Energy efficiency for the urban poor: economics, environmental impacts and policy implications

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Executive summary

South Africa's Reconstruction and Development Programme set ambitious goals for providing basic services to all, including the mass housing and electrification programmes (ANC 1994). Fulfilling these goals requires careful analysis of the options for meeting these goals, including how best to provide critical energy services. International experience shows that energy efficiency is often the most cost effective means of meeting service demand. In countries where the gap between *access* to affordable energy and the *demand* for clean energy is very large, such as South Africa, energy efficiency therefore has the potential to accomplish multiple social and economic objectives. The impacts of energy efficiency on the low income residential sector are particularly important, because of the social priorities for upliftment and empowerment of the poor. This report examines the economic and environmental impacts of energy efficiency on the urban poor, and how sustainable programmes can be implemented that take into account the South African context.

This report builds on four years of research on energy use in low-income urban areas to present an overview of the case for energy efficiency and strategies for making it happen, recognising the significant barriers to implementation The policy recommendations are particularly relevant at a time when government is deciding how to implement the Energy Policy White Paper and when energy efficiency and DSM are almost entirely the province of the national utility, rather than an integral part of national energy policy. With the changing structure and ownership of Eskom, what is good for the country may not necessarily be good for the utility. Careful policy development is required to bridge the gap between the incentives (and disincentives) for the key roleplayers in this sector.

The analysis presented in this report demonstrates the substantial economic and environmental benefits from energy efficiency interventions for the urban poor. The five interventions presented include three energy efficiency programmes (compact fluorescent lamps, efficiency refrigerators, and improved thermal efficiency of low cost housing) and two fuel switching programmes (from electricity and paraffin to cooking).

From an economic perspective, four of the five interventions (all but electricity to gas for cooking) generate substantial benefits for society. In other words, the cost to society of providing affordable energy services would be lower with the interventions than without them. The CFL and efficient refrigerator programme would also substantially reduce Eskom's cost of supplying energy services even with a substantial subsidy from Eskom for the capital costs, while the thermal efficiency programme would impose a very small incremental cost on Eskom. Given the current structure of tariffs in South Africa, however, the net income impact of the efficiency programme would be negative. This is because Eskom makes a margin on each kWh of electricity sold – so any reduction in kWh sales reduces net income. With a different regulatory regime that would decouple sales from profits (eg basing utility net income on a return on capital rather than on kWh sales), these could become profitable investments for Eskom.

Because of their high discount rates and the higher up front costs of efficiency, consumers may not consider it worthwhile to invest in energy efficiency without financing for the incremental capital costs. The CFL and efficiency refrigerator programmes, however, would break even for consumers with almost no subsidy. The thermal efficiency and paraffin to gas switch programmes would require capital subsidies of 50% and 30%, respectively. Consumers who did not participate in these programmes would see marginal increases in their electricity bill due to slightly higher tariffs, but this is more than offset by the increased disposable income for participating consumers.

The environmental impacts of energy use, particularly at the household level, are a major driver for investment in energy efficiency. Far more significant than the environmental and health costs of electricity generation are the high external costs of burning coal, wood and paraffin in low-income households. The avoided respiratory illness impacts of smoke and air pollution, reduced burns, fires and poisoning cases from paraffin, and reduced water consumption are all important local environmental benefits from these programmes. The total health cost savings from the four large scale programmes (excluding paraffin to gas switching) would be more than R10 million per year over the 40-year life of the programmes.

The main source of greenhouse gas emissions in South Africa is from the combustion of fossil fuels, so energy efficiency will also reduce national carbon emissions. Four of the five interventions analysed here are either low cost or 'no regrets' options – CFLs, thermal efficiency and paraffin to gas are all 'no regrets', while the refrigerator has a small incremental cost of 24 R/ton CO_2. The total CO_2 equivalent emissions savings from the CFL, thermal efficiency and refrigerator programmes would be 570 thousand tons CO_2 per year.

Despite the benefits of energy efficiency for the nation, utility and consumers, there are substantial barriers in the way of implementing these programmes. These include both the barriers faced by DSM programmes in industrialised countries and barriers that are much more significant in a developing country context. The lack of information, for example, is accentuated by lower levels of literacy and access to mass media. Many urban poor households also do not have access to cleaner fuels or more efficient appliances, because of poor distribution networks, the large number of people living in informal settlements without infrastructure, or because they can not afford the up front costs of access. Many urban residents are not permanent, and will not invest in more expensive appliances when they are planning to return (or send their income) to a rural home. Split incentives between the builders, owners and tenants in housing is a severe problem when the mass housing programme, and contractors, are under pressure to build the largest number of homes at the least (up front) cost. Finally, households often make their choices about fuel and appliance purchase based not just on finances but on the symbolic value of the appliances – with large electric appliances being an important symbol of modernity. This is not to say that households do not understand energy efficiency, but that they have a range of other financial and social pressures that influence their decisions.

Tackling these barriers must begin with actions that create an enabling environment for investment for energy efficiency. At a policy level, the DME and NER can provide both regulatory and financial incentives to make it financially beneficial for the electricity sector to invest in efficiency. This should include performance-based tariffs or mechanisms to decouple sales profits, removing an explicit or implicit subsidies that bias against energy efficiency, as well as promoting broad awareness of the benefits of efficiency. The timely establishment of a National Energy Efficiency Agency would be an important step towards meeting these goals, as will the NER's review of electricity generation and distribution licenses. As the main link between consumers and the industry, distributors will also play a critical role in creating an enabling environment for energy efficiency investment. In addition to well-targeted information and awareness programmes tailored to key consumer groups, distributors should investigate how they can help bridge the financing gap between what is good for the nation what the consumer sees as financially beneficial. Distributor links to suppliers and other sector stakeholders also make the well placed to provide communication links within the industry about energy efficiency technologies, consumer needs, and implementation programmes. Through such a co-ordinated and multi-level strategy, government and the electricity sector can help to realise the economic and environmental benefits of energy efficiency for those who need them the most – the poor of South Africa.

1 Introduction: Why energy efficiency for the poor?

South Africa's Reconstruction and Development Programme (RDP) set ambitious goals for providing basic services to all, including the mass housing and electrification programmes. Fulfilling these goals requires careful analysis of the options for meeting them, including how best to provide critical energy services.

The international energy policy literature has numerous examples of how energy efficiency is often the least-cost way to provide energy services, while at the same time reducing the environmental impacts of energy use (eg Lovins & Lovins 1991; Reddy & Goldemberg 1990; Gadgil & Jannuzzi 1991; Kats 1992). In countries where the gap between *access* to affordable energy and the *demand* for clean energy is very large, such as South Africa, energy efficiency has the potential to accomplish multiple social and economic objectives. Earlier South African studies have shown that significant potential for energy efficiency exists across a range of sectors, although the costs were less well understood (Thome 1995). The impacts of energy efficiency on the low-income residential sector are particularly important, because of the social priorities for upliftment and empowerment of the poor. This report therefore examines the economic and environmental impacts of energy efficiency on the urban poor, and how sustainable programmes can be implemented that take into account the South African context.

The context for energy efficiency in urban townships includes both ongoing initiatives as well as the patterns of energy use and decision making within those communities. Eskom's residential demand-side management (RDSM) programme, launched in 1995, is one of the most important ongoing initiatives. The goals of the RDSM programme are to sustain the decrease in the real price of electricity in the long term, to increase electricity's competitiveness in the small customer energy market, and to contribute toward environmental conservation and awareness. This programme works along side Eskom's commitment to extend access to electricity for the low-income sector in South Africa.

At the government level, the South African energy White Paper recognises the critical importance of energy efficiency for providing affordable energy services (DME 1998). The White Paper also includes a commitment by government to use integrated resource planning (IRP) for all electricity planning. IRP is an approach to energy planning comparing different demand- and supply-side options for providing electricity services on an equivalent basis, considering the full economic, environmental and social impacts. Implementing this policy will require sustained regulatory commitment to promote demand-side management and energy efficiency through both Department of Minerals and Energy (DME) and National Electricity Regulator (NER) policies.

At the household level, implementing energy efficiency in South Africa is also quite different than in many of the industrialised countries in which these programmes and technologies were developed. Multiple fuel use patterns – even after electrification, irregular sources of income, and social and cultural influences on purchasing behaviour, all form the context in which decisions about energy efficiency are made.

This report builds on four years of research on energy use in low-income urban areas to present an overview of the case for energy efficiency and strategies for making it happen, recognising the significant barriers to implementation (see also Simmonds 1997; Clark 1997; Borchers 1997; Simmonds & Mammon 1996; Thome 1996). The policy recommendations are particularly relevant at a time when government is deciding how to implement the White Paper and when energy efficiency and DSM are almost entirely the province of the national utility, rather than an integral part of national energy policy. With the changing structure and ownership of Eskom, what is good for the country may not necessarily be good for the utility. Careful policy development is required to bridge the gap between the incentives (and disincentives) for the key role players in this sector.

The report begins by outlining five energy efficiency interventions, and the economic and environmental benefits that they create. This is followed by a discussion of the barriers to energy efficiency in South Africa, with a focus on the urban poor. Finally, we make policy recommendations for the key role players in the sector in the final section.

2 The case for energy efficiency: economic, environmental and social benefits

2.1 Measuring the economic value of energy efficiency

The objective of performing the analysis described below is to answer a set of questions concerning the economic and financial viability of a proposed energy efficiency programme. In general, the appraisal of capital investment projects is undertaken using discounted cash flow analysis, and this approach is adopted in the methodologies described below. In this sense, evaluating an investment in an energy efficiency project or a demand-side management project is no different from evaluating any other type of capital project.

The questions being posed, summarised in Table 1, are as follows:

- **Is the project in the interests of the country?**
  This question addresses the *economic viability* of the project, i.e. does the project result in net economic benefits for the country as a whole? The principal tool used here is the *total resource cost test*, which involves calculating the total costs of providing energy services with and without the project.

- **How does the project compare with other energy efficiency options?**
  Calculating the *cost of conserved energy* can also be used to compare the cost of the project with alternatives, such as other energy efficiency projects. It can also be used to compare the cost of the project with the cost of electricity supply, and answers the question, "is it cheaper to conserve or supply energy"?

- **Is the project in the utility's interests?**
  There are two ways of approaching this question:

  The first approach determines whether the energy efficiency project is a *lower cost approach* for the utility to supply the energy service in question. The tool used here is the *utility resource cost test*, which examines only the costs which the utility incurs with and without the project, and ignores any of the revenue implications.

  The second approach concerns the *financial viability* of the project, i.e. does the project result in net benefits for the implementing agent, in this case the utility? The principal tool involved here is *utility revenue test*, which involves calculating the net impact on the utility's income. As with all capital investment appraisal techniques, the projected income stream is discounted.

- **Is the project in the interests of participating consumers?**
  This question examines the attractiveness of the project to the consumer participating in the DSM programme. The simplest technique to use is the *consumer revenue test*. This is similar to the utility revenue test, except that we take the perspective of the consumer in estimating costs and revenues.

- **Is the project in the interests of non-participating consumers?**
  This test builds on the earlier test in that it examines the impact on consumers who do not participate in the programme. The appropriate measure is the *ratepayer impact test*, which analyses the impact on electricity tariffs as a consequence of the programme. Where tariffs increase as a result of the programme, non-participants will see increased electricity bills, even if programme participants have their overall energy expenses reduced.

Details on implementing each of these methods, based on the California Energy Commission Standard Practice Manual (CEC 1987) are described in Appendix A.

Table 1: The set of questions and tests

Key Question	*Principal method/test*
Is the project in the interests of the country?	Total resource cost test
How does the project compare with other energy efficiency measures and the cost of supply?	Cost of conserved energy
Does the project benefit the implementing utility?	Utility resource cost test, or Utility revenue test
Does the project benefit the participating consumer?	Consumer revenue test
Does the project benefit the non-participating consumer?	Ratepayer impact test

2.2 Five energy efficiency interventions for the low-income sector

The analysis has investigated five energy efficiency interventions for low-income households. These are:

- the dissemination of compact fluorescent lamps (CFLs) to displace incandescent bulbs in low-income urban households;
- the installation of ceilings in low-cost dwellings and other no-cost thermal improvements (eg proper orientation on the site);
- the installation of more efficient refrigerators;
- the switch from electricity to LPG for cooking; and
- the switch from paraffin to gas for cooking.

It should be noted that while the first three are energy efficiency interventions, the last two are fuel switching strategies. While fuel switching away from electricity certainly saves electricity, it may not necessarily save energy. The two fuel switches presented here, however, do both save *primary energy* because of the high losses in electricity generation. Each of these interventions is described in more detail below.

2.2.1 Energy efficient lighting

CFL lamps use significantly less power than conventional incandescent bulbs. Many low-income households' use of electricity is less than 100 kWh/month, which implies that a large percentage of electricity use is for lighting. This is generally the case where households do not have hot water geysers, and do not cook extensively with electricity. As a result, energy efficient bulbs can have a significant impact on electricity bills.

From the utility's perspective, lighting demand has a high degree of co-incidence with peak demand, especially in the winter when the peak occurs in the evening and when daylight fades earlier. Consequently, energy efficient bulbs can have a significant impact on peak demand.

The programme analysed here involves displacing 75W incandescent bulbs with 19W CFLs.[1] It is anticipated that the programme will install 2.5 million CFLs in low-income households over a 20-year period. The peak installation rate is 150 000 bulbs per annum. It should be emphasised that this is a sub-set of a larger Eskom programme targeting all households which aims to install around 16 million CFLs over the same period (Eskom 1999).

1 This is actually a weighted average of the replacement of 60W and 100W bulbs..

2.2.2 Thermally efficient housing – installing ceilings in low-income households

The installation of a ceiling is one of the most cost-effective measures to improve the thermal performance of a dwelling. While this will improve comfort levels in both the summer and the winter, the impact on energy use will only occur in the winter as most low-income households do not make use of air conditioning or fans. Other low- or no-cost measures such as north-facing orientation of the house also improve thermal efficiency of the building, thereby reducing energy consumption.

Many households do not rely on electricity for space heating, but rather use coal (either in coal stoves or braziers), wood or paraffin. Consequently, while households may reap substantial benefits from reduced heating costs, the utility will only experience a small reduction in electricity demand. Nevertheless, heating loads peak in the evenings during winter – a time of peak electricity demand for the utility.

The programme analysed here is to install two million ceilings in low-income households over a 20-year period. This equates to an installation rate of 100 000 ceilings per annum.

2.2.3 Energy efficient appliances: refrigerators

The acquisition of a refrigerator by a low-income newly electrified household is a significant purchase. It is an expensive appliance requiring a large capital outlay, so the purchaser will be especially sensitive to capital cost as opposed to ongoing operating costs. A refrigerator usually introduces a new energy service into the household with significant benefits, including the health and financial benefits of being able to store perishable foodstuffs. In some cases refrigerators also contribute to household income – if the household runs a small retail enterprise (selling chilled drinks) or in cases where the household rents space in the refrigerator to neighbours.

In addition, modelling the impacts of more efficient refrigerators is an interesting case study in appliance efficiency since there have been significant advances in refrigeration technology. The same methodology can be applied easily for any other capital intensive appliance with a long life-time. The analysis also looks at two cases – where the refrigerator is a first-time purchase and where it is a displacement of an existing inefficient refrigerator.

The programme analysed here involves the installation of two million energy efficient refrigerators over 20 years – 100 000 per annum.

2.2.4 Switching from electricity to gas for cooking

While the *end use efficiency* of LPG stoves may be less than electric hot plates, when we consider the losses in electricity generation, the LPG fuel cycle is generally more energy efficient. When switching from electricity to LPG for cooking, there will be changes in costs and revenues, particularly for the utility. From an economic perspective the question is whether cooking with LPG incurs more or less resource costs than cooking with electricity. The perspectives of the utility and consumer are driven by the net impacts on their revenue.

As with refrigerators, there are two cases to examine here – where households currently cook on electricity and must purchase a new gas appliance, and where households face a choice between gas and electricity for cooking. In the former case, the full cost of the gas cooker must be accounted for, whereas in the latter case the consumer avoids the purchase of an electric hot plate by choosing gas.

The programme analysed here involves the dissemination of one million LPG cookers over ten years – 100 000 per annum.

2.2.5 Switching from paraffin to gas for cooking

While switching from paraffin to gas will have no implications for the power utility, the same questions concerning the economic impact and effects on the consumer apply. As such, it presents an appropriate example of a non-electricity energy efficiency intervention.

This analysis does not investigate a specific sized programme, but examines the questions based on a single household switching fuels. As before, two cases are of relevance: where the household must discard an existing paraffin stove, and where the choice is between purchasing either a new paraffin or a new gas stove.

2.2.6 Assumptions used in the analysis

Appendix C presents details on all the assumptions used in the analysis.

2.3 Energy efficiency can generate substantial economic benefits for the nation

The test used to determine the economic viability is the total resource cost test. The result calculated is the net benefit of the project, calculated as the present value of costs without the project (i.e. the avoided costs), less the present value of costs with the project. If the result is positive, then the project generates net benefits for the economy. It is possible to calculate the net benefit for a single installation (e.g. one CFL bulb), as well as the net benefit for the entire programme. The latter is naturally sensitive to the scale of the programme. The key results are presented in Table 2.

Table 2: Economic benefits (costs) for each programme

	Programme	*For single installation [R]*	*For entire programme*	
			Rm	*Rm/year*
Energy efficiency	CFLs	R106	R108	R9.1
	Ceilings	R541	R620	R63.1
	Refrigerators*	R71	R70	R17.1
Fuel switching for cooking	Elec to LPG*	(R1 710)	(R1 650)	(R168)
	Para to LPG*	R3040	N/a	N/a

* The results assume that the appliance is a new purchase, i.e. only the additional cost of the efficient appliance is incurred.

These results show the following:

- ***CFL programme***
  The installation of CFLs in homes generates substantial economic benefits. The programme as examined here would generate a total benefit of R97 million, equivalent to R8 million per annum in net benefits. Expressed as a rate of return, this is a 68% real return – well in excess of the social discount rate. The benefit-to-cost ratio is 44, also indicating a healthy economic return.

- ***Refrigerators***
  The installation of energy efficient refrigerators also indicates a positive net economic benefit. Since the net benefit per refrigerator is relatively small compared to the price of a refrigerator, this indicates that an energy efficiency refrigeration programme is only economically attractive if the difference in cost compared with a standard refrigerator is not substantially greater than R400. This result holds for cases where the customer is considering purchasing a *new* refrigerator, and so the economic cost of the efficient refrigerator is only the additional cost above that of a normal fridge. Where the new efficient refrigerators are expected to displace existing units, the results may be quite different, as discussed below.

- ***Ceilings***
  The installation of ceilings in houses generates substantial economic benefits based on the savings in energy expenditure and consumption. It should be noted that most of the energy saved in low-income households is in non-electrical fuels.

- ***Fuel switching for cooking***

The switch from electricity to gas is not economically beneficial, whereas the switch from paraffin to gas is-the later because of the relatively high external costs of paraffin use. The result for electricity to gas is surprising given the recent emphasis from Eskom and other energy sector actors to move towards "Energisation" packages for low-income households that include electric connections for lighting and entertainment coupled with a gas canister for cooking. Two points are important to note, however. First, Energisation is mainly promoted in *rural* areas where grid electricity would be considerably more expensive and there is no infrastructure already in place for distribution. Second, given the lack of data on the "economic" cost of producing LPG, prices have been used in the total resource cost calculations instead. Because of the high margins on LPG and limited distribution, current prices may significantly overstate the long run marginal cost of LPG. On the other hand, investing in a parallel distribution network to electricity could be expensive, and is also not adequately captured by these calculations. Third, the peak coincidence for cooking in newly electrified urban areas, based on Eskom's load profile data, is not as high as assumed in earlier analysis (see, for example Spalding-Fecher 1998, which has substantially different assumptions).

For the installation of a refrigerator and a new stove, two options are possible:

- where the new appliance displaces an existing one;
- where the new appliance had to be purchased anyway (as reported in Table 2).

In the first case, the initial cost should be taken as the full cost of that appliance. In the second case, the initial cost should be taken as the additional expenditure which the efficient appliance requires, i.e. the net cost of the appliance. This difference can have a significant effect where appliance costs are relatively large.

Table 3: Comparing new appliance purchase with the displacement of an existing one

		For single installation [R]	*For entire programme*	
			Rm	*Rm/year*
Refrigerator	New	R71	R70	R7.1
	Displacement	(R2 530)	(R2 480)	(R253)
Electricity to gas stove	New	(R1 711)	(R1 650)	(R168)
	Displacement	(R1 810)	(R1 720)	(R168)
Paraffin to gas stove	New	R3 040	N/a	N/a
	Displacement	R2 990	N/a	N/a

These results show that:

- a refrigeration programme is not economically attractive if the programme displaces existing refrigerators. This contrasts with the result for a programme that targets new fridge purchasers;
- the results of the fuel switching programmes are not influenced significantly, because the costs of the appliances are small compared to the operating costs.

2.3.1 The comparative costs of the programmes

The cost of conserved energy is a useful measure for comparing the cost of the energy efficiency interventions with the cost of energy supply. The results can be represented graphically as shown below.

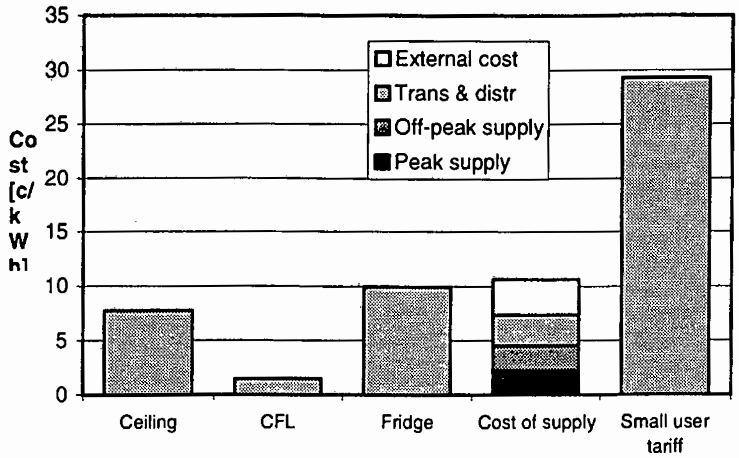

Figure 1: Cost of conserved energy

The results show that:

- the lighting programme CCE is much lower than the cost of supply, and the ceiling programme is also lower;
- the efficient refrigerator programme has a cost of conserved energy that is much closer to the cost of supply.

2.4 Energy efficiency is less expensive than new supply for Eskom, but has significant revenue impacts

There are two measures used to examine the impact on the utility:

- The utility resource cost test: i.e. does the programme reduce the utility's costs?
- The utility revenue test: i.e. does the programme increase the utility's net income?

The results are naturally sensitive to the amount of subsidy towards the cost of the installation that the utility provides. A sensitivity analysis is conducted on this variable, but the basic results are calculated for no subsidy for individual installations, and where the G&T[2] utility pays for the initial and annual overhead costs of each programme. In general these are small in comparison with the cost of the appliances. The results are also affected by whether the "take-back effect" is included or excluded. Both sets of results are reported below.

2.4.1 The utility resource cost test

The approach taken assumes that the G&T utility is responsible for the overhead costs of the programmes. Table 4 shows the impacts on utility resources for the case of a single installation and the entire programme respectively.

Two cases are examined here: for a G&T utility only, and a G,T&D utility.

Note that the utility resource cost test is not appropriate for fuel switching programmes. The concept of the utility resource cost test is to determine whether the utility incurs lower costs while providing the same service. For fuel switching, the utility no longer provides the service and so the test is inappropriate.

2 G&T = Generation and transmission; G, T & D = Generation, transmission and distribution.

Table 4: Utility resource cost test
The change in utility costs (excluding the "take-back" effect), where no utility subsidy is provided
A negative result indicates that utility costs have decreased

Programme	*For one installation [R]**		*For entire programme [Rm/yr]***	
	G&T	*G,T&D*	*G&T*	*G,T&D*
CFL	(R73)	(R95)	(R7.5)	(R9)
Ceiling	R3	R2	R0.2	R0.2
Refrigerator	(R280)	(R377)	(R27)	(R34)
Elec to LPG	N/a	N/a	N/a	N/a
Para to LPG	N/a	N/a	N/a	N/a

* Result is the present value of cost changes for a single installation

** Result is annualised amount of the present value of cost changes generated by the programme

It can be seen from Table 4 that the three programmes tested all result in lower or equal costs for the utility (the ceiling programme only has a marginal impact on costs). That is, the utility incurs lower costs while providing the same service to customers.

This positive result is partly a consequence of the fact that the utility does not provide subsidies for the actual equipment installed (although programme overheads are carried by the utility). It is interesting to test the level of subsidy that the utility would be able to provide, and still not incur increased costs. This result is reported as the "break even" subsidy in Table 5.

Table 5: Utility costs [Rm/yr]: sensitivity to G&T utility subsidy
Results are for a G&T utility implementing the programme and exclude the "take-back" effect
A negative result indicates that utility costs have decreased

Subsidy	*CFL*	*Ceiling*	*Refrigerator*	*Elec to LPG*	*Para to LPG*
0%	(R7.5)	R0.2	(R27)	N/a	N/a
25%	(R7.0)	R7	(R20)	N/a	N/a
50%	(R6.4)	R14	(R12)	N/a	N/a
75%	(R5.8)	R22	(R4)	N/a	N/a
100%	(R5.3)	R29	R3	N/a	N/a
Breakeven subsidy	100%	N/A	90%*	N/a	N/a

* This subsidy is a percentage of the additional cost of an efficient refrigerator compared with a standard refrigerator

These results show that:

- the utility can afford to subsidise a large portion, if not all, of the installation costs of CFLs and still reduce its costs overall;
- the utility can afford to subsidise a large portion of the additional cost of an efficient refrigerator;
- the utility cannot afford to subsidise the cost of energy efficient housing, because most of the savings come from non-electric fuels.

2.4.2 The utility revenue impact

This approach takes both the revenue and cost changes into account and calculates the net effect on the utility's bottom line. In many cases, the financial impact of efficiency and fuel switching projects will be negative, simply because of lost revenue. *Where tariffs are greater than the cost of supply, energy efficiency will always result in a net income loss.* Exception to this only occurs when avoided costs become very large for reasons such as extremely "peaky" demand, or avoided capital investment in distribution and transmission.

Table 6 presents the results for the entire programme. In all cases, the programmes result in negative income impacts for the utilities involved. The impacts are noticeably greater for distribution utilities since these agencies retail electricity sales and their avoidable costs resulting from energy conservation are small.

While the situation improves slightly after consideration of the take-back effect, the result remains negative.

Table 6: Utility income impact [Rm/year for entire programme]
No utility subsidies are assumed except for programme overhead costs

Programme	*Excluding "take-back" effect*		*Including "take-back" effect*	
	G&T	*Distribution*	*G&T*	*Distribution*
CFL	(R2)	(R22)	(R1.6)	(R17)
Ceiling	(R0.5)	(R0.6)	(R0.4)	(R0.4)
Refrigerator	(R16)	(R98)	(R12)	(R74)
Elec to LPG*	(R25)	(R205)	(R24)	(R203)
Para to LPG	N/a	N/a	N/a	N/a

* The take-back effect for fuel switching programmes is considered to be small and makes little difference to the results.

The sensitivity to the level of subsidy that the G&T utility provides is presented below. Results are presented for the programme as a whole, for the G&T utility only, and excluding the take-back effect. In all cases, the income impacts worsen if subsidies are provided.

Table 7: Utility revenue impact: sensitivity to G&T utility subsidy
Results are for the programme [Rm/yr] excluding the "take-back" effect
Negative result indicates that utility loses money

Subsidy	*CFL*	*Ceiling*	*Refrigerator*	*Elec to LPG*	*Para to LPG*
0%	(R2.0)	(R0.7)	(R16)	(R25)	N/a
25%	(R2.6)	(R8)	(R23)	(R25)	N/a
50%	(R3.2)	(R15)	(R31)	(R26)	N/a
75%	(R3.7)	(R22)	(R 38)	(R27)	N/a
100%	(R4.3)	(R29)	(R46)	(R27)	N/a

2.5 Participating consumers generally benefit, but tariffs could rise marginally

There are two categories of consumers of interest here: participants and non-participants.

2.5.1 Participating consumers

The revenue impact on participating consumers is naturally sensitive to the degree of subsidy provided, as well as whether take-back effects are considered or not. Table 8 presents the base-case results, which assume that no subsidy is provided to the installations and consumers are expected to pay the full cost of the programme. Only the CFL programme is viable for consumers without any subsidy because of the high up front cost of other programmes and high consumer discount rates (see Appendix C). Naturally, after consideration of the "take-back" effect, the income effect on consumers is reduced slightly.

Table 8: Consumer revenue impact
Positive results indicate that consumers benefit

Programme	*Excluding "take-back" effect*		*Including "take-back" effect*	
	Single installation [R/installation]	*Entire programme [Rm/yr]*	*Single installation [R/installation]*	*Entire programme [Rm/yr]*
CFL	R42	R0.4	R25	R0.3
Ceiling	(R330)	(R-24)	(R330)	(R28)
Refrigerator	(R25)	(R0)	(R107)	(R1)
Elec to LPG	(R222)	(R31)	(R232)	(R32)
Para to LPG	(R11	N/a	N/a	N/a

These results are naturally sensitive to the degree of subsidy provided. Table 9 presents the sensitivity analysis results. Naturally, the lighting programme needs no subsidy to make it attractive to the consumer. The thermal efficiency programme, paraffin to LPG for cooking and would require 50% and 30%, respectively. For the refrigerator programme, only an extremely small subsidy is required.

Table 9: Consumer revenue impact: sensitivity to subsidy
Results are for the programme [Rm/yr] excluding the "take-back" effect

Subsidy	*CFL*	*Ceiling*	*Refrigerator*	*Elec to LPG*	*Para to LPG**
0%	R0.4	(R24)	(R0)	(R31)	(R11)
25%	R0.43	(R12)	R0.9	(R30)	(R1)
50%	R0.47	R0	R1.9	(R29)	R9
75%	R0.51	R12	R2.8	(R28)	R19
100%	R0.56	R24	R3.8	(R27)	R29
Breakeven	0%	50%	1%	>100%	30%

- Rands per stove, not for the programme level

Another way to express the impact on consumers is the change in disposal income per household, as shown in Table 10. Particularly if some of the initial costs of these interventions are covered by a subsidy from the utility, government, or international funders, increased disposal incomes will raise consumers' standard of living and buying power. This can in turn contribute to economic growth and employment creation (see Section 2.7). Although changes in disposable income per participating household may be relatively small, the aggregate impact of the programmes could be substantial. The gains to participating consumers would be marginally offset by high tariffs for non-participants (see next section).

Table 10. Impact of programmes on participant disposable incomes

Increase in annual disposable income	*CFL*	*Ceiling*	*Refrigerator*	*Elec to LPG*	*Para to LPG*
Per household	R14	R59	R66	N/a	N/a
For total programme (Rm, 20 yr average)	15	59	66	N/a	N/a

2.5.2 Non-participating consumers

Non-participating consumers are sensitive to the potential impact on utility rates that the programmes may have. In all cases examined here, the programmes result in tariff increases. Thus, while participants' bills are expected to be reduced, non-participants will face increases in monthly energy bills. Nonetheless, these increases are generally small.

Table 11: Tariff [c/kWh] and energy bill changes [R/month]
Results are for the programme including the "take-back" effect, and no utility subsidy

	CFL	*Ceiling*	*Refrigerator*	*Elec to LPG*	*Para to LPG*
Tariff change	0.04	0.0	0.16	0.38	N/a
Participant bill change	(R1.13)	(R5)	(R5.50)	R10	N/a
Non-participant bill change	R0.24	R0.01	R1.12	R2.6	N/a

2.6 Energy efficiency reduces the environmental impacts of energy

2.6.1 Local environmental impacts

A range of environmental and social impacts occur in the extraction, production, transmission and use of the different fuels consumed in low-income households. These impacts include the following:

- *Paraffin* – health impacts such as pulmonary pneumonia and carbon monoxide poisoning (with symptoms of headaches, dizziness and even death) associated with paraffin ingestion and combustion; burns and deaths from accidental fires; and displacement and loss of property resulting from fuel-related fires.
- *Domestic use of wood and coal* – health impacts such as respiratory ailments and deaths, resulting from indoor air pollution from domestic use of wood and coal; and injuries and deaths in the coal-mining sector.
- *Coal-powered electricity generation* – health impacts such as respiratory ailments, resulting from air pollution; acidic deposition and visibility impacts resulting from air pollution; impacts on water quantity and quality from generation and coal-mining; air pollution, such as dust and methane, from coal-mining; and injuries and deaths in the coal-mining sector.
- *Electricity transmission* – potential social and environmental impacts, such as loss of productive land and loss of fauna and flora, resulting from the clearing of servitudes and the construction and maintenance of transmission lines.

While a wide range of environmental and social impacts of energy use exists, the availability of information on the different impacts varies significantly and, therefore, the ability to assess the extent and cost of the impacts to society differs. For example, there is substantial quantifiable information available on the electricity sector, while there has been no significant research on the impacts of LPG production and use and little information is available on the environmental impacts of the extraction and production of paraffin. Thus, any analysis evaluating the environmental impacts of current energy use or the potential of an energy efficiency intervention to reduce environmental impacts must be treated with caution. This is particularly relevant when evaluating the total environmental benefit of a programme involving fuel switches, as in the case of the switch from electricity-to-gas for cooking detailed below. In this example, at best we can show the environmental benefits of a reduction in electricity use. The analysis cannot demonstrate the total benefit of the programme as there is insufficient information to evaluate the environmental impacts of gas, other than greenhouse gas emissions (see next section).

Taking these limitations into consideration, Van Horen (1996a; 1996b) provides the most comprehensive work on the impacts of energy use in South Africa to date. He categorises the impacts in terms of their seriousness and of information availability. Class one impacts are those which are potentially serious and for which sufficient information exists to permit an estimate of the extent of their impact and their economic value. Class two impacts are those which are potentially serious, but for which there is insufficient information to permit an estimate of the extent of their impact and their economic value. Class three impacts are those which are unlikely to be significant relative to other impacts. The following externalities and health effects are identified as class one impacts by Van Horen:

- respiratory ailments and deaths resulting from air pollution from coal combustion;
- respiratory ailments and deaths resulting from accidental paraffin ingestion by infants;
- burns and deaths resulting from accidental fires; and
- in the case of coal fired electricity production, injuries and mortalities in coal mining, respiratory ailments and deaths resulting from air pollution from power generation, and water pricing below opportunity cost.

Van Horen (1996a, 1996b) analyses the above-mentioned impacts providing, for each impact, a range of estimates of both the physical health and environmental outcomes and the external costs of these occurrences. Based on Van Horen's central estimates, Table 12 below presents the central estimates of external costs of energy use in Rands per gigajoule, excluding greenhouse gas impacts.

Table 12: Central estimates for environmental costs of energy (R/GJ) in 1998 Rands

Energy source	*Externality cost (R/GJ)*
Electricity generation	
Health impacts	2.2
Water consumption	0.5
Coal	4.7
Wood	25.7
Paraffin	53.6

This section applies the work undertaken by Van Horen (1996a, 1996b) on local external costs to the four energy efficiency programme interventions outlined in Section 2.2 above to produce a summary of the environmental benefits associated with the potential reduction in energy use resulting from each intervention. The intervention of a switch from paraffin to gas for cooking is not included in the environmental summary, owing to the fact that there is insufficient data to estimate the size of such a programme and, therefore, the economic model was limited to calculations for a single household only. It was, therefore, not possible to compare the paraffin-to-gas intervention with the other interventions on a programme basis. Table 13 presents the average per annum reductions in environmental impacts for the proposed CFL, refrigeration and gas cooker programmes and Table 14 presents the findings on the annual environmental benefits of the proposed thermally efficient housing programme.

Table 13: Average annual reduction in environmental impacts associated with the CFL, refrigeration and gas cooker programmes

	CFL	*Refrigeration*	*Electricity to gas for cooking*
Average electricity savings per annum	117 GWh	481 GWh	849 GWh
Reduced health impacts of air pollution			
Asthma attacks (occurrence-day)	1 101	4 527	7 980
Acute bronchitis (no of people)	5	22	39
Chronic bronchitis (no of people)	1	3	6
Outpatient/GP visit (visits)	5	19	34
Deaths (no of people)	0.1	1	1
Hospitalisation (admission)	1	2	4
Respiratory symptom day (occurrence-day)	4 292	17 651	31 117
Restricted activity (occurrence day)	788	3 240	5 712
Reduced mining fatalities and injuries			
Injuries	0.1	0.4	0.7
Deaths	0.02	0.1	0.1
Water savings (Megalitres)	167	688	1 214

The shift toward more efficient electrical appliances in the CFL and refrigeration programmes results in electricity savings of 4 700 GWh and 19 300 GWh respectively *over a 40-year period*. While these savings in electricity represent lost revenue to the utility, they have direct environmental benefits in the reduction of air pollution and its associated health impacts; the reduction of coal consumption with its associated mining injuries and deaths; and the reduction of water consumption, a commodity which is scarce in South Africa. Based on 1994 average health impacts of electricity, the installation of two million efficient refrigerators would avoid 1 respiratory-related and 0.1 mining-related deaths, 0.4 mining related injuries, and 2 respiratory-related hospital admissions annually for 40 years. Similarly, the installation of approximately 2.5 million CFLs could avoid further respiratory-related hospital admissions. As mentioned above, with respect to the switch from electricity to gas for cooking, only a partial picture of the programme is shown. However, the environmental impacts of the additional gas used are unlikely to outweigh the environmental health benefits resulting from the reduction in electricity use.

Applying the external costs estimates from Table 12 to the electricity savings of the three programmes indicates a potential saving in health costs of approximately R0.2, R0.9 and R2.9 million per annum for the CFL, refrigeration and gas cooker programmes respectively.

Table 14 presents the environmental benefits of the thermal efficiency programme. Over a 40 year period, the two million ceilings installed in low-cost houses will reap substantial environmental benefits. With only 30% (600 000) of the 2 million houses targeted by the programme using paraffin for space-heating, 12 deaths, 129 burns admissions and 129 poisoning admissions could be avoided annually in paraffin-using households alone over the 40 year life of the ceilings. Applying the external cost estimates for all fuels from Table 12 to the programme energy savings reveals a potential saving in health costs of approximately R6.7 million per annum. The health cost savings are summarised in Table 15.

Table 14: Average annual reduction of environmental impacts associated with thermally efficient housing

	Paraffin	*Coal*	*Wood*	*Electricity*
Average energy savings per annum	11 million litres	67 710 tonnes	42 090 tonnes	5.5 GWh
Reduced poisonings				
Hospitalisation (no of cases)	175			
Outpatients (no of cases)	162			
Deaths	4			
Reduced fires and burns				
Hospitalisation	129			
Deaths	8			
Reduced health impacts of air pollution				
Asthma attacks (occurrence-day)		804	1 439	52
Acute bronchitis (no of people)		17 561	31 449	0.3
Chronic bronchitis (no of people)		1 373	2 459	0
Outpatient/GP visit (visits)		22	39	0.2
Deaths (no of people)		0.3	0.6	0
Hospitalisation (admission)		1	2	0
Respiratory symptom day (occurrence-day)		15 403	27 584	201
Restricted activity (occurrence day)		3 602	6 450	37
Reduced water consumption (Ml)				3.8

Table 15: Health cost savings for energy efficiency programmes

	Programme	*Programme savings (R million/year)*
Energy efficiency	CFLs	0.2
	Ceilings	6.7
	Refrigerators*	0.9
Fuel switching for cooking	Elec to LPG*	2.9
	Para to LPG*	N/a

2.6.2 Global impacts – greenhouse gas emissions reductions

South Africa ratified the UN Framework Convention on Climate Change (UNFCCC) in August 1997. While South Africa does not currently face any limits on emissions under the Convention and the accompanying Kyoto Protocol, emissions intensity (i.e. the amount of emissions per unit of economic output) in South Africa is among the highest in the world. Given that virtually all of the South Africa's greenhouse gas emissions are related to fossil fuel combustion in the energy sector, the more efficient use of energy will of necessity be a priority in the future. Moreover, as international funding for climate change mitigation projects develops, it is important to identify project concepts that meet South African social and economic goals, as well as benefiting the global environment.

Projects that have economic benefits even without considering their impact on GHG emissions are called "no regrets" projects. These are interventions that would save money for the country even if climate change were not an issue. The South African Energy Policy White Paper states that government "will follow a 'no regrets' approach in the energy sector", so identifying such options are their potential is a priority (DME 1998).

Table 16 illustrates the greenhouse gas impacts of the energy efficiency and fuel switching programme analysed. As expected, CFLs, efficient refrigerators and ceilings are low cost or 'no regrets' options.[3] Switching from electricity to gas for cooking appears to be quite expensive for the same reasons outlined in Section 2.3 – lower costs for electricity in urban vs remote rural areas, uncertainty about the true economic cost of LPG, and low apparent peak coincidence of cooking. Switching from paraffin to LPG, on the other hand, produces substantial 'no regrets' emissions reductions – both because of the lower emissions factor for LPG and the higher efficiency of a gas stove. The high negative cost for paraffin to LPG reflects the large avoided external costs of paraffin through avoiding possible fires, burns and poisoning caused by paraffin. Note that emissions reductions for the last switch are shown per household because no programme was modelled. The importance of avoided external costs of non-electric fuels is demonstrated by the results shown in the last two columns. Paraffin to LPG for cooking, for example, has a small positive cost rather than a large negative cost when avoided externalities are ignored.

Table 16: Greenhouse gas emissions impacts for each programme

		Cost of avoided emissions (including externalities)		*Cost of avoided emissions (excluding externalities)*	
Programme	*Emissions reductions (000 tons CO_2)***	*(R/ton CO_2)*	*(US\$/tonCO_2)****	*(R/ton CO_2)*	*(US\$/tonCO_2)****
CFLs	74	-96	-15	-86	-14
Ceilings	153	-294	-47	-80	-13
Refrigerators*	343	25	4	36	6
Elec to LPG*	655	2840	458	2950	476
Para to LPG*	315	-4402	-710	54	9

* The results assume that the appliance is a new purchase, i.e. only the additional cost of the efficient appliance is incurred.

** Average annual emissions reductions for the programme, except for paraffin to LPG is kg per household

*** At R6.2/US$

2.7 Energy efficiency and employment

One of the top priorities of South Africa's Growth, Employment and Redistribution (GEAR) strategy is job creation (DoF 1996). While this study was not able to evaluate the direct impact on employment from energy efficiency, two major studies in the North America suggest that DSM programmes create significantly more jobs than building new energy supply (Biewald et al 1995, Alliance to Save Energy et al 1997). A survey of a number of research studies in Biewald et al, for example, showed that DSM programmes create 1.5 to 4 times as many jobs as building a new power plant. Most of the additional employment comes not from direct employment implementing DSM programmes, but from consumers "respending" their energy bill savings: spending this additional disposable income stimulates the economy and therefore creates jobs. A South African research programme to evaluate the macroeconomic benefits of energy efficiency could provide valuable support to more aggressive energy efficiency policy to meet government objectives for job creation.

3 Why hasn't it happened already? Barriers to energy efficiency for the poor

Recent research in South Africa (eg Mehlwana 1999; James 1997) has demonstrated the significance of attitudes and perceptions in the prioritisation of appliance purchases and fuel use

3 The reason that the refrigerator programme is positive, and not negative cost, is that the total resource cost calculation includes all avoided external costs (local and global), but the cost of avoided emissions calculations calculation excludes climate change damage costs.

amongst poor households, as well as the more "traditional" barriers to energy efficiency. The major lesson from this research is that one cannot generalise about the fuel and appliance use patterns of the poor – while income is a constraint, some households, motivated by the social status attached to, or perceived modernity of, electric appliances, find means to access these appliances. The section outlines the barriers to energy efficiency in low-income households in South Africa, drawing on case studies presented in Mehlwana (1999), a companion research report from this project.

3.1 Affordability and financing

Investment in energy efficiency improvements is often constrained by the limited and irregular cash flow in poor households and the difficulties in accessing additional finance experienced by these households. Because of the affordability barrier, poor households sometimes end up investing in fuels and appliances which, ironically, are both energy and economically inefficient. Mehlwana (1999) notes that decisions to purchase and use the cheapest appliances are influenced by what consumers can afford at a moment in time. The pressures on household incomes force them to make short-term decisions and, therefore, overlook long-term factors such as the life cycle costs, efficiency and safety of an appliance.

Mehlwana (1999) demonstrates how lack of access to financing, as an integral part of affordability, constrains people's choices. Low-income households are known to use a range of means to purchase appliances, including hire purchase (HP) and stokvels or savings clubs. HP is, however, only available to consumers with regular, stable and relatively high incomes, as well as a fixed home address. This means that many households in informal, unplanned areas are excluded from HP agreements, irrespective of their incomes. Other households whose income is very low are not considered creditworthy. A prerequisite for belonging to a stokvel is also a stable and regular income. Many low-income households are, therefore, unable to save money in this manner. These households, who are unable to access either conventional or alternative forms of financing, often have to resort to paying cash for appliances – in this case only cheap and basic appliances are purchased. This accounts, in part, for the high use of paraffin wick stoves which have a low access cost.

For fuel purchases as well, households are often constrained in their choices by income flows. The decision on purchase has to take cognisance of the availability of money *at a particular point in time*. When there is little money, paraffin and coal stoves are used because one can buy paraffin or coal in small denominations. Householders *know* that buying fuels this way is expensive, but have no choice because not enough money is available to buy in bulk.

3.2 Information

When addressing the informational requirements for energy efficiency at a community or societal level, it is important to recognise that information or awareness programmes alone will not result in widespread energy efficiency. Often, low-income households have an understanding of energy efficiency and even practise energy efficiency – such as monitoring the electricity use of different appliances and back switching to less energy consumptive appliances for certain uses. There are other motivations embedded in the poverty of their situations, such as lack of access to finance, and the cost of operating appliances which require bulk energy purchases, that compel them to continue using energy inefficiently. Furthermore, developers and manufacturers may be aware of the concept of energy efficiency, but are motivated by uncertainty, risk or profits and, therefore, do not incorporate energy efficiency in their products. Information and awareness programmes need to be implemented, therefore, in conjunction with other regulatory or incentive programmes.

Furthermore, information and awareness programmes need to take into account the wide range of stakeholders involved in the delivery of energy efficiency services. Apart from participating consumers, there are a range of different stakeholders involved in the planning and implementation of energy efficiency programmes and the successful adoption of energy efficiency measures – government, utilities, manufacturers, developers, builders, NGOs and so on – all of whom have different informational requirements to guarantee their effective participation in promoting and adopting energy efficiency strategies and measures.

Finally, it is important to identify what the specific informational requirements are. Often, awareness programmes tend to provide broad information on the concept of energy efficiency and related savings, when the target audience requires more sophisticated information. Where people are already aware of broad notions of energy efficiency, the types of information required may be how to practically implement energy efficient strategies: for example how to build an energy efficient house or put in a ceiling; where to access financing to purchase energy efficient appliances or to build an energy efficient house; how to mobilise capital to finance energy efficiency for the poor; how to facilitate community participation, empowering people to choose energy efficiency and so on.

3.3 Physical access to or availability of fuels

Low-income households are, in certain circumstances, unable to secure the best mix of fuels because certain fuels are not readily available to them. For example, while paraffin networks are generally good, with both fuels and appliances being readily available, many South Africans do not have, or have only tenuous, electricity connections and are thus excluded from the use of electricity. Coal networks are well established in areas close to the coal mines, but the high transport costs of coal result in fairly weak distribution networks in the rest of the country. The coverage of gas distribution networks is also relatively weak and is inhibited by poor transport infrastructure and a lack of access to transport.

Those living in planned settlements generally have better access to the range of different fuel options than those living in informal unplanned settlements (Mehlwana 1999). Planned settlements provide road infrastructure and spatial standards, as well as a sense of permanence, which facilitates the distribution of energy services such as electricity and gas.

Furthermore, those living in their own homes, with their own electricity connections, have more secure access to electricity than those living in rented accommodation or backyard shacks. In backyard shacks, access to and use of electricity is at the landlords' discretion. Relationships between tenants and landlords are often unstable and conflicts arise about electricity use. In order avoid this conflict, many backyards would rather not access their landlords' electricity (Mehlwana 1999).

3.4 Split incentives – construction, ownership and use

In the delivery of housing, those making the initial capital investment in the construction of the house are most often separate from those who will live in and pay the operating costs of the house. Under these circumstances, it is not common to find developers investing in energy efficiency and a low-efficiency housing stock with high operating costs emerges. Apart from a few self-built developments, most subsidised low-cost housing in South Africa is built by local municipalities or private developers. Whether local municipalities or private developers, the motivation is to cut corners, minimise initial costs and increase profit margins. As a result, there are few developers who invest in energy efficiency, so poor households are forced to bear the burden of the high operating costs of houses over time.

3.5 Lack of tenure and urban/rural commitment

In many settlement types, factors that determine appliance ownership will be constrained by space and tenure problems. Because of space problems, in informal electrified settlements and backyard shacks, more households own two-plate electric stoves than stoves with ovens (White et al 1998:71; Mehlwana & Qase 1999). More importantly, the tenure problems in informal unplanned and backyards also play a direct role in the purchasing of electrical appliances or other expensive investments in efficiency. In the case of backyard dwellers, access to and use of electricity is entirely at the property owners' discretion (Mehlwana & Qase 1999; White et al 1998, Jones et al 1996). In many instances, relationships between tenants and property owners are highly unstable and vulnerable to conflicts. In order to avoid this conflict, many backyards would rather not access their property owners' electricity.

Migrant workers continue to play a large role in the urban workforce and urban communities. The migrants have deep commitment to their rural households and view life in urban townships as a temporary sojourn (see also White et al 1998: 69). Generally, they tend to invest little in their urban households and either save or remit money for the maintenance of the rural households. This socio-economic set-up has important ramifications and influences fuel and appliance use patterns. Irrespective of the type of settlement and access to different energy sources, investing in rural homes is the most important aspect for some households. Expenses on appliances are kept to a minimum. Although electricity would be available, paraffin appliances are likely to be used because they are perceived to be cheaper. The households would also be even less likely to pay a higher cost for efficient appliances, given that they are saving money to send to their rural homes.

3.6 Multiple fuel use and household needs

Multiple fuel use means that households use more than one fuel for the same end-use. In some contexts, households use one appliance for more than one end-use. In the case of the latter, a paraffin or coal stove is used for cooking, while offering space-heating. In the former case, for instance, it is common for households to use gas, paraffin, coal and/or electric stoves for cooking. Gas would be used for specific tasks (such as cooking special quick-foods) and paraffin appliances used for foods that that take longer time to cook. Therefore even though gas may be a more energy efficient cooking fuel than paraffin or electricity (and can avoid the high health costs of paraffin), we cannot assume that households will completely stop using paraffin once they buy a gas stove.

3.7 The symbolic value of appliances

Not surprisingly, consumers do not simply look at the economics of appliance choices to make their decisions. Research in South Africa has demonstrated that the symbolic value of appliances can be as important as their functional value when consumers make decisions (Mehlwana & Qase 1999; White et al 1998). For example, a majority of formal households tend to replace their non-electrical appliances with modern and sophisticated appliances immediately after electrification. This is not simply because electricity is a cleaner and more convenient fuel. There is a general perception that non-electrical appliances are not appropriate for formal households. Having many electric appliances brings both respect and envy from the neighbourhood. They are symbols of modernity and comfortable existence, and many people will go to extremes in order to acquire these appliances. The bigger the electric appliance the better: a bigger electric appliance is important more for its decorative function than for its end-use. Consumers might not be attracted to smaller, more efficient appliances, therefore, unless it had other features that enhanced the sense of "modernity".

4 Strategies: Creating an enabling environment for investment in energy efficiency

As described in section 3, various barriers currently inhibit 'optimal' investment in energy efficiency in urban low-income residential areas of South Africa. These include affordability, availability, information and awareness barriers, as well as barriers arising from the risk associated with adopting new technologies, split incentives and social influences. Clearly, strategies specifically aimed at removing or at least reducing these barriers can be developed. Examples of strategies aimed at improving the energy services of poor urban households can be found in Simmonds and Clark (1998), an earlier report written for this project, who suggest strategies that comprehensively address sector-specific market barriers and failures.

In our environment, where human resources, capital, time and other resources are scarce, interventions for development must be assessed and then prioritised. This section of the report examines the strategies presented by Simmonds and Clark (1998) from a slightly different perspective. This analysis updates the strategies emanating from Simmonds and Clark, where relevant, and then considers them in light of the question: "How can an enabling environment for investment in energy efficiency (in general) best be created?" The overall objective of this exercise is to identify and prioritise strategies which, when implemented, induce *additional* investment in energy efficiency. Essentially, the focus should be on identifying fundamentals which must be put in place to enable the 'market' (which here could mean residential end-users, or private sector organisations such as lighting and appliance retailers, ESCOs or even Eskom) to drive and profit from energy efficiency initiatives.

An enabling environment for investment in energy efficiency can be created on various different levels, and by different role-players. These are illustrated in Figure 2 below, where government, the Regulator, Eskom and local service providers are identified as the key 'enablers' or those who have the greatest leverage to create opportunities for other players such as community organisations, financial institutions, housing developers, lighting and appliance manufacturers, distributors and retailers, and ESCOs to contribute towards new investment in energy efficiency.

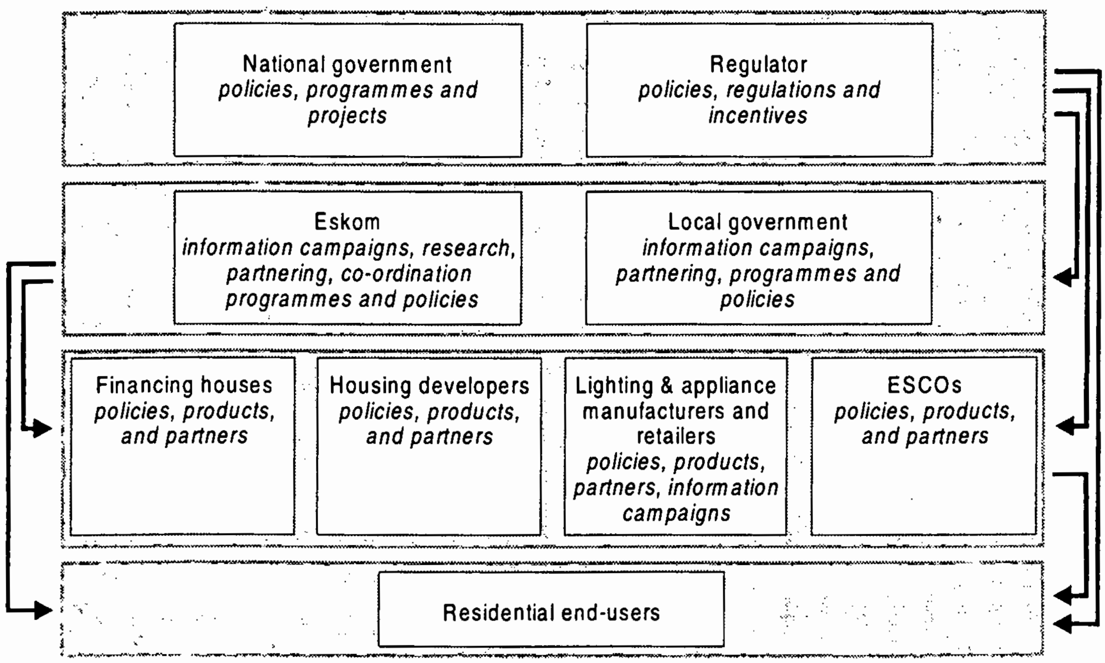

Figure 2: Creating an enabling environment for investment in energy efficiency

Through carefully designed policies, programmes and projects, government, for example, can create an environment which catalyses investment in energy efficiency related programmes from Eskom, local service providers, housing developers, lighting and appliance manufacturers, distributors and retailers, ESCOs and financing institutions. In turn, this investment should result in additional investment in energy efficiency, by end-users. Similarly, through an appropriate regulatory framework, the National Electricity Regulator could either encourage or require local service providers to invest in energy efficiency programmes that ultimately benefit residential customers and thus motivate for the adoption of efficient technologies. The remainder of this sector recommends priority enabling activities for government, the Regulator, Eskom and local service providers. These role players are identified as the key 'enablers' or those that have the greatest leverage to create opportunities for other players to contribute towards new investment in energy efficiency. The strategies are summarised in Table 17.

4.1 Government can induce new investment in energy efficiency

Taking into account government budgetary and other resource constraints, the following four priority measures are recommended:

4.1.1 Set the stage strategically

The White Paper on Energy Policy of South Africa notes that "[s]ince expenditure on energy constitutes a large portion of the country's GDP (15%) and a particularly large proportion of poor households' expenditure, it is necessary to give attention to the effective and efficient use of energy. Energy efficiency and energy conservation considerations must therefore form part of an overall energy policy". Through strategic, targeted programme planning, government can place energy efficiency on the national agenda. Important aspects of this planning process include:

- *Developing implementable strategies* and/or action plans which ensure that the energy efficiency related policy choices appearing in the White Paper on Energy Policy of South Africa are fulfilled. Execution of these strategies/action plans is central to improving government's credibility and enhancing leadership in this area.
- *Creating a level playing field* for all forms of energy including grid electricity, wind, solar, LPG, natural gas, paraffin, coal, biomass, etc, according to economic and social merit. A level playing field should provide for the balanced provision of energy forms by removing explicit and implicit subsidies.
- *Develop strategic* partnerships to make provision for weaknesses arising from budgetary constraints, as well as building on to and making use of existing initiatives. Strategic partnerships for collaborative research and development, programme design and funding purposes should be developed with:
  - other related governmental initiatives (e.g. low-cost housing programme);
  - utility-driven programmes (e.g. Eskom's energy efficient lighting initiative);
  - private sector and NGO programmes (e.g. Household Energy Action Training programme; Sustainable Energy, Environment and Development; LPG Safety Association);
  - international funding assistance agencies (e.g. Global Environmental Facility).

4.1.2 Develop and support a new National Energy Efficiency Agency

The Department of Minerals and Energy is in the process of analysing the feasibility of a national Energy Efficiency Agency, which would provide an implementation vehicle for current DME and other institutions' energy efficiency related activities. To date, a draft business plan has been delivered by consultants commissioned to investigate this issue. Due to new DME priorities, this initiative has not be carried forward, although recent reports that there could be some international assistance available for establishing this agency could improve the chances of action. This initiative should be a priority, as it would bolster other measures as described above.

4.1.3 Guide role players with information and education campaigns

The White Paper on Energy Policy contends that "[i]n formulating energy efficiency policies, government proceeds from an understanding that efficient use of energy is best achieved through the creation of an awareness of the benefits of energy efficiency measures (both economic and environmental) and the deployment of incentives to encourage such measures" (DME 1998). This approach should be endorsed, and treated as a priority area for the DME working in collaboration with the Department of Housing and the Interdepartmental Committee on Energy Efficient Housing. Information and education campaigns should not necessarily be limited to specific aspects of energy efficiency (such as appliance or lighting efficiency), but where possible should be generic to cover all household activity. In designing and/or developing campaigns, government should bring together existing materials and investigate best practice in this area. Emphasis should be placed on indicating the realisable benefits associated with efficient energy use.

4.2 The Regulator is an important promoter of electricity efficiency

As the National Electricity Regulator develops a new policy framework and strategic vision for regulation in restructured electricity markets, it must continue to recognise and plan for the important role that it can play in preserving and promoting economically viable demand-side management initiatives.

4.2.1 Provide incentives for market adoption of energy efficiency

The NER has a series of powerful tools to encourage the market to adopt energy efficiency. It could, for example, choose to adopt a performance-based tariff making approach and/or decouple sales from revenues and profit as a means of promoting and preserving utility-driven DSM.

- *Performance-based tariffs.* While performance-based tariff making is generally based on a performance measure of the entire industry, energy efficiency can also be incorporated into performance-based tariffs. Utilities that can document energy efficiency improvements may be allowed to earn higher profits and/or a higher rate of return. In the design of this system, it is important that the DSM incentive is not offset by a rate formula that rewards increased sales – that is, this type of DSM incentive only works where revenues, not tariffs, are subject to regulated caps.
- *Decoupling sales from revenues and profit.* Regulatory tariff structures often link energy sales (kWh) with utility revenues and profits, which is a clear disincentive for the utility to engage in any DSM that reduces sales. As a means of overcoming this disincentive, a tariff structure is required such that the income to the utility is not dependent on sales volumes (in kWh) but on some other measures of service. An example of this is the rate of return regulations used to determine tariff in California in the 1980s, where the utility profits were based on a return on capital invested rather than a margin on each kWh sold (Swisher, Jannuzzi & Redlinger 1997).

The NER should investigate which of these or other tools could be applied within the current context, and should develop indicators (such as fairness, transparency, market fit, and ease of administration) against which to measure the potential effectiveness of the chosen incentive(s).

4.2.2 Regulate to enforce market adoption of energy efficiency

To promote DSM, the Regulator could chose to impose a condition that to allow an entity to distribute electricity various conditions, including the implementation of DSM activity, must apply. Generally, it is advisable that a license agreement such as described here is quite detailed because the DSM activity that is ultimately carried out may not coincide with the Regulator's original intention to promote energy efficiency. For example, in accordance with a regulatory requirement that a certain amount of DSM activity (mainly education and awareness) is performed, a distribution utility could define all public/customer relations as DSM. This may or may not be related to promoting energy efficiency as originally intended by the license agreement. Instead of a license agreement stating that electricity distributors must conduct some DSM activity, the Regulator could also require that distributors demonstrate IRP capabilities. This requirement is probably more demanding on the distributor but is potentially more rewarding in terms of sustainable DSM outcomes. This report therefore recommends that, at a minimum, integrated resource planning is required of all licensees.

Table 17: Summary of key strategies to create an enabling environment for energy efficiency

Catalyser	*Key energy strategy*	*Barrier addressed*
National government	Set the stage strategically through: Developing implementable strategies Creating a level playing field for all forms of energy Developing strategic partnerships	• lack of credibility • low levels of communication • duplication of effort • uncoordinated industry role players
National government	Develop and support a new National Energy Efficiency Agency	• low levels of communication and information • low levels of credibility • duplication of effort • uncoordinated funding opportunities
National government	Guide role players through information and education campaigns	• low levels of information and communication • riskiness of adopting a new technology
Regulator	Provide incentives for market adoption of energy efficiency	• economic and financially viability • low levels of communication • high risk associated with DSM investment
Regulator	Enforce the adoption of energy efficiency	• no provision for 'public goods' made
Distributors	Invest in information and awareness programmes	• low levels of information, communication and awareness
Distributors	Bridge the financing gaps	• low levels of affordability • low levels of communication and co-ordination
Distributors	Create communication links in supply chains	• low levels of communication, co-ordination and networking • risk associated with new technologies • unavailability of technologies

4.3 Distributors can utilise their market positioning to add value to energy efficiency initiatives

Presently, the electricity distribution industry is fragmented: of the 400+ municipal distributors, only four earn half of the total surpluses being earned by all municipal distributors while most of the others are not financially viable (Van Horen & Thompson 1998). The White Paper states that the distribution industry will be consolidated into a maximum number of financially viable independent regional electricity distributors or REDs. This discussion takes a forward-looking approach and recommends policy measures which would be applicable to a financially viable RED, or alternatively to Eskom and a small number of other municipal distributors in their current form.

4.3.1 Implement aggressive information and awareness campaigns

Electricity distributors should invest heavily in information and awareness campaigns which promote energy efficiency. Distributors may choose not to focus solely on electricity services, but, as Eskom has recently begun to do, investigate the benefits associated with 'demarketing' electricity (thus promoting the use of various different fuels to fulfil household energy requirements). Electricity distributors should collaborate with the DME, the Department of

Housing and independent researchers to make the most – qualitatively and quantitatively – of this activity.

4.3.2 Bridge the financing gaps

Electricity distributors play an important role in terms of being able to leverage funding for energy efficiency. Eskom, for instance, has recently secured funding from the Global Environmental Facility and the International Finance Corporation to develop a programme to radically increase the market penetration of compact fluorescent lighting into the residential sector of South Africa. In addition, Eskom has been working, in collaboration with its international partners to secure additional funding sources (from a range of commercial lending institutions) within South Africa. Distributors can and must play key roles in undertaking these activities.

4.3.3 Create communication links in supply chains

Electricity distributors (as well as those who distribute other forms of energy) occupy strategically significant market niches in that they have direct access to users of energy and thus should develop a sense of customer requirements. They maintain ongoing partnerships with lighting and appliance manufacturers, distributors and retailers, as well as other ESCOs. Frequently, competition does not allow for collaboration between these groups, resulting in sub-optimal solutions for society as a whole. Distributors, generally at the invitation of market-driven enterprises such as the above, can play an important role in bridging communication gaps between these different links in this supply chain. Regular supplier forums for energy-efficient technologies are useful vehicles for this. Distributors can also undertake research on market shares and positioning. This type of information is generally very useful for all market players but few are prepared to offer it to their competitors. As long as confidentiality agreements are adhered to, market players generally tend to offer it to distributors for research purposes. Finally, distributors can bridge the gap between availability of certain types of technology with customer requirements.

5 Conclusions

This report has demonstrated the substantial economic and environmental benefits from energy efficiency interventions for the urban poor. The five interventions presented include three energy efficiency programmes (compact fluorescent lamps, efficiency refrigerators, and improved thermal efficiency of low cost housing) and two fuel switching programmes (from electricity and paraffin to cooking).

From an economic perspective, four of the five interventions (all but electricity to gas for cooking) generate substantial benefits for society. In other words, the cost to society of providing affordable energy services would be lower with the interventions than without them. The CFL and efficient refrigerator programme would also substantially reduce Eskom's cost of supplying energy services even with a substantial subsidy from Eskom for the capital costs, while the thermal efficiency programme would impose a very small incremental cost on Eskom. Given the current structure of tariffs in South Africa, however, the net income impact of the efficiency programme would be negative. This is because Eskom makes a margin on each kWh of electricity sold – so any reduction in kWh sales reduces net income. With a different regulatory regime that would decouple sales from profits (eg basing utility net income on a return on capital rather than on kWh sales), these could become profitable investments for Eskom.

Because of their high discount rates and the higher up front costs of efficiency, consumers may not consider it worthwhile to invest in energy efficiency without financing for the incremental capital costs. The CFL and efficiency refrigerator programmes, however, would breakeven for consumers with almost no subsidy. The thermal efficiency and paraffin to gas switch programmes would require capital subsidies of 50% and 30%, respectively. Consumers who did not participate in these programmes would see marginal increases in their electricity bill due to slightly higher tariffs, but this is more than offset by the increased disposable income for participating consumers.

The environmental impacts of energy use, particularly at the household level, are a major driver for investment in energy efficiency. Far more significant than the environmental and health costs of electricity generation are the high external costs of burning coal, wood and paraffin in low-income households. The avoided respiratory illness impacts of smoke and air pollution, reduced burns, fires and poisoning cases from paraffin, and reduced water consumption are all important local environmental benefits from these programmes. The total health cost savings from the four large scale programmes (excluding paraffin to gas switching) would be more than ten million Rands per year over the 40-year life of the programmes.

The main source of greenhouse gas emissions in South Africa is from the combustion of fossil fuels, so energy efficiency will also reduce national carbon emissions. Four of the five interventions analysed here are either low cost or "no regrets" options – CFLs, thermal efficiency and paraffin to gas are all 'no regrets', while the refrigerator has a small incremental cost of 24 R/ton CO_2. The total CO_2 equivalent emissions savings from the CFL, thermal efficiency and refrigerator programmes would be 570 thousand tons CO_2 per year.

Despite the benefits of energy efficiency for the nation, utility and consumers, there are substantial barriers in the way of implementing these programmes. These include both the barriers faced by DSM programmes in industrialised countries, as well as barriers that are much more significant in a developing country context. The lack of information, for example, is accentuated by lower levels of literacy and access to mass media. Many urban poor households also do not have access to cleaner fuels or more efficient appliances, because of poor distribution networks, the large number of people living in informal settlements without infrastructure, or because they cannot afford the up-front costs of access. Many urban residents are not permanent, and will not invest in more expensive appliances when they are planning to return (or send their income) to a rural home. Split incentives between the builders, owners and tenants in housing is a severe problem when the mass housing programme, and contractors, are under pressure to build the largest number of homes at the least (up front) cost. Finally, households often make their choices about fuel and appliance purchase based not just on finances but on the symbolic value of the appliances – with large electric appliances being an important symbol of modernity. This is not to say that households do not understand energy efficiency, but that they have a range of other financial and social pressures that influence their decisions.

Tackling these barriers must begin by actions that creates an enabling environment for investment for energy efficiency. At a policy level, the DME and NER can provide both regulatory and financial incentives to make it financially beneficial for the electricity sector to invest in efficiency. This should include performance based tariffs or mechanisms to decouple sales profits, removing an explicit or implicit subsidies that bias against energy efficiency, as well as promoting broad awareness of the benefits of efficiency. The timely establishment of a National Energy Efficiency Agency would be an important step towards meeting these goals, as will the NER's review of electricity generation and distribution licenses. As the main link between consumers and the industry, distributors will also play a critical role in creating an enabling environment for energy efficiency investment. In addition to well targeted information and awareness programmes tailors to key consumer groups, distributors should investigate how they can help bridge the financing gap between what is good for the nation what the consumer sees as financially beneficial. Distributor links to suppliers and other sector stakeholders also make the well placed to provide communication links within the industry about energy efficiency technologies, consumer needs, and implementation programmes. Through such a co-ordinated and multi-level strategy, government and the electricity sector can help to realise the economic and environmental benefits of energy efficiency for those who need them the most – the poor of South Africa.

Appendix A: Methods to test the viability of efficiency projects[4]

A.1 Total resource cost test

Economic measures of merit are used to determine whether investment in an energy efficiency intervention is economically attractive. Essentially this involves a comparison between making the investment, or not making it, i.e. with or without the project.

This method involves calculating the total resources used for the project (i.e. if an investment in energy efficiency is undertaken), as well as the resources used if the project is not undertaken. The difference between these two amounts will reveal whether the project generates a net benefit (i.e. fewer costs are incurred with the investment), or a net cost (i.e. more costs are incurred with the investment). This method assumes that the benefits of both options, i.e. the energy service provided, are similar[5].

Costs must be projected over a suitable lifetime, and discounted to calculate the present value of these costs. This is the most appropriate and standard way of dealing with costs incurred unevenly over a period. The discount rate used in this case is the social discount rate. This reflects the opportunity cost of capital to society as a whole rather than to individuals or specific institutions.

In energy efficiency projects, the type of costs usually refer to the following:

- capital and replacement costs
- costs in generation, transmission and distribution of electricity
- external environmental costs of electricity generation

Costs of generation, transmission and distribution should refer to the long-run marginal costs. While these may vary over time if there are real changes in costs, in general they will be fairly constant with time. See Appendix B for details on how to calculate these costs.

In general, an energy efficiency project will require a higher investment in capital, but incurs lower supply and environmental costs. In some cases, the lifetime of the equipment may not have expired at the end of the period chosen for analysis, particularly if there have been replacements during the time period considered. In this case, it is appropriate to calculate a residual value of the assets, very similar to the depreciated value used for accounting purposes. This residual value is then treated as a negative cost at the end of the period.

The example in the figure below compares the costs of using a compact fluorescent bulb (CFL) compared with a standard incandescent bulb. It can be seen that the CFL has a large initial cost, and another large replacement cost in year 8, whereas the incandescent has fairly even costs per annum, the only variation being due to the number of replacements per annum.

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4 These calculations are based on CEC (1987), as used in Swisher, Jannuzzi and Redlinger (1997).

5 Where the benefits of the two options are different, a full net present value calculation should be undertaken. This requires estimating the value of the benefits generated and off-setting the costs to arrive at a net benefit stream. This is then discounted to arrive at the net present value. The two values thus arrived can then be compared with each other to determine which option is more attractive.

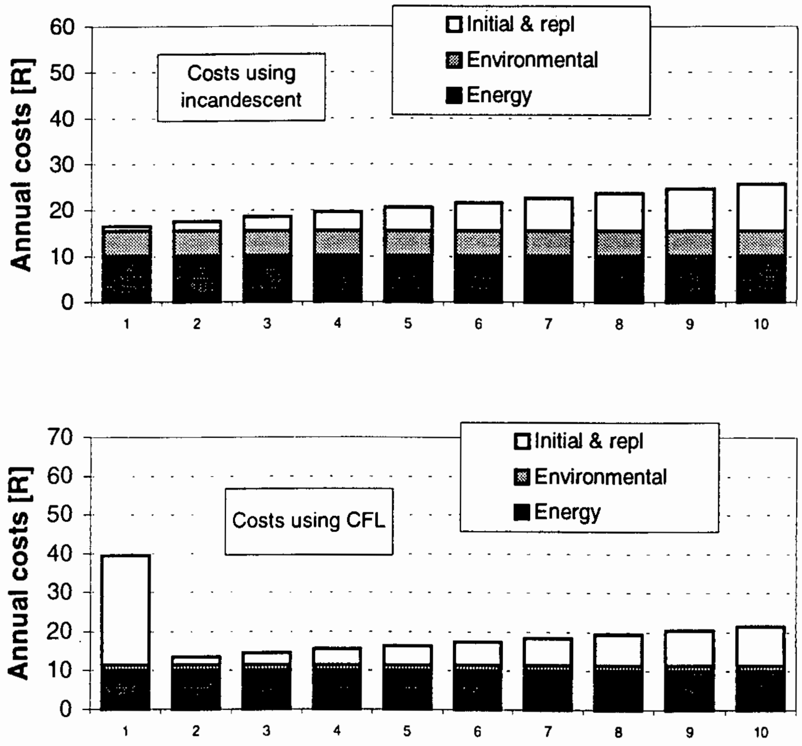


Figure 3: Total resource costs for lighting options
(figures shown for a single installation)

Discounting the cost streams shown in the figure shows that the total resources required for the CFL are lower than those required for the incandescent. Investment in the energy efficiency option is thus considered to be economically attractive.

A.2 Cost of conserved energy

An alternative method to examine the economic viability of investment in energy efficiency is to calculate the cost of conserved energy (CCE). This method provides an estimate of how much it costs to conserve a unit of electricity. This method is intuitively attractive as it allows comparison with the unit costs of generating power. It also allows energy efficiency options to be ranked in order to ascending cost.

The method involves calculating the annualised value of all investments made (both initial and any replacement costs), and dividing this by the annual amount of electricity saved. This provides the CCE - a figure with units R/kWh and represents the cost per unit of electricity saved as a result of the project.

The annualised value of investments spread unevenly over a time period can be calculated by amortising the present value of these investments. As with the total resource costs, the social discount rate is used to represent the opportunity cost of capital to the country as a whole.

This figure should then be compared with the cost of providing electricity, including any external environmental costs. The cost of energy supply should take account of differing costs of peak and off-peak demand based on the load profile of energy use. If the CCE is less than the cost of supply (including external environmental costs), then the energy efficiency investment is attractive.

Figure 4 compares the cost of conserved energy for a CFL with the cost of supply and the small user tariff. Note that the cost of supply is broken down into its constituent parts showing the contribution to the cost of usage during peak times, off-peak times as well as external environmental costs. Since the lamp is assumed to be used heavily during peak times, the overall supply cost fairly high.

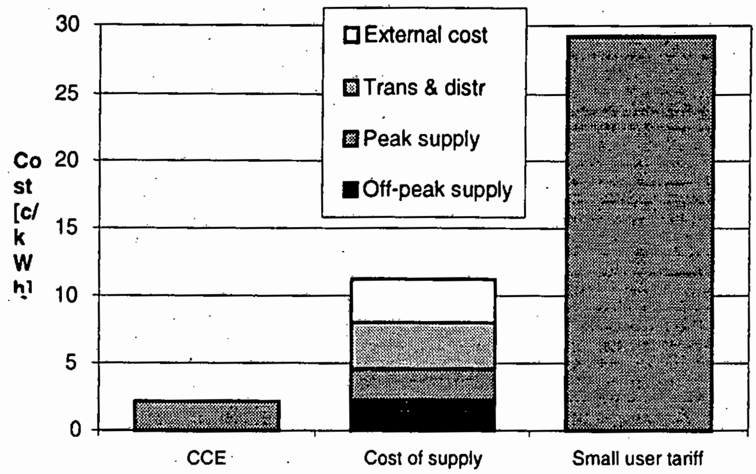


Figure 4: Cost of conserved energy for CFL compared with cost of supply and small user tariff

A.3 Utility resource cost test

This test looks at the costs incurred by the utility with and without the project. It does not take into account the revenue effects that result from lost sales.

In summary, the main costs incurred by the utility will arise from:

- *Investment costs*: the utility's contribution (a subsidy) towards the capital costs of the project
- *Avoided supply costs* (a benefit to the utility): generation, transmission and distribution costs which are avoided as a result of lower energy consumption. This will depend on the load profile of consumption and the costs of peak and off-peak supply. The costs to use in this method are the avoided costs of supply. These will be the short-run marginal costs. In circumstances of excess capacity, these costs will start low and will increase over time.
- *Additional supply costs from the take-back effect* (a cost to the utility): where some of the energy savings are compensated by additional electricity consumption, the utility will incur additional supply costs.

Note that external environmental costs are not included in this analysis as the methodology is only concerned with cost impacts on the utility. Where the lifetime of the asset, or its replacement, exceeds the duration of the time period selected for analysis, it is legitimate to include the residual value of the asset in the overall calculation of the present value. This residual value is discounted in the present value calculation.

All costs for each year can be discounted back to year 1 to generate the present value of all costs.

This exercise is undertaken for the scenarios "with" and "without" the project. The test is whether the present value of costs with the project are lower than without.

A.4 Utility revenue impact

This methodology tests the revenue impact on the utility. In general with an energy efficiency project, the utility will incur a set of investment costs, will avoid certain costs of supply and will lose revenue from lost sales. In addition, it is possible that electricity saved by the consumer will be compensated by additional consumption of other electrical services. This so-call "take-back" effect will result in additional supply costs and additional revenue for the utility. Together all these factors will contribute towards a net income stream as a consequence of the project, which can be discounted to determine whether the utility is a net winner or loser as a result of the project. The discount rate to use in this analysis is the utility's cost of capital.

In many cases the investment costs will be shared between the utility, the consumer and possibly a grant funding institution. This methodology can be used to determine the level of investment which the utility can afford to make, i.e. the subsidy provided by the utility towards the energy efficient appliance. Note that as long as the marginal cost of providing power is less than the average cost, a utility will almost always lose money from energy efficiency unless the regulatory authority puts in place a mechanism to decouple kWh sales from profits.

In summary, the main impacts on the utility's revenue will arise from:

- *Costs*: as described above.
- *Lost revenue* (a cost to the utility): sales foregone as a result of the lower energy consumption. This is a function of the tariff structure.
- *Additional revenue from the take-back effect* (a benefit to the utility): additional sales from the take-back affect.

As an example, Figure 5 presents the revenue impacts for installation of a single CFL. It assumes that the utility is responsible for 50% of the cost of the bulb (as well as 50% of any replacements). In this case it can be shown that the present value of the revenue impacts is negative, and so it is concluded that the utility will not benefit from the project.

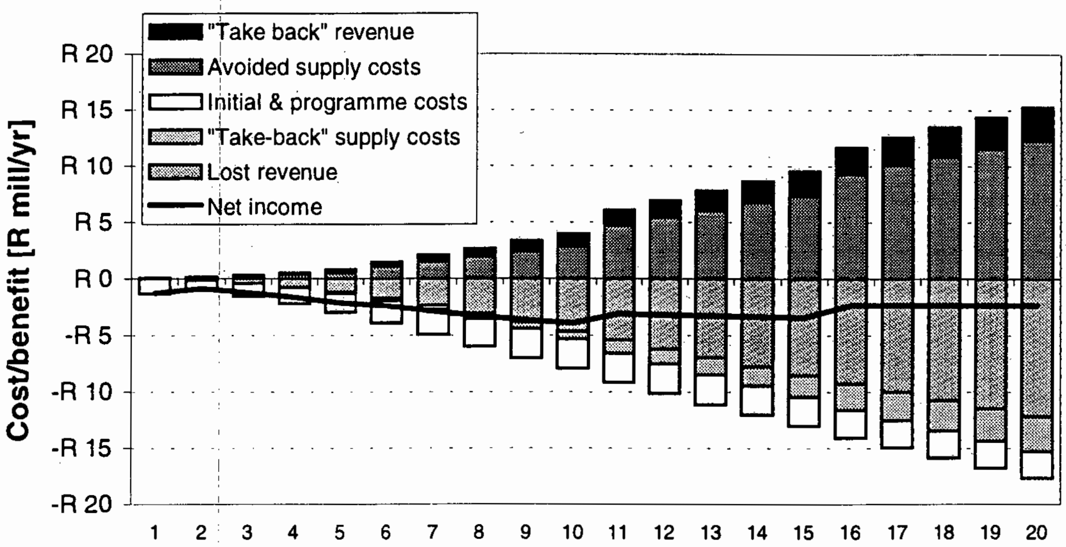


Figure 5: Revenue impacts on utility of CFL project
(impacts are for the entire programme with a 50% utility subsidy)

Increasing the level of subsidy naturally makes the project less attractive to the utility. There will be a break-even subsidy point at which the project is no longer attractive to the utility. It can be shown that this project is never attractive to the utility, even at a 0% subsidy level.

A.5 Participant test: consumer income impact

This technique is designed to test the income impact on the consumer in a very similar way to the previous methodology. It is assumed that the consumer pays a portion (between 0% and 100%) of the capital costs, and that a stream of costs and benefits for the consumer are incurred as a result of the project. Discounting using the consumer's discount rate generates the present value of the income stream, which can be used to determine whether the consumer benefits or not from the project.

In general the set of costs and benefits will be:

- *Investment costs*: The consumer's contribution to the capital and replacement cost of the appliance. This will be the total cost of the equipment less contributions by the utility and grant funds.
- *Avoided electricity charges:* Reduced electricity bills as a result of reduced expenditure (assuming that tariffs remain constant).
- *Additional electricity charges* as a result of the "take-back" effect.

Taking account of the additional electricity charges from the "take-back" effect will give a true picture of the actual income impact on the consumer. It should be noted though that the consumer also gains the additional energy services that make-up the take-back effect, and so a negative income impact including the take-back effect should not necessarily be interpreted as the consumer "losing" as a result of the project. It is necessary to look at the income impact on the consumer both excluding and after taking account of the "take-back" effect.

As with the previous methodology, the degree of subsidy provided by the utility can be varied to test at what point the project is attractive to the consumer, i.e. the consumer breakeven point. Using the data presented in Figure 5 it can be shown that the project results in a positive income impact on the consumer even if the consumer pays 100% of the cost of the CFL.

A.6 Non-participant test: Impact on electricity rates

Where a fairly substantial programme of energy efficiency interventions are implemented, there will be impacts on the overall financial position of the utility. If the reduction in energy sales is significant, the utility will experience both reduced costs and reduced revenues. If it assumed that the utility should not be adversely affected by these, it may be necessary to adjust the tariff in response to these factors.

This methodology examines the impact on rates for a consumer class as a result of the revenue and cost implications of an energy efficiency programme. The revenue requirement of the utility, before implementation of the programme, is given by:

$$\mathbf{RR_0 = SALES_0 * TARIFF_0}$$

Where RR_0 = Revenue requirement before implementation of the programme
$SALES_0$ = Total sales before implementation of the programme
$TARIFF_0$ = Tariff before implementation of the programme

The new tariff, after the programme is given by:

$$\mathbf{TARIFF_1 = RR_1 / SALES_1}$$

$$\mathbf{= (RR_0 - \Delta RR) / (SALES_0 - \Delta SALES)}$$

Where RR_1 = Revenue requirement after implementation of the programme
$SALES_1$ = Total sales after implementation of the programme
$TARIFF_1$ = Tariff after implementation of the programme
ΔRR = Change in supply costs as a result of the programme
$\Delta SALES$ = Change in sales as a result of the programme

This can be represented graphically as in Figure 6.

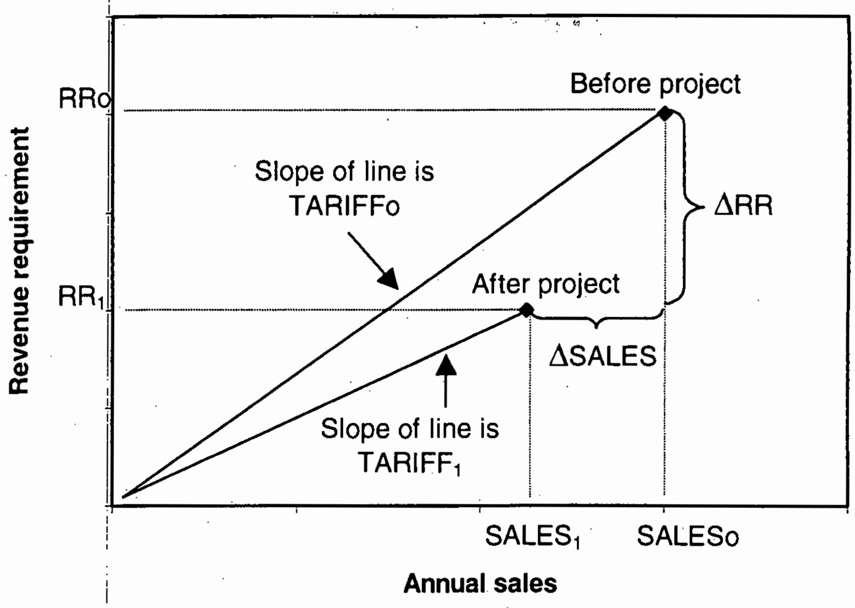


Figure 6: Changes in sales, revenue requirement and tariffs as a result of energy efficiency project

Where a programme results in tariff changes, it is necessary to examine the impact on participants and non-participants in the programme. While an increase in tariffs will be offset by reduced energy consumption for participants, non-participants will face higher charges. Examining the effect on rates is often called the "non-participants' test" as an increase in rates will have a negative impact on non-participants.

As an example, the programme installing 2.5 million CFLs in households over ten years is expected to save 87 800 MWh per annum (on average), and to avoid R1.6m in supply costs. As a result, tariffs will increase by 0.04 c/kWh as demonstrated in Table 18 (in fact, this calculation is a simplification as additional costs and savings gradually increase over the years rather than in one step change).

Table 18: Ratepayer impact for CFL programme

	Before programme	*After programme*	*Change*
Annual sales [GWh]	31 732	31 645	-0.3%
Revenue requirement [Rm]	3 491	3 492	0.05%
Tariff [c/kWh]	11.00	11.04	0.3%

Since tariffs will increase by 0.04 cents as a result of the programme, non-participants will experience a marginal increase in their bills.

Appendix B: Marginal costs of electricity supply

EDRC proposes using two measures for use in calculating the costs of electricity supply. The first, termed here the "economic long-run marginal cost" (LRMC) is used for economic perspectives on energy efficiency, i.e. in the total resource cost test. The second measure, termed "utility avoided long-run marginal cost", is based on the method used by Eskom.

B.1 Economic long-run marginal cost

The principle behind this method is to incorporate future costs of capacity expansion in evaluating alternative investment projects. It is based on the method generally used for pricing analysis and is described by KfW (1993) and IEA (1998).

The method involves projecting cost streams associated with additional load. The LRMC then arrived at is given by:

$$LRMC_1 = \text{Present value (Capital costs + operating costs) / Present value (energy)}$$

$$= \Sigma\,(C_i + O_i)/(1+dr)^i \,/\, \Sigma\, S_i/(1+dr)^i$$

where C_i = additional capital costs in year i

O_i = additional operating costs in year i

S_i = additional sales in year i

dr = discount rate

Care should be taken to ensure that future sales from all investments included in the analysis are taken into consideration, or a residual value is attached to assets at the end of the period considered. For example, if a new plant is built in year 10, with an expected lifetime of 30 years, then operating costs and expected generation for the full lifetime of the plant should be included.

Capital costs need not refer directly to the cost of building new capacity, but could be calculated as the additional costs of bringing forward the commissioning of anticipated capacity required to replace old plant. Note that with this measure, each year would have a new LRMC, although this may not change significantly if demand and supply growth are constant over time.

B.2 "Utility avoided" long-run marginal cost

The utility avoided long-run marginal cost attempts to more accurately measure the actual costs which the utility will incur on an annual basis over the long run. In this sense, it is a revenue requirement for the utility, or a long-run avoided cost.

The method takes the same projected costs streams as above, but deals with capital costs in a different way. Instead of discounting future capital costs to the base year, it levelises these costs over the lifetime of the plant. The avoided cost is then calculated as

$$LRMC_2 = \text{(Levelised capital costs + annual operating costs) / energy}$$

This cost can be calculated on an annual basis, taking into account all levelised capital costs for capital expenses incurred from the start of the time horizon to the year under consideration.

For both methods, costs can be allocated to different time periods depending on loss of load probability.

B.3 Differences between the two methods

In the case where any additional demand requires additional capacity to be constructed, these two methods yield the same result.

Where additional demand can be accommodated for a number of years without the need to make additional investments in capacity, the avoided cost method will calculate lower costs (in c/kWh) in the early years, but costs will increase gradually to the estimate provided by the economic LRMC.

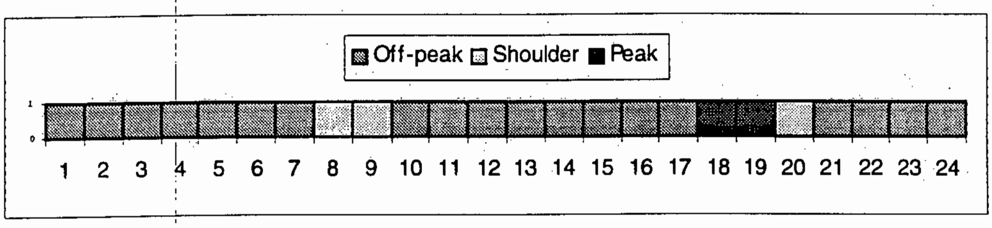
In South Africa's case, where surplus capacity exists, these two methods will yield different results for the initial years following 1999.

B.4 Application to South Africa

Eskom calculates marginal costs of generation according to the second method. These results are expressed as costs for each hour of the week, for different periods, e.g. 1997-2000, and use a discount rate of 6%.

For the purposes of this study, these results have been averaged into three time periods:

- Peak period: 18:00 – 20:00
- Shoulder period: 8:00 – 10:00 and 20:00 – 21:00
- Off-peak period: All other times



Using these figures, it is possible to make an approximation of the LRMC using method 1 (economic LRMC), based on some assumptions regarding operating costs, lifetime of new investments. The results are adjusted to use a discount rate of 8%. These results were used in the analysis, but are not reported separately here due to confidentiality restrictions by Eskom.

Appendix C: Assumptions used in the analysis

C.1 General assumptions for all interventions

C.1.1 Discount rates

Discount rates reflect the time value of money and are used in the calculation of the present value of future costs and revenues. Discount rates depend on the specific perspective adopted. In this context there are three different perspectives of interest.

Firstly, there is the national perspective relevant to the question as to whether an intervention is in the national, or economic, interest. The relevant discount rate here is the social discount rate, which reflects the return which can be expected from a similar category of investment. It is usual for national authorities to indicate a discount rate which is used for the evaluation of a wide range of cross-sectoral projects. In developing countries, where capital is considered scare, high discount rates are usually used. This is the case in South Africa where a real discount rate of 8% is usually recommended for government infrastructure projects.

The other two discount rates of interest are those relevant to the perspective of the utility and the consumer. These rates essentially reflect the cost of capital available to the utility and low-income households. In South Africa Eskom has one of the cheapest costs of capital and is rated by credit-rating agencies on a par with the national debt. This is not surprising given that Eskom is a public utility with an impressive financial record. Eskom's real discount rate is taken at 6% (as used by Eskom in capital appraisal projects), and so is lower than the social discount rate.

Consumer discount rates are expected to be significantly higher as low-income households generally pay a premium for capital. In fact, many low-income households reply on especially punitive sources of capital such as hire-purchase and so-called "load sharks" (see Banks 1999). While this is partly a reflection of the high transaction costs of dealing with small amounts of capital usually loaned by households, it is principally a consequence of the lender's evaluation of the risks of lending to these households. Nevertheless, it is probable that credit for low-income households is an example of an "incomplete market", that is a case where the usual market systems fail to provide an appropriate response to the needs of this group of households. It can be difficult to determine an appropriate discount rate for this group, partly because circumstances can change significantly for different individuals. Nevertheless, a discount rate of 30-40% seems appropriate, and 30% is chosen for the analysis.

Table 19: Discount rates (nb these are *real* rates)

Social discount rate	Utility discount rate	Consumer discount rate
8%	6%	30%

C.1.2 Energy prices and calorific values

Energy prices can vary significantly for different towns and cities, and even within a town. While electricity prices are usually uniform for a specific distributor, prices of paraffin, gas and coal vary with the specific supplier and the quantity purchased. The figures presented here reflect averages as found by the SAtoZ household survey in urban areas. The price of electricity is Eskom's price to prepayment customers.

Typical calorific values for different fuels are also presented in Table 20.

Table 20: Energy prices to low-income urban households and calorific values of fuels

		Electricity	Paraffin	LPG	Coal	Wood
Price	Units	c/kWh	R/litre	R/kg	R/kg	R/kg
	Price	29	1.80	4.00	0.26	1.00
Calorific value	Units	MJ/kWh	MJ/litre	MJ/kg	MJ/kg	MJ/kg
	Value	3.6	38	50	27	16

The electricity price given above is the price paid by end-users. For the analysis from the perspective of Eskom, it is assumed that the consumer is the customer of a municipality (as most urban households are). In this case, the lost revenue is only the bulk supply tariff, which is in the region of 11c/kWh.

C.1.3 Marginal costs of energy supply

Marginal costs of energy supply can be broken down into generation, transmission and distribution costs.

Appendix B presents details on the marginal costs of generation.

The marginal costs of transmission and distribution are taken as:

- Marginal cost of transmission: R27/kW/yr
  This cost is derived from the average payments to Eskom transmission by Eskom generation and distribution. It is closer to an average cost than a true marginal cost. Since the transmission system does not have excess capacity, it is assumed that this average cost is close to the long run marginal cost.
- Marginal cost of distribution: 1.8c/kWh
  This cost is taken from Eskom's IEP7 data. It is similar to, although slightly lower than the value used in Eskom's electrification cost benefit analysis software (4c/kWh). It refers only to the marginal operating costs related to energy consumption. Most of the distribution costs are fixed (usually expressed as Rands per customer per month) and not related to energy consumption.

It should be noted that the *avoided costs of distribution are limited to avoided operating costs*. It is possible that a portion of capital and upgrading costs will be avoided by reduced energy demand resulting from the programmes. However, the extent of these costs is difficult to determine. It should be noted that urban areas are now close to 90% electrified, and so there is little scope to avoid new construction costs, even if they were found to be potentially significant.

C.1.4 External costs of energy supply

The external costs of energy supply reflect the environmental and other social costs associated with their use. These costs can be especially difficult to quantify in monetary terms, and are usually expressed as ranges rather than precise figures. Most work on external costs of energy supply relate to environmental costs of electricity generation, costs of fires and burns associated with paraffin use in the home, and the costs of illness and death caused by indoor air pollution from coal and wood burning. These impacts are described in Section 2.6.1. This analysis distinguishes between the global external costs associated with greenhouse gases and the local environmental impacts. The total external cost is used for the total resource cost calculation, while only the cost of local impacts is used when calculating the cost of avoided greenhouse gas emissions. The local external costs are taken from Van Horen's (1996a) study of household external impacts and impacts of electricity generation. The damage cost of greenhouse gases is based on the work of Fankhauser and Pearce (1993) for the IPCC – it represents a damage cost of US$22 per ton of carbon, or US$6 per ton of CO2 (37 Rands at 6.2 R/US$) (reported in Pearce 1995). The external cost assumptions are summarised in Table 21.

Table 21: External cost assumptions by fuel
Source: Van Horen (1996a); IPCC (1996); Fankhauser and Pearce (1993)

Fuels (units)	*Local impacts*		*Greenhouse gas impacts*		*Total external cost*	
	R/GJ	*R/unit*	*R/GJ*	*R/unit*	*R/GJ*	*R/unit*
Electricity (kWh)	2.6	0.01	10.7	0.04	13.3	0.05
Coal (kg)	4.7	0.13	3.9	0.10	8.6	0.23
Wood (kg)	25.7	0.40	0	0	25.7	0.40
Paraffin (litre)	53.6	2.04	2.7	0.10	56.3	2.14
Gas (kg)	-*	-*	2.1	0.10	2.1	0.10

* No research available on local impacts of LPG

C.1.5 Residential load curves and on-peak electricity use

The load curve of electricity use is principally used in the calculation of supply cost as a function of peak, shoulder and off-peak use. For these purposes it is sufficient to calculate the percentage of electricity used during peak and shoulder times. This will vary for different end-uses.

Peak times are taken to be from 18:00 to 20:00 Monday to Friday. Shoulder period is taken as 8:00 – 10:00 and 20:00 – 21:00 Monday to Friday. Off-peak is all other times, and all weekends.

Load curves of "township" and "newly electrified" households (provided by Eskom) are used in the calculation of the figures presented below. The results of these two groups are averaged to arrive at the results. The different load curves experienced during summer and winter are incorporated in the results.

Table 22: Percentage of electrical energy consumed during peak periods

Application	*Lighting*	*Cooking*	*Space-heating*	*Refrigeration*	*All end-uses*
Peak use	9%	7%	18%	10%	10%
Shoulder use	16%	9%	10%	13%	14%

C.1.6 Take-back effect

The analysis takes into consideration the fact that a certain percentage of the money saved through electricity conservation will be spent on additional electricity use. It is assumed in the calculations that 25% of the electricity saved will be used on other energy applications. Similarly, 25% of demand savings will also be lost to the take-back effect.

The size of the take-back effect is somewhat arbitrary and there is no clear evidence for the assumptions used in the analysis. The figure is primarily used to test the scale of impacts which consideration of "take-back" may have.

C.2 Programme specific assumptions

C.2.1 Energy efficient lighting

The principal assumptions used in the analysis of lighting appliances are as follows:

Table 23: Assumptions for energy efficient lighting

	CFL	*Incandescent*	*Source*
Cost [R/bulb]	R27*	R3.00	Eskom lighting programme
Lifetime [hours of use]	8 000	1000	Discussion with Eskom
Power rating [W]	19	75	Standard light power ratings
Hours of use [hours/day]	3.2	3.2	Demand profiles & IEP7

* Replacement cost is R13

C.2.2 Thermal housing

The cost of a ceiling is taken to be R450.00 per ceiling, based on work by Simmonds (1997).

The energy consumption before installation of the ceiling is taken as the average for a low-income urban household. While it is clear that one household would not probably not use these fuels in the combination specified, taking an average of all households allows the analysis to estimate the impacts for a large programme rather than one specific household. The energy consumption figures are taken from the SAtoZ survey.[6]

The overall annual energy savings are estimated as 20%, which represents a 50% saving on space heating for three months of the year (see Simmonds 1997 for methodology for estimating energy savings).

Table 24: Weighte average energy consumption for space heating before and after installation of ceiling

	Before ceiling Source: SAFocus	*After ceiling* Assumed saving of 50%
Electricity [kWh/mth]	0.5	0.3
Coal [kg/month]	7.3	3.7
Wood [kg/month]	4.5	2.3
Paraffin [litres/month]	1.2	0.6
Gas [kg/month]	n/a	n/a

C.2.3 Efficient refrigeration

Table 25: Characteristics of refrigerators

	Efficient fridge	*Standard fridge*	Sources
Cost [R]	R 3 000	R 2 400	Suppliers
Power [W]	88	100	Marbeck (1997)
Duty cycle [hrs/day]	7.9	15.6	Marbeck (1997)

C.2.4 Cooking appliances

Table 26: Characteristics of stoves

Electric stove		*LPG stove*		*Paraffin stove*	
Cost [R]	*100*	*Cost [R]*	*40*	*Cost [R]*	*50*
Use [hrs/day]	2.5	Use [hrs/day]	2.5	Use [hrs/day]	2.5
Efficiency [%]	65%	Efficiency [%]	50%	Efficiency [%]	30%
Power [kW]	1.2	Power [kg/hr]	0.11	Power [l/hr]	0.24
ADMD [kW]	0.9	Supply loss	5%	Supply loss	5%

6 These must be updated with the 1998 survey results – awaiting information from Eskom Marketing Intelligence.

C.2.5 Programme overheads

For each intervention, the programme overhead costs are taken as R750 000 in year one and R450 000 per annum thereafter.

C.2.6 Greenhouse gas emissions factors

The emission factors for fuels in South Africa are shown in Table 27, as emissions per delivered unit of energy.

Energy source	*South Africa* *kg CO_2/GJ*	*IPCC default factors** *kg CO_2/GJ*
Coal**	104	94.6
Paraffin	71.5	71.3
Gas	56.1	56.1
Electricity delivered**	287.4	..
Wood	0	..

Source: Davis & Horvei (1995); IPCC (1996); author's calculations.

* IPCC default CO_2 emission factors for comparison.
** Incl. CO_2 equivalent for methane emissions related to coal mining.
*** excluded losses in T&D.

Table 27: CO_2 emission factors

The emission factor for electricity was calculated based on the coal burned by Eskom power stations for electricity generation in 1996. In that year, Eskom burned 85.4m t which led to an emission of 157m t CO_2 or 266 kg CO_2/GJ electricity generated in coal-fired power stations; applied to the total electricity generated by Eskom, this amounts to 243 kg CO_2/GJ. For transmission and distribution (T&D), a 10% loss is assumed.

To this, the CO_2 equivalent of methane coming from mining coal for electricity generation is added, which is approximately 473 000t methane or approximately 9.9m t of CO_2 equivalent. Altogether, the emission factor used in this report amounts to 287.4 kg CO_2/GJ electricity delivered to the end-user. For more detail on this calculation, see Praetorius and Spalding-Fecher (1998).

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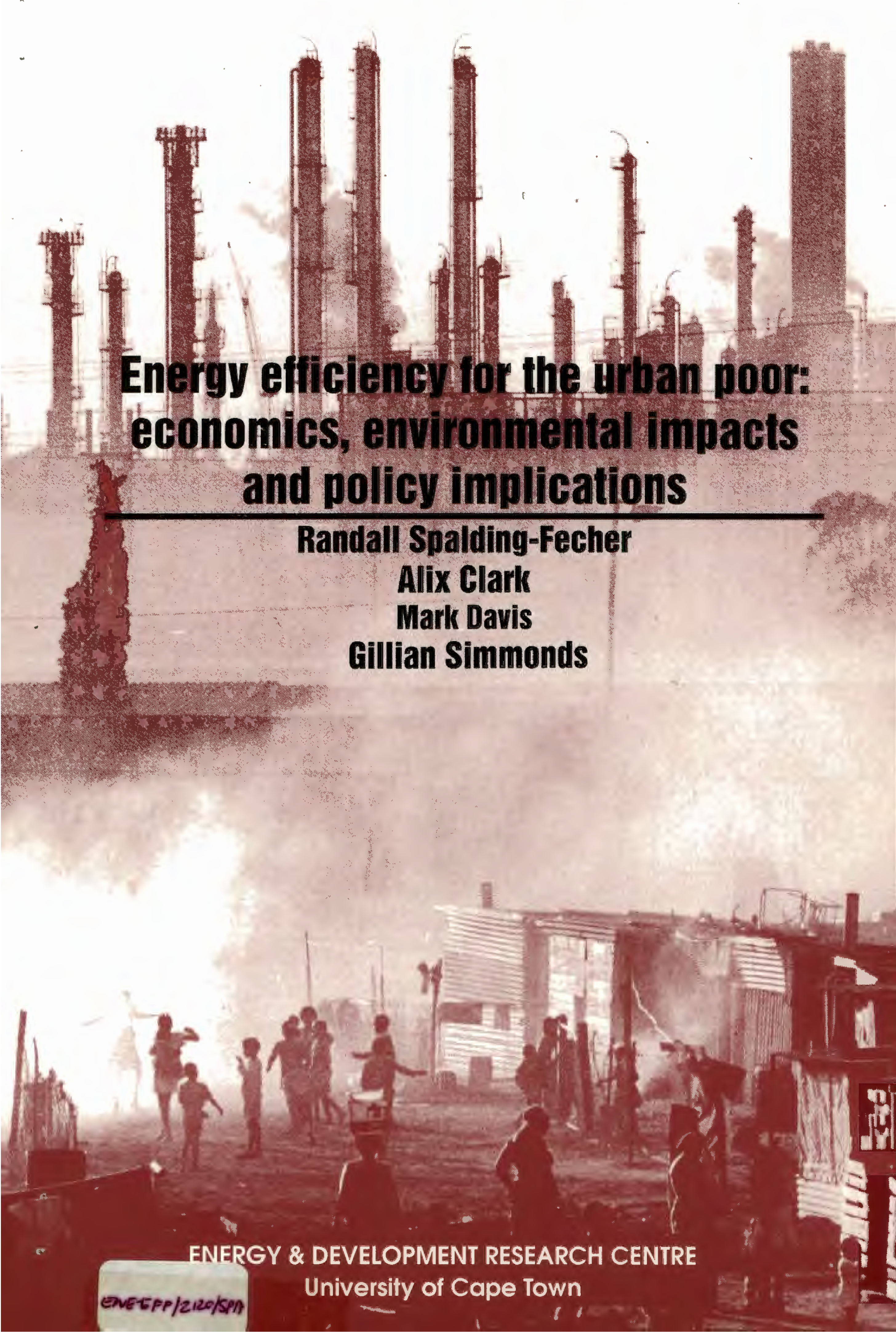

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