costs of electricity supply – one based on marginal and the other on average costs. In this analysis, average costs are used, and since Eskom currently has excess generation capacity, average costs in the short-to-medium term are higher than marginal costs (this is because installed plant is being paid off, and only comparatively little capital investment is being made in new plant).

The NPV for the non-urban portion of the electrification programme is calculated to be negative R13.8 billion. This is equivalent to negative R3 500 per customer. Since the NPV is negative, it indicates that the utility will lose money on the programme, and a capital injection of R13.8 billion is required to make the programme viable.

A sensitivity analysis on the key variables reveals the extent to which this result is affected by changes in assumptions. Figure 6 shows the sensitivity of the NPV to changes in capital costs, consumption and revenue losses. For all cases examined in the sensitivity analysis, the NPV was found to be highly negative. Although seen that the results are most sensitive to variations in capital costs. In fact, a 30% reduction in capital costs leads directly to a 30% increase in the NPV. This suggests that the results are dominated by capital costs.

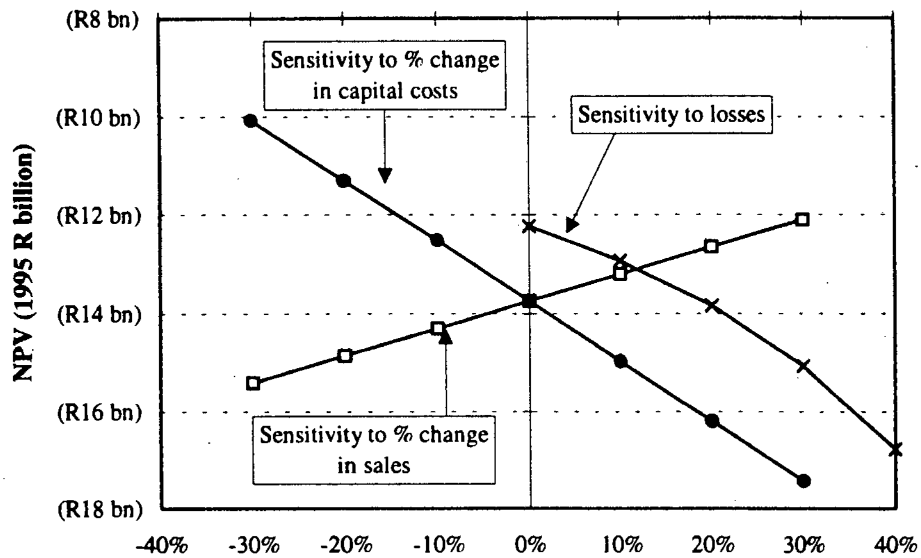


Figure 5: Sensitivity of NPV to key variables
(losses refer only to revenue losses)

Table 4 presents the sensitivity of the NPV to changes in the discount rate. Usually, a capital intensive project where revenues are received over a long period is adversely affected by higher discount rates. However, in this case the NPV of the project improves as the discount rate increases. This is because the programme sustains operating losses in the future and so a higher discount rate decreases the present value of these losses.

Real discount rate	2%	4%	6%	8%	10%
NPV (1995 R billion)	-21.4	-17.0	-13.8	-11.4	-9.50

Table 4: Sensitivity of NPV to the real discount rate

3.3 Financial operating losses

Given that the present value of capital costs (R10.8 billion) is close to the total NPV of the programme (-R13.8 billion), it is clear that operating losses are relatively small in comparison to capital costs. However, it is worthwhile examining the trends in operating losses/surpluses as these are important for the overall effect on debt and pricing policies.

Figure 6 presents the net operating losses/surpluses for the non-urban portion of the programme. These figures are defined as the net operating costs, exclusive of interest payments on capital and any expenditure on refurbishment. It can be seen that operating losses peak at around R200 million per year, and gradually decrease over time. It should be stressed that this result is highly sensitive to variations in the key assumptions. Most importantly, the introduction of capacity differentiated supplies is accompanied by real price increases (using proposed tariffs – Barnard 1995), and without these increases, losses are greater. In addition, relatively small variations in consumption growth assumptions, as well as changes in support costs and bulk supply costs will affect this result. If refurbishment costs are added, then the operating losses peak at around R450 million per year and do not decline as rapidly as shown in Figure 6. Refurbishment costs are a significant factor later in the programme as older equipment is replaced.

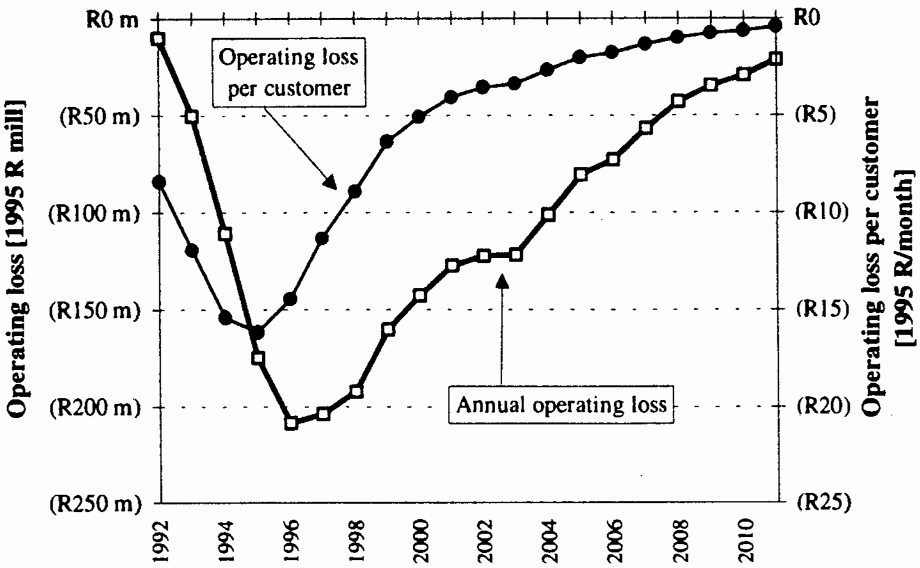


Figure 6: Operating losses for non-urban electrification
(excluding finance charges and refurbishment costs)

At their maximum, operating losses are only 14% of annual capital expenditure, and this explains why the NPV is largely driven by capital costs.

Expressed as an operating loss/surplus per customer, it can be seen that the loss peaks at around R15/customer/month. Thereafter, the loss gradually decreases, approaching a figure close to zero towards the end of the time horizon. This relatively small margin per customer explains why variations to assumptions such as support costs and tariffs make a substantial difference to the overall result.

3.4 Accumulated debt

Operating surpluses, if they exist, are small and are insufficient to cover even refurbishment costs. As a result, revenues from electricity sales are not able to cover the interest payments on debt incurred (or returns to equity) for the capital investments. Without subsidies, a debt trap develops, where more debt is incurred in order to pay off interest on outstanding debt.

If no subsidies are available, and assuming a nominal interest rate of 16% (and 10% inflation), the total accumulated debt for non-urban electrification in 2011 will be in the order of R38 billion, in 1995 terms. This is over three times the residual value of assets in this year (where assets are depreciated over 20 years) and is equivalent to an accumulated debt of R9 500 per customer. A subsidy of R32 per customer per month is required to keep accumulated debt less than the value of depreciated assets. If this subsidy was available, the accumulated debt in 2011 would be R11 billion.

4. Capacity differentiated supplies in rural areas

The results presented above are premised on the use of capacity differentiated supplies. Overall, in non-urban areas of the country, the assumptions in the study mean that 21% of households choose a 2.5A supply, 66% choose a 20A supply, and the remaining 13% choose a 60A supply.

The savings of utilising capacity differentiated supplies are naturally higher in low-density rural parts of the country, largely as a result of the lower-capacity lines that are installed. Figure 7 shows the difference in unit capital costs between using capacity differentiated supplies and standard 60A technology in low-density areas.

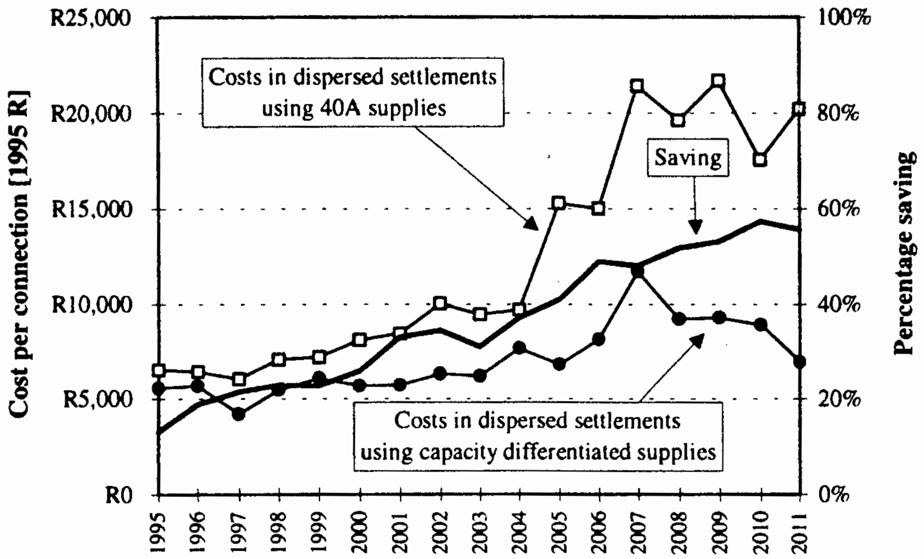


Figure 7: Cost reductions from using capacity differentiated supplies in low density rural areas of the country

Figure 8 shows that the cost reductions approach 60% towards the end of the programme. For the earlier part of the programme, before more remote areas are reached, cost reductions are in the order of 20-30%. It can be seen that without the use of capacity differentiated supplies, the unit capital costs reach exceptionally high levels in low density locations – approaching R20 000 per connection. Although these figures contain a certain degree of error, particularly for later years, they indicate the trend of costs and the order of magnitude in potential savings.

On a national basis, the effect of using capacity differentiated supplies is to decrease the capital requirements by 30%. The bulk of these savings are achieved later in the programme as more remote and expensive areas are electrified. Since the NPV of the programme and debt accumulation are both largely dictated by capital costs, savings in capital lead directly to similar improvements in these two financial parameters.

Although load-limited supplies provide a service that is inferior to standard grid connection, the option of continuing with current connection policies implies a heavy cost penalty. The size of the capital requirements indicate that there is potentially a large role for off-grid electrification options.

5. Industry restructuring and rural electrification

At present the distribution industry in South Africa is highly fragmented, with most municipalities exercising the right to supply electricity consumers in their area of jurisdiction. Although it has been speculated that this system gives rise to inefficiencies, this has not been rigorously demonstrated. However, there are certain financial effects that are a consequence of the fragmented nature of the industry. Firstly, small municipal distributors find it difficult to raise adequate finance for electrification projects. This is partly a consequence of their status as municipal suppliers, and partly a result of their limited asset and revenue base. In comparison, Eskom has a large asset and revenue base, an influential treasury department, and finds it relatively easy to raise capital on local and international markets at reasonable rates. Secondly, small municipal distributors are in a weaker position to cover operating losses on their electrification programmes, including the payment of finance charges on loans. In contrast, Eskom is able to cover short-term losses fairly easily, and is able to lever substantial cross-subsidies from other consumers.

For these reasons, there are initiatives to rationalise the industry. The Electricity Working Group, appointed by Government to prepare proposals for the future of the electricity distribution industry, has proposed the model of a single national distributor as the optimal organisational form.

The first observable effect of rationalising the distribution industry is the shift in the spatial distribution of electrification. The modelling assumed that there were fixed electrification targets for each province, over a twenty-year time horizon. Within each province, electrification projects were selected on the basis of least cost, constrained by the institution's rights of supply. Where Eskom does not have access to many urban localities, it is forced to achieve its targets in more remote rural areas. In the case of a national distributor being established, this entity has supply rights to the entire country and so there is a tendency to concentrate on high-density areas in the first few years of the programme, and leave low-density areas to later in the programme. This effect is illustrated in Figure 8.

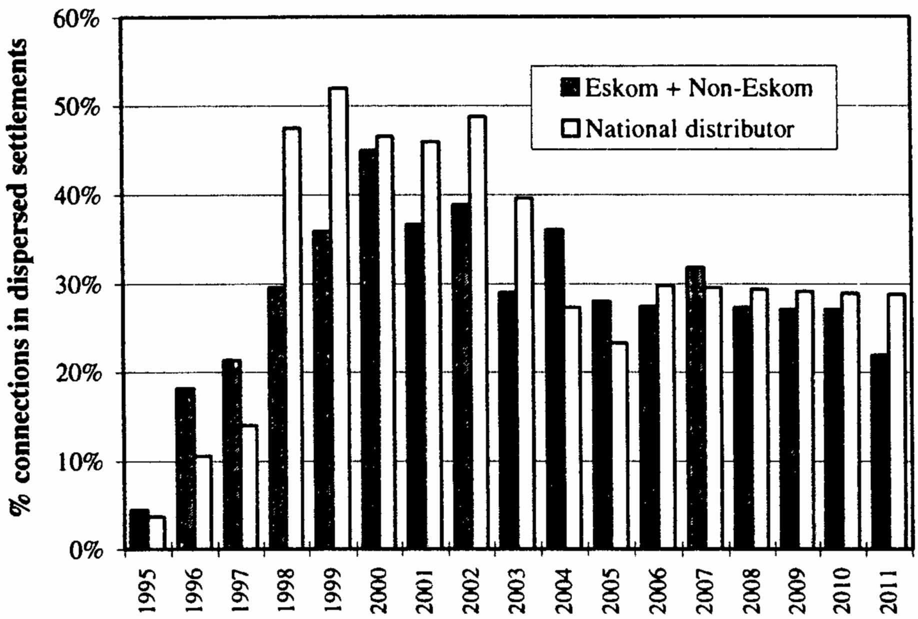


Figure 8: The effect of industry rationalisation on electrification in low density areas

6. Subsidies for rural households

Given that capital costs are high and operating costs exceed revenue, at least in the early period of the programme, it is clear that subsidies are required to prevent debt reaching excessively high levels. There are different ways in which the required subsidy can be calculated. Section 2 reported that a subsidy of R32 per household per month would be required to keep debt levels within acceptable limits. However, a subsidy based on this formula would automatically increase as the number of customers increased, even as revenues from electricity sales picked up and capital costs declined as electrification targets decreased. A more acceptable way of calculating subsidy levels is to look directly at the annual cash flow, and examine how much of this would have to be subsidised in order to keep a cap on debt levels. Using this method, the subsidy will peak during the period of maximum connection rates and decline later in the programme.

Figure 9 shows the extent of subsidies required for non-urban electrification. They peak at R1.1 billion per annum (in 1995 terms) and thereafter decline to around R800 million per year. Expressed as a figure per customer per month, the subsidy declines over a ten-year period and levels off at R20 per customer per month.

Expressed as a subsidy per unit of electricity sold (as opposed to electricity consumed), the subsidy starts off at very high levels of around R1/kWh and declines rapidly (as sales increase and subsidy requirements decline). By the year 2000 the subsidy reaches 24c/kWh and levels off towards 8c/kWh later in the programme. On average the subsidy is 17c/kWh, and this can be seen as the price increase (a 65% increase) which would be required to make the programme viable without any subsidies or cross-subsidies.

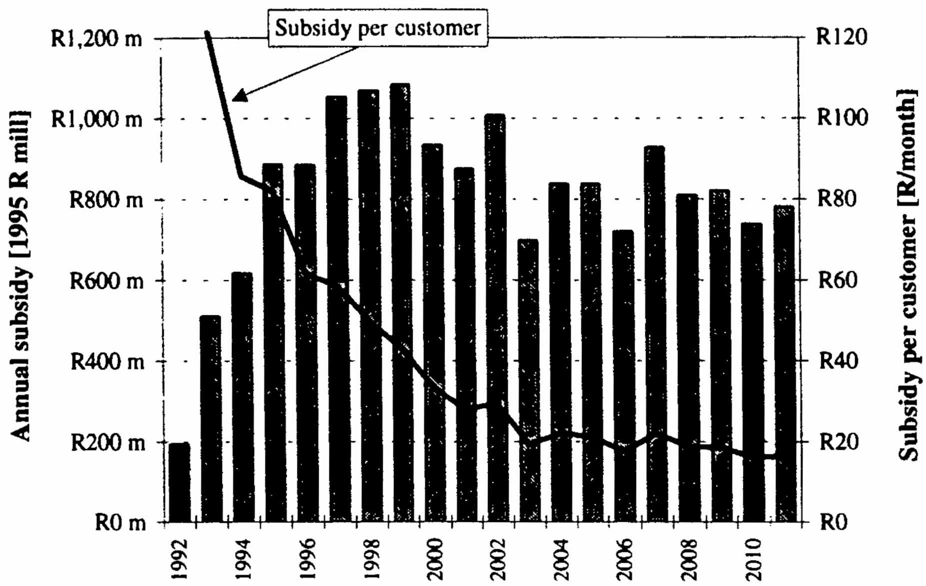


Figure 9: Subsidies required for non-urban electrification

These figures indicate the size of the subsidies required to make non-urban electrification financially viable (where viability is defined rather loosely by the requirement that debt does not exceed the depreciated value of installed electrification assets in 2011). Subsidies can be available as lump transfers from the state, or as cross-subsidies from other consumers. It is difficult to look at cross-subsidies in isolation from the subsidies required for the urban portion of the programme. If the electrification programme is viewed as a whole, a general price increase of 0.39c/kWh would be required to met all cross-subsidy requirements, assuming an annual growth rate of 7% in total electricity consumption. This is equivalent to a once-off 4% general electricity price increase. If only domestic customers are to pay for electrification, then a much larger price increase of 2.6c/kWh would be required – equivalent to a 16% increase. It should be noted that these results are sensitive to assumptions regarding the rate of electricity consumption growth in South Africa, and this sensitivity is shown in Figure 10.

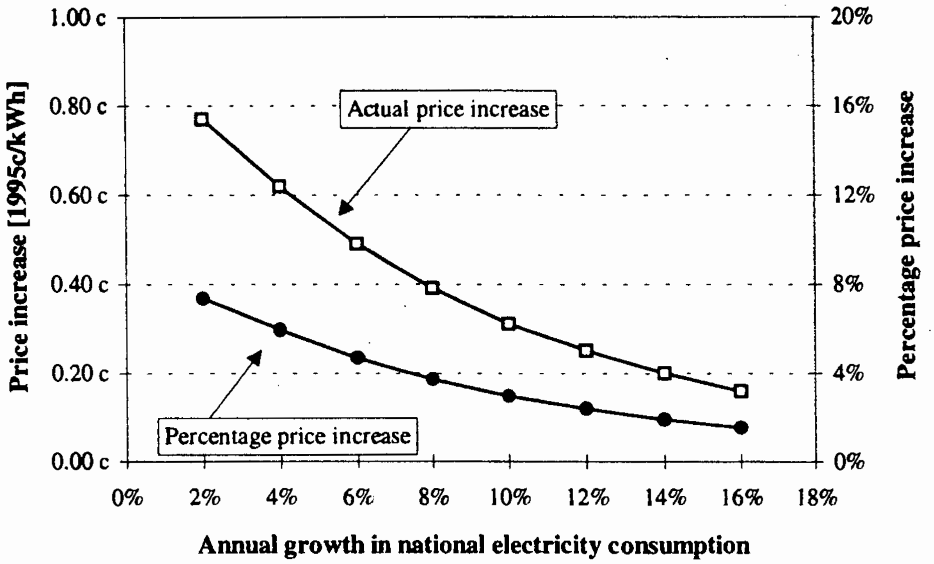


Figure 10: Sensitivity of required price increase to overall growth in electricity consumption

7. Comparisons with urban electrification

In the preceding discussion, references to the financial implications of non-urban electrification have been made without any comparison with similar figures for urban areas. It is to be expected that, expressed in unit terms, the financial impact of urban electrification will be more favourable, or at least not as dire. This section will compare some key parameters for urban and non-urban electrification.

Table 5 compares some financial parameters for electrification of urban areas (defined as all metropolitan areas and localities currently supplied by municipal distributors), with electrification of non-urban areas. As noted before, this definition of non-urban will include a number of 'effectively urbanised' locations which lie outside municipalities' areas of supply.

	Non-urban	Urban	Difference
Ave capex/connection	R 4 740	R3 850	20%
NPV/connection	R3 500	R2 280	35%
Debt/connection1	R9 500	R6 700	30%
Subsidy/connection	R32/month	R22/month	30%
Subsidy/kWh	17c/kWh	11c/kWh	27%

1 Accumulated debt in 2011, assuming no subsidies and 16% finance charges

Table 5: Comparison of urban with non-urban electrification

Capital costs, on average, are some 20% lower in urban areas, and Figure 11 shows the trends over time. The modelling shows that, at least in the early years, electrification in urban areas can be quite expensive, as distribution infrastructure is established. However, as the programme develops costs decline to around 25% of non-urban costs. In this modelling it is assumed that non-urban areas are offered capacity differentiated supplies, and urban areas continue to use normal domestic supply standards.

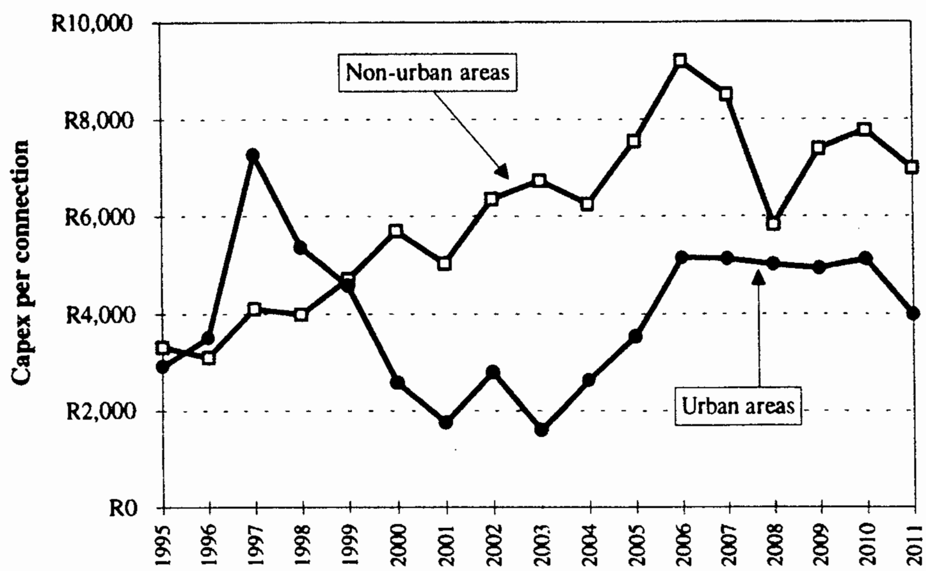


Figure 11: Capital costs per connection for urban and non-urban areas

For other financial parameters, including the NPV per connection, the accumulated debt (assuming no subsidies), and the required subsidy, there is a 25-30% difference. Much of this difference can be attributed to the difference in capital costs, and the remainder to higher sales levels in urban areas.

8. Conclusions

This report has presented a number of indicators describing the financial effects of electrification in areas outside of the main urban centres. It should be stressed that the difficulty of adequately defining 'rural' areas, and linking this definition to existing demographic data has meant that a fairly broad definition of the term 'rural' has been used. The key results are summarised below.

- If the proposed connection targets are met outside main urban areas, then access to electricity in these areas will reach 50% by the year 2000, and 67% by 2010.
- Average capital costs are R4 740 per connection, and there is a clear trend towards higher costs as the programme progresses (in the region of R6 000 – R9 000 per connection). If capacity differentiated supplies are not used, capital costs increase, on average, by 30%. The cost penalty is particularly severe towards the end of the programme as more remote locations are reached.
- The NPV of the programme is highly negative at negative R13.8 billion, which is equivalent to negative R3 500 per connection. A sensitivity analysis showed that this result is strongly sensitive to capital costs, although the NPV remains negative even if capital costs decline by 30%.
- If all financing requirements are met through debt, then the total accumulated debt in 2011 will be R38 billion, equivalent to R9 500 per connection. This debt is over three times the depreciated value of assets at this time (where assets are depreciated over 20 years).
- An average subsidy of 17c/kWh, or R32 per customer per month, would suffice to keep debt within acceptable levels. Cross-subsidies for the entire electrification programme (including urban areas) could be obtained from a 0.39c/kWh general price levy – a 4% increase.
- Financial indicators for urban areas show a 20-30% improvement over those for non-urban areas.

As is widely believed, rural electrification is not financially viable and extensive subsidies are required to cover losses. This analysis has quantified the extent of these subsidies, and has shown that it is capital costs, rather than operating losses, which drive the financial impact of the programme. This suggests that major cost-saving gains are to be made in considering innovations in supply technologies rather than in operating procedures.

Whether operating loses turn to surpluses is highly sensitive to relatively small changes in tariffs and costs. In order to ensure the sustainability of the programme, it is important that revenues cover non-finance related operating costs. However, this analysis indicates that operating losses for non-urban electrification are likely to remain negative over a 20-year time horizon, although losses will tend to decline to relatively small levels over time. It should be noted that, given the scale of uncertainties, this result is not robust, particularly where assumptions have had to be made to describe conditions ten or more years into the future.

Capital costs are high, much higher than current proposals for capital limits – R2 000 per connection in urban areas and R3 000 in rural areas (Barnard 1995). Given average costs of over R4 000 (and certain areas have costs way in excess of this), it is clear that there is potential for photovoltaic systems to play a significant role. Although these systems are only able to supply very limited loads (lights and radio/television), evidence of consumption growth in a number of newly electrified settlements suggests that many households currently use only a similar range of appliances.

Appendix: List of assumptions

A.1 Technology choice

Where capacity differentiated supplies are offered, it is assumed that there are different take-up rates in low and high density areas, as presented below.

Technology choice				
	2.5A	*20A*	*60A*	*Total*
Rural	60%	40%	0%	100%
Urban	0%	80%	20%	100%

A.2 Discount rate, time horizon

The discount rate used is 16% and an inflation rate of 10%.

The time horizon is twenty years, and assets are depreciated over this period to calculate the residual value of assets.

A.3 Capital costs and refurbishment

Capital costs are calculated from Distribution Technologies capex model. the assumptions used in the modelling are presented below. Costs are based on 1995 quotes from contractors.

Bulk sub-station transformer size	20 MVA
Bulk HV line type	88kV Panther as average
Bulk MV line type	22 kV Mink as average
MV/LV infrastructure % losses	9%
Bulk % losses	3.5%

MV infrastructure technology:

	Low density:	MV Maypole technology
	High density:	Optimised MV/LV 3-phase technology

Service connection costs (excl. meter)	1 - 100 connections:	R440/connect.
	100 - 500 connections:	R415 per connect
	500 connections:	R396 per connect
Metering costs:	Electricity Control Unit	R 350
	Circuit breaker & earth leakage	R 150

ADMD:	Rural:	1.06 kVA
	Urban:	1.94 kVA

Refurbishment is calculated as 20% of original capital (inflated to current values) at year 10.

A.4 Losses, load factor and support costs

Losses are expressed as a percentage of total energy supplied.

Technical losses						
	1992	*1993*	*1994*	*1995*	*1996*	*1997 on*
Rural	15%	15%	15%	15%	15%	15%
Urban	8%	8%	8%	8%	8%	8%

Revenue losses						
	1992-95	*1996*	*1997*	*1998*	*1999*	*2000 on*
Rural	30%	25%	20%	15%	10%	10%
Urban	40%	35%	30%	25%	20%	20%

Load factor			
	2.5A	*20A*	*60A*
Rural	25%	35%	40%
Urban	25%	40%	40%

Support costs [1995 R/cust/month] for 1995			
	2.5A	*20A*	*60A*
Rural	R25	R25	R25
Urban	R25	R25	R25

A.5 Tariffs and connection fees

Tariffs [1995 R]						
	1995	*1996*	*1997*	*1998*	*1999*	*2000 on*
Homelight[1]	25.8	24.8	23.0	22.8	22.6	22.4
2.5A	R14/mth	R14/mth	R14/mth	R14/mth	R14/mth	R14/mth
20A	25.8	24.4	24.4	24.4	24.4	24.4
60A	25.8	24.4	25.3	26.2	27.1	28.0

1 Used where capacity differentiated supplies are not introduced.

Connection fees [1995 R]						
	1995	*1996*	*1997*	*1998*	*1999*	*2000 on*
Homelight[1]	R45	R45	R45	R45	R45	R45
2.5A	R45	R9	R9	R9	R9	R9
20A	R45	R45	R90	R135	R181	R272
60A	R45	R272	R363	R545	R727	R909

1 Used where capacity differentiated supplies are not introduced.

A.6 Price changes over time

Price changes relative to inflation			
	Inflation	*Homelight tariff*	*Ave bulk costs*
1992	10%	-5%	-5%
1993	10%	-2%	-2%
1994	10%	-1%	-1%
1995	10%	-5.5%	-5.5%
1996	10%	-7%	-7%
1997	10%	-1%	-1%
1998	10%	-1%	-1%
1999	10%	-1%	-1%
2000 on	10%	0%	0%

All other prices and costs (support costs, material costs) are assumed to remain constant in real terms.

A.8 Connection rates

Two national scenarios are used: one follows the RDP or NEES medium-rate scenario, and the other is 20% less than this. These totals are broken down into Eskom and non-Eskom (assuming existing rights of supply), and the combined total is used for the case of a single national distributor. The tables below only show the RDP scenario.

Connection targets (RDP scenario) - National distributor										
	E Cape	*Mpum.*	*KwaZul*	*N-W*	*N Cape*	*North*	*F.S.*	*G'teng*	*W Cape*	*Total*
1992	12 400	19 600	70 000	21 400	5 300	14 200	14 200	28 700	14 200	200 000
1993	25 100	26 900	71 800	26 800	14 300	32 200	52 000	46 600	23 300	319 000
1994	35 900	25 100	70 000	17 900	14 300	48 500	34 100	64 700	39 500	350 000
1995	61 400	27 200	75 800	22 000	11 000	65 000	39 800	68 800	29 000	400 000
1996	87 600	33 600	85 800	35 400	10 200	39 000	35 400	91 200	31 800	450 000
1997	81 000	32 400	86 400	36 000	10 800	39 600	34 200	93 600	36 000	450 000
1998	86 600	32 600	84 800	41 600	9 200	43 400	32 600	86 600	32 600	450 000
1999	82 400	32 000	86 000	41 000	8 600	46 400	32 000	86 000	35 600	450 000
2000	62 500	24 700	71 500	31 900	6 700	42 700	24 700	57 000	28 300	350 000
2001	58 700	24 500	73 000	31 700	6 500	42 500	24 500	58 600	30 000	350 000
2002	57 100	24 700	73 200	31 900	4 900	42 700	24 700	58 900	31 900	350 000
2003	39 400	17 800	53 700	21 400	3 400	30 300	16 000	43 000	25 000	250 000
2004	39 400	17 800	53 700	21 400	3 400	30 300	16 000	43 000	25 000	250 000
2005	39 400	17 800	53 700	21 400	3 400	30 300	16 000	43 000	25 000	250 000
2006	30 300	14 000	42 700	17 900	2 600	25 000	12 500	35 700	19 300	200 000
2007	30 300	14 000	42 700	17 900	2 600	25 000	12 500	35 700	19 300	200 000
2008	23 000	14 000	42 700	14 000	3 500	21 200	14 000	42 800	24 800	200 000
2009	23 000	14 000	42 700	14 000	3 500	21 200	14 000	42 800	24 800	200 000
2010	23 000	14 000	42 700	14 000	3 500	21 200	14 000	42 800	24 800	200 000
2011	28 700	17 900	52 000	17 900	4 400	25 000	17 900	53 900	32 300	250 000

Connection targets (RDP scenario) - Non-Eskom only (urban areas)

	E Cape	Mpum.	KwaZul	N-W	N Cape	North	F.S.	G'teng	W Cape	Total
1992	5 000	1 100	21 700	2 900	1 600	3 100	6 800	1 000	6 800	50 000
1993	12 200	6 600	38 100	6 500	5 100	6 300	33 500	1 500	12 200	122 000
1994	17 400	4 800	25 200	5 000	6 900	4 100	8 200	18 500	9 900	100 000
1995	20 700	5 000	22 600	3 500	4 600	5 800	12 100	17 000	8 700	100 000
1996	33 900	18 800	2 200	9 500	8 400	3 900	16 900	35 700	20 700	150 000
1997	31 000	17 600	900	10 100	9 000	4 500	15 700	38 100	23 100	150 000
1998	25 500	14 100	16 000	8 300	5 500	900	12 300	49 600	17 800	150 000
1999	23 200	13 500	15 300	7 700	4 900	3 900	11 700	49 000	20 800	150 000
2000	18 100	8 100	21 200	6 000	3 000	3 900	6 200	20 000	13 500	100 000
2001	18 000	9 700	7 800	7 700	2 800	7 400	7 900	23 500	15 200	100 000
2002	20 100	11 800	37 500	11 600	2 200	11 300	9 900	27 500	18 100	150 000
2003	13 500	10 400	22 000	6 600	1 600	8 100	4 900	19 000	13 900	100 000
2004	13 500	10 400	22 000	6 600	1 600	8 100	4 900	19 000	13 900	100 000
2005	19 100	10 400	3 300	8 500	1 600	10 000	6 800	24 500	15 800	100 000
2006	10 000	6 600	42 300	5 000	800	4 700	3 300	17 200	10 100	100 000
2007	10 000	4 800	44 100	5 000	800	4 700	3 300	17 200	10 100	100 000
2008	6 400	4 800	40 500	2 900	1 700	900	2 900	26 200	13 700	100 000
2009	6 400	4 800	40 500	2 900	1 700	900	2 900	26 200	13 700	100 000
2010	6 400	4 800	40 500	2 900	1 700	900	2 900	26 200	13 700	100 000
2011	6 400	4 800	40 500	2 900	1 700	900	2 900	26 200	13 700	100 000

Connection targets (RDP scenario) - Eskom only (Non-urban areas)

	E Cape	Mpum.	KwaZul	N-W	N Cape	North	F.S.	G'teng	W Cape	Total
1992	7 400	18 500	48 300	18 500	3 700	11 100	7 400	27 700	7 400	150 000
1993	12 900	20 300	33 700	20 300	9 200	25 900	18 500	48 100	11 100	200 000
1994	18 500	20 300	44 800	12 900	7 400	44 400	25 900	46 200	29 600	250 000
1995	40 700	22 200	53 200	18 500	6 400	59 200	27 700	51 800	20 300	300 000
1996	53 700	14 800	83 600	25 900	1 800	35 100	18 500	55 500	11 100	300 000
1997	50 000	14 800	85 500	25 900	1 800	35 100	18 500	55 500	12 900	300 000
1998	61 100	18 500	68 800	33 300	3 700	42 500	20 300	37 000	14 800	300 000
1999	59 200	18 500	70 700	33 300	3 700	42 500	20 300	37 000	14 800	300 000
2000	44 400	16 600	50 300	25 900	3 700	38 800	18 500	37 000	14 800	250 000
2001	40 700	14 800	65 200	24 000	3 700	35 100	16 600	35 100	14 800	250 000
2002	37 000	12 900	35 700	20 300	2 700	31 400	14 800	31 400	13 800	200 000
2003	25 900	7 400	31 700	14 800	1 800	22 200	11 100	24 000	11 100	150 000
2004	25 900	7 400	31 700	14 800	1 800	22 200	11 100	24 000	11 100	150 000
2005	20 300	7 400	50 400	12 900	1 800	20 300	9 200	18 500	9 200	150 000
2006	20 300	7 400	400	12 900	1 800	20 300	9 200	18 500	9 200	100 000
2007	20 300	7 400	400	12 900	1 800	20 300	9 200	18 500	9 200	100 000
2008	16 600	9 200	2 200	11 100	1 800	20 300	11 100	16 600	11 100	100 000
2009	16 600	9 200	2 200	11 100	1 800	20 300	11 100	16 600	11 100	100 000
2010	16 600	9 200	2 200	11 100	1 800	20 300	11 100	16 600	11 100	100 000
2011	21 600	14 200	7 200	16 100	6 800	30 300	16 100	21 600	16 100	150 000

References

Barnard H 1995. Directive on residential tariffs and their application. Sandton: Eskom.

Bezuidenhout J (Eskom) 1995. Personal communication.

Davis M 1995a. Electricity consumption growth in newly electrified settlements. EDRC, University of Cape Town.

Davis M 1995. Photovoltaic energy systems and rural electrification. *Development Southern Africa* 12(5): 637-48.

Davis M 1996. The financial impacts of electrification in the electricity distribution industry. EDRC, University of Cape Town.

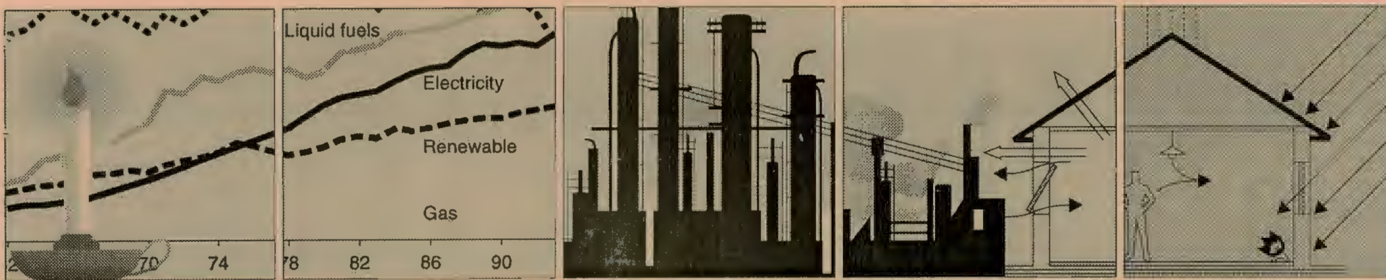
Els D 1994. The financing requirement of the national electrification programme. National Electrification Forum, Johannesburg.

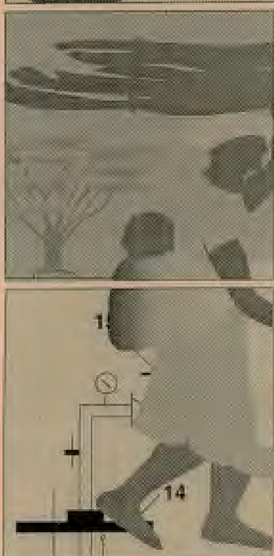
Eskom 1992. Electrification Monthly Report December 1992. Sandton: Eskom.

Eskom 1993. Electrification Monthly Report December 1993. Sandton: Eskom.

Eskom 1994. Electrification Monthly Report December 1994. Sandton: Eskom.

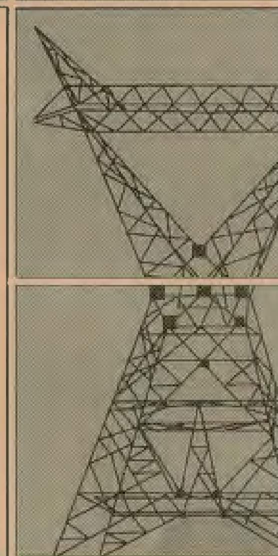
Eskom 1995. Electrification Monthly Report 1995. Sandton: Eskom.

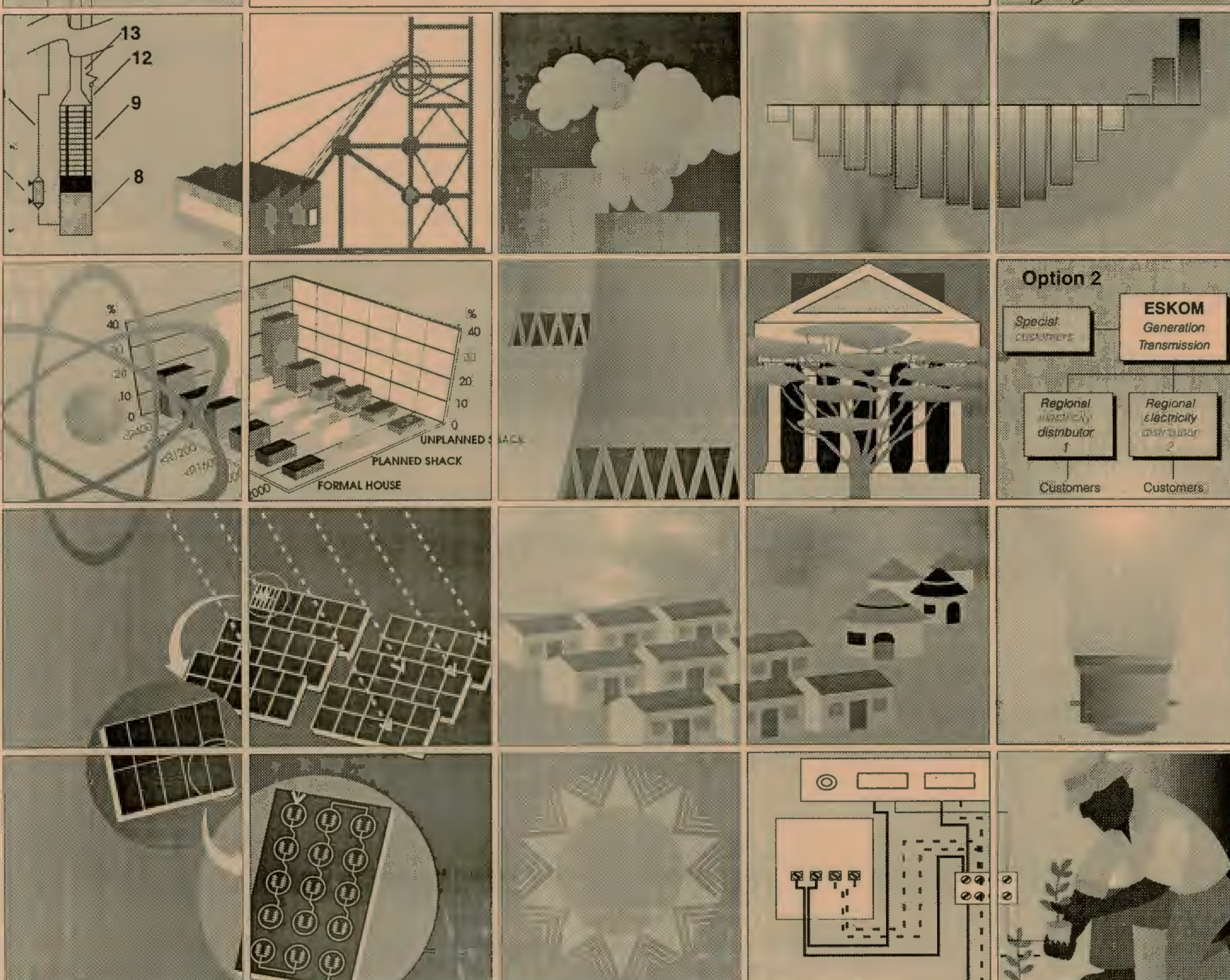




The financial impacts of rural electrification

MARK DAVIS





EDRC REPORT SERIES

ENERGY & DEVELOPMENT RESEARCH CENTRE
University of Cape Town