The real cost of conserving energy: Energy efficiency in low-income urban households

---

RANDALL FECHER

August 1998 (revised)
ENERGY & DEVELOPMENT RESEARCH CENTRE
University of Cape Town

Table of contents

List of tables

List of figures

Executive summary

This paper forms part of a synthesis of research on energy efficiency in low-income urban households by the Energy and Development Research Centre (EDRC). The research falls under EDRC's Energy Efficiency, Equity and Environment (E4) project, which is co-sponsored by Eskom and the International Development Research Centre of Canada.

The purpose of this volume is to show the magnitude of the national benefits resulting from residential energy efficiency in low-income urban households. The report synthesises the financial and economic analysis that has been conducted for individual energy efficiency interventions over the course of the E4 project, and presents a combined economic analysis from the perspectives of the nation and Eskom. This analysis standardises many of the key assumptions and presents them systematically for the benefit of the reader. The previous reports under this research programme that are referenced include work by Simmonds (1997) on thermal improvements, Clark (1997) on energy-efficient lighting, Thorne (1997) on life-cycle costs of fuel/appliance combinations, and Borchers (1997) on fuel-switching strategies.

The results of the analysis show that significant economic benefits can be achieved while saving energy and avoiding generation capacity investments. Eight of the ten interventions that save energy for low-income households are less expensive than the cost of new energy supply, and the other two will also be less expensive if the use of household hot water rises with access to running hot water. Avoided environmental and health risks play a major role in these benefits, but are by no means the only source of savings. Economic benefits are also apparent from Eskom's perspective, as all four interventions avoid new peak generation capacity at a lower cost than building new plants, even if Eskom subsidises the intervention heavily. This is not the case, however, with the net benefit *to Eskom*.

Using Cost of Conserving Energy (CCE) as a measure to compare energy efficiency and fuel switching interventions with new supply, all but two of the interventions are below the benchmark values for the cost of paraffin, gas and electricity. The CCE for thermal improvements is slightly higher than the cost of new coal, but provides other comfort and health benefits. Switching from paraffin to solar hot water heating with electric backup will also be economically attractive if household hot water use rises: the same will also make switching from paraffin to gas for water heating more attractive.

For the electricity sector, thermal improvements, energy-efficient lighting, and switching to gas for cooking and space heating can avoid peak capacity at or significantly below that of new plants. While switching to electric lighting from paraffin and candles will increase capacity requirements somewhat, this is small in comparison to the savings from the first four interventions. If solar hot water heaters have an electric geyser for backup, however, there is the potential for a large peak load (particularly in winter), even though annual electricity use will be small: gas or paraffin backup should be explored instead given the low cost of solar water heating.

Although calculations of the cost of conserving energy are affected by changes in key input variables such as appliance cost and efficiency, the cost of conserving energy generally remains below the cost of new supply. A significant increase in the cost of a ceiling would make thermal improvements somewhat expensive, as would highly inefficiency gas appliance for switching from electricity to gas, but both of these scenarios are unlikely. The effect on Cost of Avoided Peak Installed Capacity (CAPIC) from changes in appliance cost, discount rate and peak coincidence is much more significant. If the peak coincidence of power use for electric cooking and space heating were 10% lower than assumed here, the fuel switching interventions would be more expensive that a new peak power plant.

To understand the magnitude of the energy saving interventions, it is useful to compare them to total national energy use. Total domestic electricity consumption

in 1996 was nearly 4 800 GWh (Eskom 1996b). Just thermal improvements and energy-efficient lighting would save 210 GWh, or 5% of current consumption – and this is only looking at the low-income urban sector. Of course, this is electricity saved in 2007 – by which time baseline consumption could easily reach 6 000 GWh. Because we are focusing on peak electricity, it is also useful to compare the savings to electricity generated by peaking pump storage stations. Total electricity sent out from Eskom's pump storage stations in 1996 was 2 220 GWh (Eskom 1996b). In other words, just these two interventions could theoretically save a 10% of all of the electricity produced by peak capacity in 1995, with economic benefits for every kilowatt hour saved. The total energy savings from all interventions, including paraffin, coal and other fuel savings, comes to over 2 300 *GWh* equivalent in 2007 – almost half the total domestic electricity consumption of the entire country today.

Comparing installed capacity to avoided peak capacity is even more striking. Eskom's current pump storage facilities have a net maximum capacity of 1 400 MW. Without a concerted strategy for demand-side management and energy efficiency, that capacity will necessarily increase dramatically after currently mothballed plants are brought back on line, and as domestic power use during peak hours climbs. The four interventions outlined in this report that avoided peak capacity would, however, eliminate the need for over 2 400 MW of peak capacity in 2007 – more than is currently in place. Again, it is important to recognise that these are all savings from the low-income urban sector – middle- and upper-income households are not included. In addition, the significant savings of base-load power have not been included in this analysis. Further research is needed on the implications for domestic gas markets of switching to gas for cooking and space heating on a large scale.

As important as the specific results of this analysis is the methodology presented, which compares demand- and supply-side options for energy services on an equal basis. Analysts and stakeholders in the energy sector may disagree over the assumptions used, particularly the long run marginal cost of energy. The methodology, however, is robust enough to incorporate changes in these assumptions. In fact, this approach provides a tool for weighing up different options from a national perspective over a range of assumptions, to facilitate better allocation of national resources. The methodology is probably best suited, however, to interventions that only involve one fuel, because the calculations become more complex and less straight-forward for fuel switching. Other analytical tools should be explored to understand what kinds of fuel switches are beneficial for consumers and the nation.

The analysis from Eskom's perspective also raises important questions about the methodology as well as the regulatory structure of the electricity industry. The calculation of CAPIC from Eskom's perspective shows that all of the electricity saving interventions are at or well below the cost of new supply. Eskom might argue, however, that the relevant measure is not CAPIC but the Net Annual Benefit, which includes revenue losses as well as avoided electricity costs. From a net benefit perspective, none of the interventions is attractive to Eskom. In an environment where Eskom generates profits through a margin on each kWh sold, energy efficiency will almost never be attractive for the utility even if it is economically beneficial for the country. This is why many countries have moved to "rate of return" regulation for public utilities, where utilities make a return on capital regardless of how much electricity is sold. Including energy efficiency investments in the rate base, in some cases even with a higher rate of return than for supply-side capital, provides economic and financial incentives for utilities to invest in efficiency programmes that are good for the country. The South African government and National Electricity Regulator would do well to consider these issues in the current debates on the future structure and regulatory framework for the industry.

Energy efficiency and fuel switching interventions in low-income urban households can provide significant economic, environmental and energy saving benefits. The interventions presented here are good examples of 'low hanging fruit'

– savings that produce 'win-win' results for communities and the nation. If South African policy makers, industry, and community organisations do not move forward with energy efficiency strategies for the poor, they will be foregoing a golden opportunity to meet the national goals of economic efficiency, environmental sustainability, and equity. In an era where the decisions of South-African policy-makers are complicated by a constant barrage of conflicting priorities and insufficient analysis, one thing is clear: it is generally cheaper to save energy than to produce it.

1. Introduction

This paper forms part of a synthesis of research on energy-efficiency in low-income urban households by the Energy and Development Research Centre (EDRC). The research falls under EDRC's Energy Efficiency, Equity and Environment (E4) project, which is co-sponsored by Eskom and the International Development Research Centre of Canada.

The purpose of this report is to show the magnitude of the national benefits resulting from residential energy efficiency in low-income urban households. The report synthesises the financial and economic analysis that has been conducted for individual energy efficiency interventions over the course of the E4 project, and presents a combined economic analysis from the perspectives of the nation and Eskom. This analysis standardises many of the key assumptions and presents them systematically for the benefit of the reader. The previous reports under this research programme that are referenced include work by Simmonds (1997) on thermal improvements, Clark (1997) on energy efficient lighting, Thorne (1997) on life-cycle costs of fuel/appliance combinations, and Borchers (1997) on fuel-switching strategies.

As discussed throughout this volume, conducting this type of analysis in South Africa involves many necessary assumptions, some of which individual analysts may dispute. More important, however, is the methodology used for this analysis, as it can accommodate changes in any of the basic assumptions. The interventions analysed here are illustrative, but by no means comprehensive. The objectives of this analysis, therefore, are not only to highlight the tremendous potential of these interventions to meet efficiency, equity, and environmental goals, but also to lay out a framework that can be used for ongoing energy-efficiency research in the low-income sector.[*]

Section 2 defines the scope of the analysis and the interventions considered. Section 3 then outlines the methodology used, including general principles and key assumptions. Sections 4 through 7 show examples of the actual calculations of energy savings and economic benefits from a national perspective, while Section 8 addresses Eskom's costs for the same interventions. Finally, Section 9 presents 'cost of conserved energy curves' and 'cost of avoided installed peak capacity curves', which combine both energy savings and costs for the nation and Eskom. Conclusions follow in Section 10, and spreadsheets with all of the calculations appear in the Appendix.

2. Scope of analysis

This analysis forms part of a broader effort to synthesise the strategies and recommendations for energy-efficiency interventions in the low-income urban sector. Because there is not sufficient data or previous research on all possible interventions and strategies, only those that were the focus of the E4 project are included in this economic analysis. The exception is appliance labelling, for which strategies have been developed, but for which data for economic analysis is relatively limited. In addition, some interventions could improve environmental quality and equity, yet increase energy usage. While these measures may be socially and economically desirable, they have not been included in this report – although some measures that save energy but increase electricity use have been. For fuel switching in particular, all of the interventions chosen have both energy savings and economic benefits. For these interventions, therefore, there is no trade-off between economic efficiency and energy efficiency – the interventions benefit both the consumer and society.

---

[*] The author is grateful for the comments received from Ashok Gadgil and Jonathan Koomey (Lawrence Berkeley National Laboratory) and Jean Louis Pabot (Eskom)

2.1 Interventions included

The interventions included in the cost of conserving energy analysis are as follows:

- Energy-efficient lighting: switching from incandescent to compact fluorescent lamps.
- Thermal improvements to low-cost housing: ceilings and passive solar orientation.
- Fuel switching: switching from one fuel/appliance combination to another, such as:
    - paraffin to gas for cooking, water heating and space heating;
    - electricity to gas for cooking and space heating;
    - paraffin to solar hot water heating with electric backup;
    - paraffin and candles to electricity for lighting.

In addition, switching from paraffin to electricity for cooking was analysed, but this increased energy use and was therefore not included in the summary analysis.

The rationale for these interventions is discussed in detail in the companion volume to this report entitled 'Energy strategies for the urban poor' (Simmonds & Clark 1998). For thermal improvements, the focus is on taking advantage of the window of opportunity to improve new RDP housing when it is built, rather than relying on more costly retrofits. For energy-efficient lighting, the link to the electrification programme and Eskom's energy-efficient lighting programme will speed the penetration of efficient bulbs and the economic benefits they bring. Fuel switching may be more successful if it targets new homes, or families whose current homes are being electrified, but for the purposes of this analysis the entire urban low-income urban sector is considered.

Although efficient electricity use is a priority in identifying urban interventions, given the ambitious targets for the electrification programme, this analysis is not confined to electricity. Energy savings and economic benefits from changes in the use of other fuels are also considered.

2.2 Time frame for energy savings analysis

To provide a basis for comparison, all energy and electricity savings are calculated at year 10, or annual savings in 2007 – relative to what demand *would have been* in that year, not relative to actual use in 1997. Energy consumption is likely to rise even with significant energy-efficiency interventions, as development proceeds, but these measures would significantly mitigate that growth while providing equivalent or superior energy services to low-income households.

2.3 Length of time for efficiency programmes

The energy-efficiency interventions analysed in this report will take time to implement. The thermal improvements programme is based on the goals of the RDP housing programme over the next five years. For energy-efficient lighting, Eskom expects to distribute bulbs over the entire ten-year period once a programme is launched. Fuel switching is more complex, since the changes may be related (though not restricted) to new housing and electrification programmes. For the purposes of this analysis, we assume that fuel switching occurs gradually over the ten-year period. For purposes of assessing the cost of conserving energy, however, the costs per household is calculated, which is independent of when that particular household changes their energy use pattern.

2.4 National and Eskom perspective

While the larger part of this report is devoted to analysing the economics of energy efficiency from a national perspective, the analysis of the key question of building the next power plant also includes Eskom's perspective. The costs and benefits to Eskom of avoiding new peak installed capacity are presented following the national analysis. Alternative measures for Eskom's perspectives are also discussed. The cost of conserving *energy* calculation is presented only from the national perspective.

3. Methodology

3.1 General principles

3.1.1 Economic versus financial analysis

Because the purpose of this report is to demonstrate the costs and benefits of energy efficiency for society as a whole, the results are based on economic rather than financial analysis. Economic analysis considers all of the costs and benefits to society, which include but are not limited to the private costs that are normally used in financial analysis. The first set of cost of conserving energy curves shown at the end of this report are therefore from a national perspective, not that of Eskom or individual consumers. This is followed, however, by an analysis from Eskom's perspective. For the economic analysis from a national perspective, the following steps were taken to convert any financial data into economic costs:

- In all cost elements, taxes and subsidies are removed. Fuel and appliance costs, for example, do not include VAT. Fuel costs, where possible, are based on long run marginal costs instead of current prices (see section 3.2.3).
- External costs and benefits are added to the analysis. The 'avoided external costs' from reducing energy use would include reduced health risks associated with decreased indoor air pollution, reduced risks of paraffin and candle fires and burns, reduced incidence of paraffin poisoning, and the reduced impact of coal-fired power generation on water quality and air pollution. Note that switching fuels (eg from paraffin to electricity) can eliminate some external costs while adding others. Not all serious external costs have been (or can be) quantified for South Africa, so this report relies on the work of Van Horen (1996a; 1996b), updated by Borchers (1997) and modified as presented under 'Key assumptions'.
- A social discount rate was used, rather than a corporate or individual discount rate. This discount rate reflects society's preference for long-term benefits and sustainability (Pearce & Warford 1993). The justification for the discount rate chosen is presented under 'Key assumptions'.

The economic data and assumptions are then used to determine the total costs of the different interventions, taking into account the timing of different costs and benefits as described in the next two sections.

3.1.2 The cost of conserving energy versus life cycle costs

There are (at least) two basic approaches to ranking different options for providing energy services using demand- and supply-side options. One is to do an economic cost-benefit analysis based on the 'life cycle costs' of different options for meeting an energy service demand. For example, to make a decision about which fuel/appliance combination is economically superior for cooking, we could analyse all the costs associated with provided cooking services from these combinations – including fuel costs, appliance and fuel access costs, ongoing maintenance costs and external costs. All of the costs occurring in future years would be discounted to the present to arrive at a present value life cycle cost. Whichever option had the lowest present value life cycle cost (for the equivalent service) would then be the most beneficial choice from the perspective of society.

Another approach, which is presented here, is referred to as the 'cost of conserving energy' (CCE) or 'cost of saving energy', modified from the work of Gadgil and Jannuzzi (1991). This technique was developed to rank a large number of demand-side options of various sizes and to compare them to the cost of new energy or power. To calculate CCE we identify all of the costs associated with a demand-side management interventions less any savings compared to the base case. Because we want to know how much we pay *not* to use energy, *the energy savings themselves are not normally included in the cost calculations.* In other word, CCE is based on all of the costs, *other than energy,* to conserve rather than use more energy.

For example, if we install energy efficient lighting, we incur new costs of the compact fluorescent, but avoid the costs of incandescent bulbs. We also may reduce the external costs associated with electricity by using less power. The *net* increase in cost, then, is the incremental cost for the purposes of CCE. If we divide this annual cost by the annual energy savings, the CCE is expressed in R/MJ or R/kWh and is directly comparable to the cost of new energy. If our intervention costs 2 c/kWh, for example, and the current cost of electricity is 5 c/kWh, then it makes sense to invest in efficiency rather than electricity production.

Obviously not all of the costs are annual: a compact fluorescent bulb, for example, is purchased once and lasts for five to ten years. Capital costs are converted to annual costs by 'levelizing' them, as described in the next section. This allows us to compare interventions that have different economic lives (for example, appliances that have different working lives). The costs that are included in the CCE analysis are detailed in Section 3.2.2 below.

This approach works well for interventions that conserve one type of fuel. Interventions that save primary energy by encouraging switching between fuels, however, are more problematic. The cost of energy (eg Rand/MJ of primary energy) is not the same for different energy sources, because of the varying quality of energy (ie the ability to perform useful work) and the market structures for different fuels. Because the primary energy cost changes during a fuel switch, we must add the cost of the new fuel to our incremental cost used in the CCE calculation and divide that cost by the amount of initial fuel/energy source that is saved. (Swisher, Jannuzzi and Redlinger 1997). The implications of this technique are discussed in the conclusions to this paper.

3.1.3 Levelised costing

Calculating the cost of conserving energy is complicated by the fact that different costs and benefits occur at different times. Some occur only once, such as the cost of installing a ceiling in a house; others, such as avoided external costs of coal for space heating, occur throughout the life of the technology intervention. To convert one-time costs to annual costs, we use the technique of 'levelised costing', in which one-time capital costs are converted to annual (or daily, or any time period) costs. They can then be added to annual operating savings, changes in maintenance costs, or any other ongoing changes. The relationship between the levelised capital cost and initial capital cost is same as that between loan payments and loan capital. The present value of the levelised capital costs, using the appropriate discount rate, over the life of an intervention (like the term of a loan) is equal to the initial capital cost.[1]

The levelised capital cost is then added to any other annual costs and benefits to yield a total levelised cost. This is the cost that, divided by energy savings, gives us the cost of conserving energy, which is comparable to the cost of supplying energy. The calculations are shown in detail under each intervention below.

3.1.4 Cost of avoided peak installed capacity

Another measure of the cost-effectiveness of energy efficiency investments is the cost of avoided peak installed capacity (CAPIC). CAPIC refers to the incremental cost of avoiding future capacity investments for peak electricity generation. The emphasis is on peak capacity because of the disproportionate impact on peak loads from residential electricity demand. Unless a given end-use occurs only during

---

[1] All values in this report are levelised to the end of the year, as is standard practice in energy efficiency analysis. The formula for the levelised annual cost (c) of a total investment (I) over n years at interest rate r is: $c = I \times r/[1-(1+r)^{-n}]$.

peak hours (eg 18:00 to 20:00), however, energy-efficiency interventions will avoid some base load capacity as well. CAPIC therefore will *overestimate* the cost of avoiding capacity, because all of the costs of the intervention are divided by only the peak capacity avoided (see Koomey et al (1990) for further explanation).

The CAPIC from energy-efficiency investments can be compared to the cost of building new plants to indicate where the utility and country should be investing. If the CAPIC for efficiency investments is lower than the cost of new peak plants, then efficiency investments should be given priority. An energy efficiency project with a CAPIC of R1000 /kW, compared to a new pump storage facility at R1800 /kW, would save R800 for every kilowatt avoided rather than installed.

3.1.5 Programme costs

To implement the energy efficiency measures analysed in this report will obviously require expenditures on a programme that could include financing, appliance distribution schemes, awareness campaigns, and other measures. Subsidies are not part of programme costs from an economic perspective because they are merely transfers from one group to another, much like VAT, rather than additional expenditure on labour, materials, equipment, etc. In the Eskom analysis, however, various subsidy levels are explicitly included. Incremental programme costs should be included in a full analysis of the cost of conserving energy. However, since these programmes have not yet been formulated, much less evaluated financially, non-subsidy programme costs are not included in these calculations. It is expected, based on experience in other countries and Eskom's own integrated electricity planning documents (Eskom 1997), that in most cases the programme costs will not nearly outweigh the significant economic benefits of these interventions.

3.1.6 National versus Eskom costs

From the perspective of the nation, the economic analysis investigates the costs of providing a given level of energy service. Because the objective is to assess the least expensive way of meeting that level of service, the analysis only needs to consider the costs (or change in costs) of different interventions. Eskom's perspective is more complex, however, because Eskom's role in the electricity sector is not entire clear. For a private firm, and energy efficiency project would only be implemented if it produces a net benefit, which for a private utility would have to included revenue losses from decrease sales. If we assume that Eskom is similar to a consumer co-operative, then the key test for energy efficiency interventions would be whether they result in lower tariffs (often called the "Ratepayer Impact Test"). If Eskom is an asset owned by the state whose purpose it is to provide social benefits, then a measure such as Total Resource Cost (see Swisher, Jannuzzi and Redlinger 1997 and Surtees 1998) would be useful. This paper examines how CAPIC could be used for a utility and whether it is an appropriate measure.

3.1.7 Uncertainty and sensitivity

All of the input data for this analysis carries with it a degree of uncertainty, either because the values are simply not known or because they vary over time or by location. The benchmark economic costs of fuels, for example, are difficult to quantify without an in-depth technical analysis of current and future energy-producing technologies. Similarly, appliance costs can vary significantly from town to town, and the purchasing choices that individual consumers make influences the benefits from that appliance/fuel choice. Borchers (1997) has discussed the uncertainty and limitations associated with the fuel switching analysis in more detail than will be presented here. In most cases the central value used to calculate incremental costs is the 'best estimate' based on the data that is available in South Africa, and the experience of the authors of the supporting studies (eg Thorne 1997; Clark 1997; Simmonds 1997). Where ranges exist, an effort has been made to estimate what costs the urban poor would most likely face. However, significant research is still needed to clarify where the urban poor fall within the range of costs for, for example, appliances or locally available fuels.

A sensitivity analysis is presented in each section of the cost curves to test the impact of changing several key variables on whether efficiency interventions are less expensive than using energy.

3.2 Key assumptions for all interventions

3.2.1 Social discount rate

The discount rate is used to convert future costs into their present value. Discounting reflects the general understanding that payments in the future are not worth the same as payments today because, for example, money received today could be invested to yield a higher value in the future. The discount rate reflects an individual or societal preference for receiving payments today rather than in the future. Of course costs in the first year, such as the cost of a new appliance, do not need to be discounted, but all those in future years must be. On the other hand, the discount rate is used to convert the initial cost of an appliance to an annual levelised cost (see explanation in Section 3.1.3).

The discount rate used in economic analysis is generally lower than that used in financial analysis, because it reflects the opportunity cost of capital for society, rather than for individuals or firms. In recent years this real discount rate has been at 8% for government projects in South Africa, so this value is used here (Davis & Horvei 1995: 5.5). There are additional arguments for a low social discount rate, including society's concern for long-term sustainability. High discount rates tend to undervalue future impacts (particularly future costs) of current policies, while lower discount rates give more equal weight to future and present impacts. When dealing with projects with significant social and environmental impacts (positive or negative), some authors maintain that values below 5% are more appropriate (Perrings 1991).

Interestingly, Eskom uses a discount rate of 6% in their analysis of future electricity planning, reflecting their financial stability and relatively easy access to capital. Private firms would typically use a real discount rate of 10-15%. For the Eskom analysis, the 6% discount rate is used.

3.2.2 Cost components included in levelised costs

For detailed explanation of cost components, see the original papers on thermal improvements (Simmonds 1997), energy-efficient lighting (Clark 1997) and economic costs of appliance/fuel combinations (Throne 1997).

For thermal improvements, the incremental costs include:

- the cost of installing ceilings in new homes (other passive solar interventions are low or no-cost);
- avoided external costs.

For energy-efficient lighting, the incremental costs include:

- the cost of the CFL;
- avoided cost of incandescent bulbs;
- avoided external costs.

The incremental costs of fuel-switching interventions are based on the following costs and savings:

- new appliance cost;
- cost of access to the new energy source (such as electricity connection, gas bottle deposit);
- new fuel cost
- electricity connection maintenance;
- avoided costs of old appliance (assumes that appliance was replaced at the end of its economic life); and
- external costs of new fuel less external costs of old fuel.

3.2.3 Long run marginal energy costs

The benchmark against which we compare the CCE is the long run marginal cost (LRMC) of energy. The LRMC of supplying energy to urban households should include the costs of production and distribution for new energy supplies over the life of the supply technologies required to deliver energy (ie power plants, refineries). For electricity, this would include the long run costs of generation, transmission and distribution for both peak and off-peak electricity. Current prices for fuels are generally based on the historical, depreciated costs of energy investments or rapid fluctuations in demand, and so do not accurately reflect the future costs of energy supply.

Estimating the LRMC for electricity is complicated by four factors: first, projections of LRMC delivered to the end-user, where they exist, are generally not in the public domain; second, for electricity we must distinguish between LRMC for peak and off-peak because of the different load profile of each end-use; third, Eskom uses a 6% discount rate to levelise the capital cost portion of electricity cost, rather than the 8% national discount rate; finally, because Eskom currently has surplus capacity, the LRMC is likely to rise rapidly over the next ten to 15 years as capacity constraints are reached and new construction is required.

For the purposes of this analysis, Eskom's future costs of electricity are the most relevant because it will take several years to develop a robust demand-side management programme that reliably avoids the need for electricity production. Eskom must decide in the next few years whether and what kind of peak plants to build so that they would be on-line in 2007. (Craemer 1997). Pump storage facilities in particular can require seven years of planning and construction before they are commissioned (Eskom 1996c). Instead of varying the cost of electricity every year, then, this analysis compares CCE to the cost of electricity in 2007 (expressed in 1997 Rand).

One indication of future costs for peak electricity to the end-user is Eskom's proposed Domestic Time of Use Tariff for peak periods (the evening peak is from 18:00 to 20:00). This tariff (42 c/kWh) less taxes would reflect the projected costs of bringing peak electricity to the end-user, including transmission and distribution losses (Surtees, 1997).[2] To convert this ex-VAT cost of 36.8c/kWh to cost per kWh sent out from the plant, we must multiply by kWh delivered/kWh sent out, which is the efficiency of transmission and distribution. The estimated LRMC of peak electricity for Eskom is therefore 33.2 c/kWh sent out. For the national perspective, the capital portion of this cost must be adjusted upward to reflect the higher national discount rate (just as higher interest rates mean higher loan payments for the same principal). Up to 80% of the peak electricity cost is capital charge (Pabot 1998), so the LRMC of peak electricity for the nation is 38.5 c/kWh sent out.[3]

For off-peak electricity, Davis and Horvei's (1995) manual for the Department of Minerals and Energy puts the overall LRMC at 6 c/kWh for generation and 8.3 c/kWh including transmission and distribution, based on Eskom's average load factor.[4] These costs were based on the assumptions that Eskom uses for long-range financial analysis of electrification. The 8.3 c/kWh is the cost for Eskom per unit of electricity sent out, and does not include transmission and distribution losses. For the national economic cost, we must again adjust the capital portion of electricity cost, which is roughly 50% of the total (Pabot 1998). Correcting for the different national discount rate yields an economic LRMC of 9.2 c/kWh. This 'off-peak' rate, of course, includes the morning peak and the hours on either side of the evening

---

[2] This assumes that any profits included in the tariff are factor payments to Eskom and distributor capital rather than monopoly profits.

[3] This adjustment is based on the difference in levelized capital costs over 30 years for 8% versus 6% discount rate. The capital payments with 8% interest would be about 20% higher. If we take 80% of 33.3 c (26.6c) and adjust it upward by 20%, then we have a new cost of 31.83 c (adjusted capital cost) + 6.83 c (operating costs) = 38.46 c/kWh.

[4] The formula is: Total cost = Generation cost (R/kWh) + T&D cost (R/kW) x load factor (kW/kWh).

peak, so is an average of these different periods. To convert this cost per kWh sent out to cost per MJ of primary energy, we first multiply by generation efficiency (0.343) and then by a 0.278 MJ/kWh.

For other fuels, far less information is available on LRMC. In these cases, the economic cost is taken as the fuel price less taxes. Clearly more research will be needed to clarify the economic costs of these fuels. LRMC of energy is shown in Table 1, including cost per unit of primary energy. These are the benchmarks that will be used to compare with CCE in this analysis.

Fuel	*Units*	*Cost (c/unit)*	*Cost (c/MJ primary)*
Electricity			
- Peak	c/kWh	38.7*	3.7
- Off-peak	c/kWh	8.9*	0.9
Coal	R/kg	0.24	0.9
Paraffin	R/l	1.31	3.45
Gas	R/kg	1.99	4.0
Wood	R/kg	0.48	3.1
Candles	R/candle	0.50	14.5

* cost per kWh sent out from plant, including transmission and distribution costs

Source: Simmonds (1997: 10-11); Surtees (1997); Davis and Horvei (1995: 6.7)

Table 1: Estimated economic LRMC of energy

The actual cost of electricity for a particular *end use* depends on what share of the electricity is used during the peak and off-peak periods, or the peak electricity use (PEU)[5]. The peak period here is taken to be from 18:00 to 20:00. The PEU will vary by end uses: lighting, for instance, will be used more during the evening peak, while water heating is used over more hours of the day. PEU by end-use is another area that requires significant research to improve the accuracy of DSM forecasts and planning. The estimated PEU and resulting electricity costs for each end-use is shown below in Table 2.

End-use	*Percentage*	*Elec. cost (c/kWh sent out)*	*Elec. cost (c/MJ primary)*
Cooking	50	23.9	2.3
Water heating	50	23.9	2.3
Space heating	50	23.9	2.3
Lighting	70	29.7	2.8

Table 2: Peak electricity use assumptions

3.2.4 Eskom costs and revenue

By encouraging energy efficiency, Eskom will avoid the cost of producing electricity, particularly peak electricity. Currently, however, because there is surplus capacity in South Africa, Eskom's marginal cost of electricity is only a few cents per kWh. This surplus will be exhausted over the period covered by this analysis. As described above, Eskom's costs in this analysis are the LRMC of generation, transmission and distribution in 2007 (in 1997 Rands), to reflect the true long run costs to Eskom of supplying electricity services. Eskom has stated that, without major interventions, they will have to build new large-scale plants by 2007 (Craemer 1997).[6] To summarise, the assumptions for Eskom's cost per kWh sent out from the plant are 33 c/kWh peak and 8.3 c/kWh off-peak, while cost per kWh

---

[5] Peak electricity use = peak hours of use / total hours of use

[6] This does not include commissioning units are already on order, such as Majuba.

delivered is 37 c/kWh peak and 9.3 c/kWh off-peak. Revenue for Eskom is based on 1997 household tariffs of 26 c/kWh (Surtees 1997).

3.2.5 Fuel cycle efficiencies

The efficiency of energy use is a critical determinant of the economic benefits of conserving energy. For a comparative study of energy needs of delivering equivalent energy services, we should assess not only the changes in final energy needs, but also the energy needed to produce and deliver that final energy to the household. Therefore, ideally we would compare fuel cycle efficiencies instead of appliance efficiencies only. Because of a lack of data, however, energy needed for the refining, transporting and supplying energy carriers such as coal, paraffin, wood and candles to the household can not be considered in the analysis. Only for electricity are data available and included in the following calculations. For reasons of simplification, this difference in treatment is justified since the generation of electricity from primary energy has a very low efficiency of about 34%. However, for a comprehensive study, losses in refining crude oil to paraffin and in distributing gas would also have to be included. The assumptions for fuel cycle efficiency are shown below, with the middle of the range efficiency for appliances. Only those end-use appliances that are addressed in subsequent fuel-switching analysis are included.

Conversion/appliance	*Efficiency (%)*	*Conversion/appliance*	*Efficiency (%)*
Electricity generation	34.3	Paraffin space heater	73
Electricity transmission and distribution*	90	Gas space heating	75
Paraffin wick stove	28	Electric radiant heater	100
Gas ring	50		Lumen hours/MJ
Electric hot plate	65	Candle	56
Electric storage geyser	70	Paraffin wick lighting	330
Gas geyser	70	Incandescent bulb	3000
Paraffin wick/pot for water	28		
Solar water heating with electric storage backup	234**		

Source: Thorne (1997), Eskom (1996), Eskom (1995), Cowan et al (1992)

* Reflects 10% technical losses from transmission & distribution

** Most of the energy for this system comes from sunlight, so output energy divided by input electrical energy is greater than 100%

Table 3: Fuel cycle efficiencies

3.2.6 Appliance and access costs

For the fuel-switching calculations, the cost of appliances and access costs for fuels are the major components of incremental costs. The costs used in this analysis are drawn from the survey work by Thorne (1996) on the costs of energy services. The assumptions for average appliance cost are shown in Table 4 below.

Appliance	*Cost (Rand)*	*Appliance*	*Cost (Rand)*
Paraffin wick stove	107	Paraffin space heater	31
Gas ring	35	Gas space heating	245
Electric hot plate	104	Electric radiant heater	52
Gas geyser	4300	Paraffin pressure lighting	192
Solar water heater with electric storage backup	4770	Incandescent bulb	2.1
		Candle	0.40

Source: Adapted from Thorne (1996 and 1997)

Table 4: Cost of appliances for the low-income sector

The two main access costs for fuels are the cost of an electricity connection and the cost of a gas bottle deposit. For the electricity connection, the economic cost of R2 170 (the cost to society, not necessarily what the customer pays) was distributed across end-uses based roughly on power usage. In addition, the maintenance cost for an electrical connection of approximately R25 per month was also distributed across end-uses similarly. Because the fuel-switching strategies outlined in this project recommend gas use mainly for cooking and space heating, the access cost is divided equally between these two end-uses. The summary of access costs by end use is presented in Table 5 below.

End-Use	*Power share (%)*	*Elec. Access cost (R)*	*Annual elec. maintenance cost (R)*	*Gas access cost (R)*
Cooking	25-30	597	83	78
Space heating	15-20	380	52	78
Lighting	5-10	163	23	
Water heating	35-45	868	120*	
Refrigeration	5-10	163	23	
Total		2170	300	156

Source: Adapted from Thorne (1997)

* R60 for electric backup for solar water heating

Table 5: Access and maintenance cost for fuels

3.2.7 Economic life of interventions and technologies

Economic costs and benefits are spread over the life of an appliance or other energy efficiency intervention. The overall cost of conserving energy depends on the life because capital costs are levelised over the life of capital investments. The economic life of a ceiling is assumed to be 20 years. This is conservative because many of the low and no-cost thermal improvements (eg siting and orientation) will have an impact for even longer. For energy-efficient lighting, CFLs are assumed to last ten years, or 10 000 hours at 1000 hours per year. The economic lives of appliances relevant to fuel switching are shown in Table 6. Even though appliances have different economic lives, the *levelised* cost of the interventions is comparable because it already takes into account appliance life.

The life of an electrical connection is estimated at 30 years. For access to gas, the up-front cost is a deposit on the gas bottle. Theoretically, the consumer can exchange that gas bottle for a new one indefinitely. For the sake of simplicity, the access cost is also levelised over 30 years in this analysis. There are no access costs for paraffin.

Appliance	*Life (years)*	*Appliance*	*Life (years)*
Paraffin wick stove	3	Paraffin space heater	9
Gas ring	5	Gas space heating	5
Electric hot plate	4.5	Electric radiant heater	6
Electric storage geyser	22	Paraffin wick lighting	4.5
Gas geyser	27	Incandescent bulb	0.8
Solar water heater with electric storage backup	17	Candle	0.01

Source: Adapted from Thorne (1997)

Table 6: Economic life of appliances

3.2.8 External costs of fuel use

The most systematic work on external costs of energy use in South Africa is Van Horen's (1996a; 1996b) analysis of the external costs of electricity and household fuels. Van Horen finds that these external costs are significant relative to the price of fuels, but that there is also an 'unavoidable degree of uncertainty' over some estimates. This uncertainty is indicated by the ranges for external costs given in Table 7. Estimates of the cost of climate change caused by carbon dioxide emissions have some of the highest uncertainty ranges. These costs have been excluded from this analysis because of uncertainty about their values. Given that some serious external costs, such as acid rain and water pollution from coal mining, have yet to be quantified, these numbers probably underestimate the magnitude of external costs. Note that gas has not yet received the attention that other fuels have, so estimates of external costs are unavailable. Given the clean-burning properties of gas, however, its contribution to health and other pollution impacts is likely to be much smaller than that of coal and wood.

Energy source	*External cost*		
	Low	*Central*	*High*
Electricity generation (mills/kWh)	5.1	7.2	9.1
Coal pollution	1.61	3.61	6.45
Wood pollution	4.42	19.8	53.76
Paraffin poisoning	3.49	14.18	51.95
Fires and burns from paraffin*	3.45	27.07	50.76
Total paraffin	6.99	41.25	102.71
Fires/burns: candles*	8.16	63.17	118.44

Source: Adapted from Van Horen 1996a and 1996b

* Paraffin is estimated to account for 30% of the total fires and burns cost, while candles account for 70%.

Table 7: External costs of energy (R/GJ except for electricity)

3.2.9 Avoided peak generation capacity

When switching from electricity, or using electricity more efficiently, avoided peak generation capacity is another key benefit. If peak electricity demand is reduced for the life of a generation plant, then the cost of building that plant can be avoided. This is particularly important in the residential sector, where much of the demand for power occurs during the morning and evening peak. Note that we must assume that reducing peak demand will directly reduce the need for peak capacity. Given a reserve margin of 10% and 10% transmission and distribution losses, a 1 kW reduction in demand would actually result in 1.2 kW in capacity savings. While this may not always hold in the short term or for small changes in peak demand, over the long run demand reductions should equate to corresponding reductions in capacity needs.

In the simplest analysis, if households switched from electricity to gas for cooking, then the capacity needed to power their electric hotplate would not be needed in the future. Total avoided capacity, therefore, is a function of the number of households switching, the wattage of their appliances, and the percentage chance that the appliance is being used during a peak period (peak coincidence of power use)[7]. The peak coincidence assumptions used in this analysis are based on typical load profiles and are shown below in Table 8.

End-use	*Peak coincidence (%)*
Cooking	70
Water heating	70
Space heating	90
Lighting	70

Table 8: Assumptions for peak coincidence of power use for electric appliances (percentage chance that appliance is on during peak)

Note that the peak coincidence of these end-uses may be somewhat higher than for middle- and upper-income households. With lighting, for example, the programme targets the most heavily used bulbs, so that the chance of them being on in the evening during the winter is high. For space heating in poorly insulated houses and shacks there is also a higher chance that appliances will be in use during the peak than in more expensive well-insulated housing. Peak coincidence for cooking depends on when people cook their evening meal, which is in turn related to social customs and work hours.

3.2.10 Number of low-income urban households

Estimating the number of low-income households that would be affected by these interventions is complicated by the limited national data on household types. The total number of electrified and non-electrified urban households is given in the National Electricity Regulator's reports (NER 1996). Electrified households, however, include middle- and high-income households, which are not targets for these strategies. Based on earlier research (Marbeck 1996), the number of middle- and high-income urban households is estimated at 2.7 million for 1996. The resulting distribution of low-income households is shown in Table 9.

Type	*Households*
Electrified	1 156 000
Non-electrified	1 038 000
Total	2 194 000

Source: NER (1996); Marbeck (1996)

Table 9: Estimated distribution of low-income urban households (December 1996)

3.2.11 CAPIC calculation

To calculate the CAPIC, we need to know the cost of the energy efficiency intervention over the life of an avoided plant – roughly 30 years. The incremental cost over that period, then, is the present value of the total annual cost over 30 years. Dividing this cost by peak capacity avoided yields CAPIC. Examples are shown in the calculation sections below.

3.2.12 Penetration rates for fuel switching

Although some fuel switching (to electricity, for example) may occur with the construction of new housing and electrification, previous studies have shown that

---

[7] For a given end use, peak coincidence of power use = peak demand / maximum demand

fuel switching of any kind generally occurs gradually (Davis 1996). Because of the currently underdeveloped fuel switching strategies of both Eskom and DME, and limited analysis on the rate at which people might switch, assumptions are required regarding what share of households will switch and how quickly they will do so. The assumptions were based on three principles:

- the fuel switches chosen are all economically beneficial and save energy, so there is a long-term incentive for national actors and households to pursue them;
- half of the households would switch by the end of ten years;
- this switching would occur gradually over those ten years.

4. Calculation of energy savings

4.1 Energy-efficient lighting

4.1.1 Household model

Clark (1997) has presented analysis on the impact of switching from incandescent to compact fluorescent lighting, and this analysis builds on that work, with some modification based on the standard assumptions presented above. The annual electricity savings from a single bulb can be expressed as:

Annual electricity savings $=[(W_i - W_{CFL})/(1 - \text{transmission losses})] \times$ *annual hrs, where*

$W_i =$ *Wattage of incandescent*

$W_{CFL} =$ *Wattage of CFL*

A 15 W CFL is assumed to replace a 60W incandescent to be on the conservative side, even though a 15 W CFL produces as much light output as a 75 W bulb. Transmission and distribution losses are approximately 10%, so the savings (of electricity sent out from the plant) would be:

Annual electricity savings = 45W/.9 x 1000 hrs per year = 50 kWh (180 MJ)

Savings of peak electricity would include the peak electricity use:

Annual peak electricity savings = Annual energy savings x PEU

Annual peak electricity savings = 50 kWh x 0.70 = 35 kWh

To translate these savings into primary energy savings, the efficiency of generating electricity must be considered as well:

Primary energy savings = electricity savings at plant / generation efficiency

Primary energy savings = 180 MJ / 0.34 = 535 MJ

4.1.2 Programme model

The programme model is used to calculate the total energy savings in year 10 from a co-ordinated energy efficiency programme including CFLs. Programme savings in year 10 are based on the distribution of 500 000 bulbs per year over ten years. By 2007, five million bulbs would have been installed.

Programme electricity savings (yr 10)=annual electricity savings/ bulb x total bulbs

Programme electricity savings (yr 10)= 50 kWh x 5 000 000 = 250 GWh

Programme peak electricity savings (yr 10)= annual peak electricity savings/bulb x total bulbs

Programme peak electricity savings (yr 10)= 35 kWh x 5 000 000 = 175 GWh

Primary energy savings, taking into account generation losses, are as follows:

Primary energy savings (yr 10)= annual primary savings/ bulb x total bulbs

Primary energy savings (yr 10)= 525 MJ x 5 000 000 = 2625 TJ[8]

4.2 Thermal improvements

4.2.1 Household model

Simmonds (1997) calculates the energy savings from thermal improvements in low-cost housing using the QUICK model that incorporates building characteristics and local climate to assess the need for energy use in space heating. The results show that the addition of a ceiling and other low and no-cost measures to improve the passive solar design of RDP houses can reduce energy use for space heating by around 70%. The annual energy savings by fuel used for space heating are shown in Table 10.

Fuel used	*Savings (units)*	*Savings (MJ)*
Electricity	294 kWh	1058
Coal	98 kg	2646
Wood	155 kg	2403
Paraffin	39 l	1482
Gas	30 kg	1494

Table 10: Annual energy savings from thermal improvements by fuel

Constructing a household model of energy savings requires an assumption about the energy consumption patterns for space heating. New households that are electrified will, over time, shift towards greater use of electricity (Davis 1996), so over time proportionally more electricity will be avoided. The assumptions about fuel mix for space heating among RDP housing are shown in Table 11.

Fuel source	*Share in year 1 (% of homes)*	*Share in yr 10 (% of homes)*	*Share in yr 20 (% of homes)*
Electricity	16	24	48
Coal	16	14	8
Wood	12	10	4
Paraffin	36	32	20
Gas	1	1	1
None	19	19	19
Total	100	100	100

Table 11: Assumptions of fuel mix for space heating

To develop a single household model, a theoretical 'average house' was calculated using the weighted average of energy savings across all types. Because this weighting changes over time, the programme model was used to calculate the average energy savings for each year. This annual average saving per household changes from 1809 MJ in year 1 to 1980 MJ in year 10 to 2265 MJ in year 20 as houses shift from coal, wood and paraffin to electricity for space heating. Average annual savings for an 'average house' is 1995 MJ. Savings of peak electricity rises from 24 kWh in year 1 to 71 kWh in year 20 for the same reason. Note that peak electricity savings appear low because not all houses with thermal improvements were using electricity for space heating. It is not possible to choose to put ceilings only into homes using electricity for space heating.

4.2.2 Programme savings

Programme savings in year 10 are based on the construction of 200 000 homes per year over five years. The ceilings in these homes are assumed to last for 20 years. Since the fuel mix is changing throughout the 20-year life of the intervention, however, the average household savings is not exactly the same as annual energy

---

[8] Note: 1 MJ = 10^6 J; 1 TJ = 10^{12}J = 10^6 MJ

savings in year 10.

Programme energy savings (year 10) = annual energy savings per house in yr 10 x total houses

Programme energy savings (year 10) = 1980 MJ x 1 000 000 = 1 980 TJ

Programme peak electricity savings (year 10)= annual peak elec. savings in yr 10 x total houses

Programme peak electricity savings (year 10)= 41 kWh x 1 000 000 = 41 GWh

4.3 Fuel switching

Eight different fuel-switching scenarios were analysed (see list in 'Scope' section). Switching from electricity to gas for cooking is shown as an example of the calculations.

4.3.1 Household model

The household model calculates the energy savings based on the relative efficiencies of the two fuel/appliance combinations. Energy used by an individual household is based on appliance energy consumption and hours of use per day (see Thorne 1996). For example, if an electric hot plate consumes 2 kW of power, and operates 2.3 hours per day on average, then annual electricity use is 1679 kWh (2 x 2.3 x 365) or 6044 MJ. This is within the range of electricity use found by Simmonds and Mammon (1996) in their quantitative survey of the low income urban sector.

To calculate the total energy input with electricity, however, we must consider the efficiency of generation, transmission, and distribution. Much of the energy content of primary fuels is lost during the transformation to delivered electricity. The thermal efficiency of Eskom's power plants is just over 34% (Eskom 1996b), while technical transmission and distribution losses are around 10% (Davis 1996).

Primary energy input = delivered electricity / [generation efficiency x T&D efficiency]

Primary energy input = 6044 MJ/ (.343 x .9) = 19 580 MJ

Useful energy is a function of primary energy use and fuel cycle efficiency.

Useful energy = primary energy x generation, T&D efficiency x old appliance efficiency[9]

Useful energy = 19 580 MJ x .343 x .9 x .65 = 3 929 MJ

To determine how much primary energy input is needed from the new fuel, we divide useful energy by the new fuel cycle efficiency

Primary energy for new fuel = useful energy required / new appliance efficiency[10]

Primary energy for new fuel = 3 929 MJ / 0.50 = 7 858 MJ

The difference in primary energy use is:

Annual energy savings = initial primary energy use - new primary energy use

Annual energy savings = 19 580 MJ - 7858 MJ = 11 722 MJ

Note that if the total efficiency of the new fuel cycle is less than that of the initial fuel cycle (eg switching from paraffin to electricity for cooking, which have fuel cycle efficiencies of 28% and 20%, respectively), then energy use will increase instead of decrease.

Peak electricity savings in this case depend on the initial amount of electricity used.

Annual peak electricity savings = delivered electricity x peak electricity use

Annual peak electricity savings = 1 866 kWh x 0.5 = 933 kWh

---

[9] For switches not involving electricity, the equation would only be *Useful energy = primary energy x appliance efficiency*.

[10] This could include generation and T&D efficiency if the switch was *to* electricity.

4.3.2 Programme model

The programme models for fuel switching consider the number of houses eligible for a switch (ie how many use that fuel for that end-use) and the rate at which the switch will take place (see discussion under 'Key assumptions'). Based on the work of Simmonds and Mammon (1996), we can assume that approximately 90% of low income urban electrified households use electricity for cooking.[11] While this number may be much lower for newly electrified homes, this analysis considers the entire low-income urban sector. If half of these homes switch over ten years, the number of them that have switched by year ten is:

Number of switches by yr 10 = Low-income urban electrified homes x 0.9 x 0.5

Number of switches by yr 10 = 1.04 million x 0.9 x 0.5 = 0.52 million

Annual energy savings in yr 10 = number of homes x annual energy savings per home

Annual energy savings in yr 10 = 0.52 million x 11 722 MJ = 6096 TJ

Similarly for peak electricity savings:

Annual peak electricity savings in yr 10 = number of homes x annual peak savings per home

Annual peak electricity savings in yr 10 = 0.52 million x 933 kWh = 485 GWh

5. Calculation of avoided peak electricity capacity

Energy efficiency interventions in the residential sector potentially replace future investments in peak electricity generation capacity. The magnitude of avoided peak capacity depends on the power consumption of the appliances that will be replaced, and the percentage chance that the appliance would be on during the peak period (ie 'peak coincidence of power use'). The assumptions about peak coincidence of power use for different end-uses are shown in Table 8 in the section on 'Key assumptions'. We also assume that, over the long run, avoiding peak demand will translate one to one into avoiding peak capacity.

5.1 Energy-efficient lighting

5.1.1 Household model

Capacity reduction depends on not only the difference in power use of CFLs and incandescent bulbs, but also transmission losses, the reserve margin required by suppliers (related to plant availability), and the peak coincidence of power use.

Avoided capacity = (Wi - WCFL) x peak coincidence /[(1 - trans. losses) x plant availability factor]

Wi = Wattage of incandescent

WCFL = Wattage of CFL

For energy-efficient lighting, the avoided capacity per bulb would be:

Avoided capacity = 45W x 0.7/[0.9 x 0.9] = 38.9 W

5.1.2 Programme model

Avoided capacity for the programme is a function of the number of bulbs distributed.

Programme avoided capacity (year 10)= avoided capacity per bulb x total bulbs

Programme avoided capacity (year 10)= 0.0389kW x 5 million = 194.5 MW

---

[11] This number will vary with the time since electrification, so 90% may be high for newly electrified homes.

5.2 Thermal improvements

5.2.1 Household model

Calculating avoided capacity for thermal improvements is more complex because in the 'business as usual' scenario, consumption of electricity in newly electrified homes would increase over time. Power use in year 10 would therefore be significantly greater than in the first years, but lower than in later years. Similarly, avoided capacity for an 'average' household would increase over time. Year 10 is still used as the benchmark, however, since that is when new generation capacity is likely to be commissioned without improvements in energy efficiency.

Simmonds (1997) demonstrates that thermal improvements to low-cost housing would substantially eliminate the need for space heating during peak periods, even though it might be used during other periods (eg later at night). Avoided capacity is therefore based on the power use of space heating and peak coincidence of their use.

Avoided capacity in yr 10 = share of houses using electricity for space heating x power use x peak coincidence /[(1 - trans. losses) x plant availability factor]

Avoided capacity in yr 10 = 0.28 x 1.5 kW x 0.9 /(0.9 x 0.9) = 0.467 kW

5.2.2 Programme model

Avoided capacity for the programme is a function of the number of households.

Programme avoided peak capacity (year 10)= avoided capacity per average household x total houses

Programme avoided peak capacity (year 10)= 0.467kW x 1 million = 467 MW

5.3 Fuel switching

As in the previous section, switching from electricity to gas for cooking is shown below as an example of the calculations. The switch from electricity to gas for space heating would be similar. Switching from paraffin or candles to electricity for lighting and from paraffin to solar hot water heaters with electric backup would actually *increase* the demand for peak capacity, although the total impact on capacity would be relatively low for lighting.

5.3.1 Household model

Capacity reduction depends not only on power use of electric cooking appliances, but also on transmission losses, the reserve margin required by suppliers (related to plant availability), and the peak coincidence of power use.

Avoided capacity in yr 10 = power use x peak coincidence / [(1 - trans. losses) x plant availability factor)]

Avoided capacity in yr 10 = 2.0 kW x 0.7/(0.9 x 0.9) = 1.73 kW

5.3.2 Programme model

Avoided capacity for the programme is a function of the number of households switching.

Programme avoided peak capacity (year 10)= avoided capacity per house x total houses

Programme avoided peak capacity (year 10)= 1.73kW x 520 000 = 899 MW

6. Calculation of national cost of conserving energy

To calculate annual incremental costs, we must first convert any capital costs to annual costs by 'levelising' them over their economic life. The annual incremental cost is then the annualised capital cost plus additional annual costs (external cost, maintenance, etc) less any avoided annual costs (eg the costs of incandescent bulbs).

6.1.1 Energy-efficient lighting

As described in Clark (1997), installing CFLs incurs an initial cost for the new lamp, but results in savings of electricity costs, incandescent bulb costs, and reduced external costs of electricity. The electricity cost savings are not included in the CCE calculation (see 'methodology' section above), but all other costs must be on an annual basis.

For a R50 CFL, the annual capital cost equivalent at 8% discount rate is R7.5. CFLs will avoid the cost of incandescent bulbs and reduce the external costs of electricity by reducing electricity use.

Avoided bulb costs = number of incandescent bulbs x avoided bulbs per year

Avoided bulb costs = R 2.50 x 1.3 bulbs = R 3.25

Avoided external costs = annual electricity savings x external costs per kWh

Avoided external costs = 50 kWh x R.0072 /kWh = R 0.36

The total incremental cost is therefore:

Incremental cost = annualised CFL cost - avoided bulb cost - avoided external cost

Incremental cost = 7.5 - 3.25 - 0.36 = R3.84 /year

The CCE is this incremental cost divided by annual electricity savings.

CCE = incremental annual cost / annual electricity savings

CCE =R3.84 / 50 kWh = 7.7 c/kWh

To compare with the cost of peak electricity, we divide instead by annual peak electricity savings.

CCE(peak) = incremental annual cost / annual peak electricity savings

CCE(peak) = R3.84 / 35 kWh = 11.0 c/kWh

In terms of primary energy, the CCE is the incremental cost divided by primary energy saved.

CCE = incremental annual cost / annual primary energy savings

CCE =R3.84 / 525 MJ = 0.7 c/MJ

6.1.2 Thermal improvements

The only thermal improvement intervention that has a significant cost is the ceiling. Other measures such as siting for passive solar benefits, orienting windows toward the north, and appropriate window sizing are low- or no-cost. The benefits that flow from these measures over 20 years are reduced fuel costs and reduced external costs associated with those fuels. The cost components of the CCE calculation are therefore the annualised cost of the ceiling and the avoided external costs.

Avoided external costs are a weighted average of the external cost savings for homes using different fuels for space heating, as shown in Table 12.

Fuel used for space heating	*Annual avoided external cost (R)*	*Percentage of homes using fuel type*	*Weighted external cost savings (R)*
Electricity	2.1	16	0.3
Coal	9.6	16	1.5
Wood	47.6	12	5.7
Paraffin	41.1	36	14.8
Gas	N/A	1	N/A
Total			**22.3**

Table 12: Calculation of weighted average fuel cost savings for thermal improvements (year 1)

This is only the fuel cost savings for year 1. In future years the fuel mix changes. By year 10, for example, avoided external costs are R18.4. The average avoided external cost per year is R18.1.

The levelised cost of a R450 ceiling over 20 years at 8% is R45.8 per year.

The total incremental cost is therefore:

Incremental cost = annualised ceiling cost - avoided external cost

Incremental cost = 45.8 – 18.1 = R27.7 /year

The CCE is this incremental cost divided by average annual energy savings.

CCE = incremental annual cost / annual energy savings

CCE = R27.7 / 1995 MJ = 1.4 c/MJ

To compare this with the cost of peak electricity, we divide instead by annual peak electricity savings.

CCE(peak) = incremental annual cost / average annual peak electricity savings

CCE(peak) = R27.7 / 43 kWh = 58 c/kWh

Note that the CCE for peak electricity appears high because not all homes that have thermal improvements use electricity for space heating. For a home that uses electricity, the savings of approximately 147 kWh of peak electricity per year would yield a CCE of 15.6 c/kWh peak.

6.1.3 Fuel switching

As in the previous sections, switching from electricity to gas for cooking is presented here as an example of the fuel-switching analysis. The fuel-switching calculations have more components, because switching fuels involves appliance costs, external costs, and access costs. In addition, we must add the cost of the new fuel to get the total incremental cost. In the case of switching from electricity to gas for cooking, the cost of the electricity connection is considered a sunk cost, as is the cost of maintaining the connection (because the house may still use electricity for other end uses). The incremental cost is therefore the new appliance, fuel access, fuel and external cost less the old appliance and external cost.

The levelised cost of a gas ring is R9.1/yr (R35 over 4.8 years) while an electric hot plate is R27.1 /year (R104 over 4.8 years). Similarly the access cost of gas for this end-use is R7.0 /yr (R78 over 30 years). The additional external costs of gas use are assumed to be minimal, while the avoided external costs from electricity are R12.1 /yr (1679 kWh x 0.72 c/kWh). The new fuel costs are based on the amount of gas that will be used (7857 MJ x 4 c/MJ = R314).

The total incremental cost is therefore:

Incremental cost = new appliance cost + new access cost + new external cost + new fuel cost - old appliance cost - old external cost

Incremental cost = 9.1 + 7.0 + 0 + 314.0 – 27.1 – 12.1 = 290.8 R/yr

Clearly the new fuel cost dominates this result.

For fuel switching we must divide this cost by the total amount of energy from the old fuel, rather than the net savings, because the incremental cost is the cost to avoid that entire old fuel use. The CCE for fuel switching is therefore the incremental cost divided by annual old fuel use in terms of primary energy.

CCE = incremental annual cost / annual old fuel use

CCE = R290.8 / 19 580 MJ = 1.5 c/MJ

To compare this intervention with the cost of peak electricity, we divide instead by annual peak electricity savings.

CCE(peak) = incremental annual cost / average annual peak electricity savings

CCE(peak) = R290.8 / 933 kWh = 31 c/kWh

7. Calculation of national cost of avoided peak installed capacity

To avoid installing peak capacity, interventions must last as long as the life of a plant. The economic benefits must also be assessed over that time period to determine the CAPIC. The cost of an intervention over 30 years is the present value of the annual incremental cost (calculated in the previous section) over 30 years discounted at the appropriate discount rate.

7.1 Energy-efficient lighting

The annual incremental cost of the efficiency lighting intervention is R3.84. The present value of R3.84 /yr over 30 years at 8% discount rate is R43.2. CAPIC is this 30-year incremental cost divided by avoided peak capacity.

CAPIC = incremental cost over 30 years / avoided capacity

CAPIC = R43.2 / 0.0389 kW = R1 112 /kW

Given that a new peak plant costs approximately R1 800/kW, this represents a savings of R700 for every kilowatt avoided. From the national perspective, therefore, the 194 MW of capacity avoided by the energy efficient lighting programme would save R130 million.

7.2 Thermal improvements

The annual incremental cost of thermal improvements is R27.7. The present value of R27.7 /yr over 30 years at 8% discount rate is R312.

CAPIC is this 30-year incremental cost divided by avoided peak capacity.

CAPIC = incremental cost over 30 years / avoided capacity

CAPIC = R312 / 0.467 kW = R668 /kW

From the national perspective, the 467 MW of capacity avoided through thermal improvements would save the country more than R500 million.

7.3 Fuel switching

The annual incremental cost of switching from electricity to gas for cooking is R290.8. The present value of R290.8 /yr over 30 years at 8% discount rate is R3274.

CAPIC is this 30-year incremental cost divided by avoided peak capacity.

CAPIC = incremental cost over 30 years / avoided capacity

CAPIC = R3274 / 1.73 kW = R1894 /kW

This cost is close to the cost of a new peak plant, so it is not clear whether there would be substantial savings in terms of capacity cost for the nation..

8. Calculation of Eskom cost of avoided peak installed capacity and net benefit

Applying CAPIC to a utility is difficult because, while CAPIC is only supposed to include economic costs other than energy, a utility may also be concerned about revenue losses (depending on the regulatory framework in which they operate). If we assume that Eskom is a state-owned asset and therefore is only the costs of providing services to the nation that are important, then CAPIC for Eskom would only include the investment cost or subsidy that Eskom provided for energy efficiency interventions. External costs would not be included because Eskom does not benefit from those changes, nor would the costs of gas when switching fuels because the consumer would bear this cost. CAPIC is then essentially a capital cost of avoiding future peak power plants.

Another possible test of the benefits to a utility would be the "net annual benefit", which would include the lost revenue plus Eskom's subsidy of the programme, less avoided generation, transmission and distribution costs. This may be more appropriate when the utility is privately owned or operates with specific revenue targets, rather than under a "rate of return" regulatory system.[12]

8.1 Energy-efficient lighting

For energy efficient lighting, Eskom's capital cost is the subsidy for a compact fluorescent lamp. At Eskom's discount rate of 6%, the levelised cost of a CFL is 6.8 R/yr. Over 30 years, the life of an equivalent power plant, the incremental cost is R76.5. CAPIC is therefore:

CAPIC (at 100% subsidy) = incremental cost over 30 years / avoided peak installed capacity

CAPIC (at 100% subsidy) = R76.5 / 0.0389 kW = R1967 /kW

This assumes that Eskom pays for the entire bulb. If the subsidy were only 50%, then Eskom's CAPIC would be R983/kW, which is approximately half the cost of a new peak power plant. In other words, by avoiding the construction of 195 MW (see calculations of avoided capacity above) through an efficient lighting programme in which Eskom paid for half the cost of the bulbs, Eskom would save more than R150 million. This is without considering revenue losses and operating savings.

To calculate net benefit, we should also include lost revenue and avoided cost of generation, transmission and distribution (electricity cost) for Eskom. As already discussed, avoided electricity cost is based on the long run marginal cost of electricity delivered to the consumer, weighted for peak and off-peak usage (see Section 3.2.3).

The value of lost revenue and avoided electricity cost are calculated as follows:

Annual revenue loss = delivered kWh saved x price of electricity

Annual revenue loss = 45 kWh[13] *x R0.26 /kWh = R11.7*

Annual avoided electricity cost = delivered kWh saved x marginal cost of electricity

Annual avoided electricity cost = 45 kWh x R0.29 /kWh = R12.9

Note that the marginal cost of electricity is weighted for peak and off-peak use (eg 70% at 37 c/kWh and 30% at 9.3 c/kWh).

If Eskom paid the full cost of the bulb, then the Eskom's net annual benefit for the

---

[12] Under a rate of return regulatory system, the utility is guaranteed a given return on capital invested, regardless of how much electricity they sell. Tariffs may be adjusted annually to take into account unforseen changes in sales.

[13] Given a T&D efficiency of 90% (eg 10% losses), 50kWh sent out is equivalent to 45 kWh delivered.

intervention would be as follows:

Net annual benefit = avoided electricity cost - annual revenue loss - subsidy

Net annual benefit = 12.9 – 11.7 - 6.8 = -R5.6 /yr

Eskom would therefore lose R5.5 per year on each bulb if it had to pay the full cost of the bulbs. Note that if Eskom did not have to pay for the bulbs, there would be a benefit of R1/yr because the cost of electricity for lighting in the long run is greater than current tariffs. Over the entire lighting programme, this would amount to 5 million R/yr (or a loss of 28 million R/yr if Eskom pays for the bulbs).

Whether this intervention is beneficial for Eskom, therefore, depends on both how much Eskom subsidises the capital cost and also on how Eskom's income is regulated. If revenue losses are compensated, or if net profits/surpluses for Eskom are based on a return on capital rather than sales, then Eskom will have more incentive to pursue these programmes.

8.2 Thermal improvements

For thermal improvements to low cost housing, Eskom's capital cost is the subsidy for a ceiling. At Eskom's discount rate, the levelised cost of the ceiling is 39 R/yr. Over 30 years, the life of an equivalent power plant, the incremental cost is R442. CAPIC is therefore:

CAPIC (at 100% subsidy) = incremental cost over 30 years / avoided peak installed capacity

CAPIC (at 100% subsidy) = R442 / 0.467 kW = R946 /kW

This assumes that Eskom pays for the entire ceiling. If the subsidy were only 50%, then Eskom's CAPIC would be R473/kW, which is approximately half the cost of a new peak power plant. In other words, by avoiding the construction of 467 MW (see calculations of avoided capacity above) through an energy efficient housing programme in which Eskom paid for half the cost of the ceilings, Eskom would save more than R600 million. This is without considering revenue losses and operating savings.

To calculate net benefit, we should also include lost revenue and avoided cost of generation, transmission and distribution (electricity cost) for Eskom. . The cost of electricity will be different than for lighting, because the peak electricity use for space heating is lower than for lighting. In other words, space heaters use more proportionally energy outside of the peak periods than do CFLs.

The value of lost revenue and avoided electricity cost are calculated as follows:

Annual revenue loss = delivered kWh saved x price of electricity

Annual revenue loss = 86 kWh x R0.26 /kWh = R22

Annual avoided electricity cost = delivered kWh saved x marginal cost of electricity

Annual avoided electricity cost =86 kWh x R0.23 /kWh = R20

If Eskom paid the full cost of the ceiling, then the Eskom's net annual benefit for the intervention would be as follows:

Net annual benefit = avoided electricity cost - annual revenue loss - subsidy

Net annual benefit = 20 – 22 - 39 = -R42 /yr

Eskom would therefore lose R42 per year per house if it had to pay the full cost of the bulbs. Note that if Eskom did not have to pay for the bulbs, it would still lose 3 R/yr. Over the entire housing programme, this would amount to 3 million R/yr.

As in the CCE calculations, the electricity usage appears low because it is averaged across all RDP homes, many of which do not use electricity for space heating.

8.3 Fuel switching

Switching from electricity to gas for cooking eliminates the entire electricity consumption for cooking, which will be substantially greater than efficiency improvements in certain end-uses. The peak electricity use for cooking is likely to be lower than for lighting, so the economic cost of electricity for Eskom is lower (and the avoided generation cost is smaller).

For switching from electricity to gas for cooking, Eskom's capital cost is the subsidy for the new appliance and access cost (ie gas bottle deposit). At Eskom's discount rate, the levelised cost of these two is 14.3 R/yr. Over 30 years, the life of an equivalent power plant, the incremental cost is R161. CAPIC is therefore:

CAPIC (at 100% subsidy) = incremental cost over 30 years / avoided peak installed capacity

CAPIC (at 100% subsidy) = R161 / 1.73 kW = R93 /kW

This assumes that Eskom pays for the entire gas ring and deposit. If the subsidy were only 50%, then Eskom's CAPIC would be R47/kW, which is more than R1700/kW less than a new plant. By avoiding the construction of 898 MW (see calculations of avoided capacity above) through an programme to promote cooking fuel switching in which Eskom paid for half the up front cost, Eskom would save more than R1.5 billion. This is without considering revenue losses and operating savings.

To calculate net benefit, the value of lost revenue and avoided electricity cost are as follows:

Annual revenue loss = kWh saved x price of electricity

Annual revenue loss = 1679 kWh x R0.26 /kWh = R437

Annual avoided electricity cost = kWh saved x marginal cost of electricity

Annual avoided electricity cost = 1679 kWh x R0.23 /kWh = R387

The capital cost to Eskom for the programme depends on how much of the intervention Eskom subsidises. Eskom can not benefit from the external cost savings, or the savings to the consumer of not having to buy the old appliance. For Eskom, therefore, the subsidy cost is related to the cost of a gas ring and the access cost for gas. The levelised annual cost of a gas ring and access at Eskom's discount rate are R8.6 and R5.7/yr respectively. The total up-front cost is therefore R14.3/yr. If Eskom paid the full up front cost of the gas ring and bottle deposit, then the Eskom's incremental cost would be as follows:

Net annual benefit = avoided electricity cost - annual revenue loss - subsidy

Net annual benefit = 387 – 437 - 14 = -R64 /yr

Again, Eskom incurs a net cost for the intervention, even without any subsidy, because the tariffs are higher than the LRMC. This points to the need to understand LRMC in more depth, given how sensitive the evaluation is to this value.

A summary of Eskom's CAPIC and net benefit is presented in Table 13.

Fuel switch or intervention	*Thermal efficiency*	*Energy-efficient lamps*	*Electricity to gas*	
End-use		*Lighting*	*Space heating*	*Cooking*
Avoided peak capacity in yr. 10 (MW)	467	194	867	899
CAPIC (R/kW):				
- 50% subsidy	473	983	273	47
- 100% subsidy	946	1967	546	93
Annual net benefit per household*				
- no subsidy	-3	1	-40	-49
- 50% subsidy	-22	-2	-73	-57
- 100% subsidy	-42	-6	-106	-64

*per bulb for lighting

Table 13. Summary of Eskom CAPIC and Net Benefit for all interventions

9. Cost curves

The summary of CCE and CAPIC for all interventions from the national perspective is presented in Table 14. These values plus the total programme energy and capacity savings in year 10 were used to construct the 'cost curves' for the nation.

Fuel switch or intervention	*Thermal efficiency*	*Energ- eff. lamps*	*Elec. to gas*		*Paraffin to elec.*	*Paraffin to SWH*	*Candles to elec.*	*Paraffin to gas*		
End-use		*Lighting*	*Space htg*	*Cooking*	*Lighting*	*Water htg*	*Lighting*	*Space htg*	*Cooking*	*Water htg*
Energy savings in yr. 10 (TJ)	1980	2624	4 884	6 096	1227	2618	715	107	1688	2523
CCE (c/MJ)	1.4	0.7	2	1.5	-9	6	-13	2	-1	5
Peak elec. savings in yr. 10 (GWh)	41	175	395	485						
Cost of conserving peak elec. (c/kWh)	65	11	41	31						
Avoided peak capacity in yr. 10 (MW)	467	194	867	899						
Cost of avoided peak capacity R/kW)	669	1112	2102	1894						

Table 14: Summary of national costs of conserving energy for all interventions

Fuel switch or intervention	*Thermal effic'y*	*Energy eff. lamps*	*Elec. to gas*		*Paraffin to elec.*	*Paraffin to SWH*	*Candles to elec.*	*Paraffin to gas*		
End-use		*Lighting*	*Space htg*	*Cooking*	*Lighting*	*Water htg*	*Lighting*	*Space htg*	*Cooking*	*Water htg*
Energy savings in yr. 10 (mil MJ)	1980	2624	4 884	6 096	1227	2618	715	107	1688	2523
Cost of conserving energy (c/MJ)	2.3	0.8	2	1.5	-1	9	-6	5	2	9
Peak elec. savings in yr. 10 (GWh)	41	175	395	485						
Cost of conserving peak elec. (c/kWh)	107	12	42	33						
Avoided peak capacity in yr. 10 (MW)	467	194	867	899						
Cost of avoided peak capacity (R/kW)	1106	1216	2169	1973						

Table 15: Summary of national costs of conserving energy for all interventions excluding externalities

9.1 National curves

The CCE curves presented below show both the cost of saving energy or capacity and the amount of energy or capacity saved by the programme. Four curves are shown: two for the cost of conserving energy (Figures 1 and 2) to show the impact of externalities, and one each for cost of conserving peak electricity (Figure 3) and cost of avoided peak installed capacity (Figure 4).

The benchmark values (in c/MJ primary energy) for CCE are the cost of new energy supply, which are roughly 3.7 c for peak electricity, 4 c for gas, 3.5 c for paraffin, 1 c for off-peak electricity and 1 c for coal (see section 3.2.3). The benchmark for cost of conserving peak electricity is the LRMC of peak electricity, 39 c/kWh. For CAPIC, the benchmark is the cost of a new peaking plant, approximately R1800 /kW for a pump storage facility.

The interventions that reduce electricity use (thermal improvements, energy-efficient lighting, and switching to gas for cooking and space heating) all come in below the cost of new electricity. Thermal improvements, for example, has a CCE of 1.4 c/MJ, compared to a weighted average cost of electricity for space heating of 2.3 c/MJ primary energy (see Table 2). Thermal improvements will also save the use of paraffin, coal, gas and wood. The CCE is below the cost of new paraffin and wood, but slightly above the cost of cheap coal. Given the quality of life improvements associated with reducing home coal use, this intervention has benefits compared to all fuels. Energy efficient lighting, at 0.7 c/MJ, costs less than off-peak electricity, even though it saves significant peak electricity as well.

For the fuel switches, several actually have negative costs, so society benefits even without considering the energy savings. The only switches that appear to be relatively expensive are paraffin to solar water heating with electric backup and paraffin to gas water heating. The solar water heater with electric back up option, however, is based providing equivalent service to a paraffin wick stove used 4-5 hours per day – roughly 2 300 MJ per year of 'useful energy'. This would only require the back up storage geyser to operate less than two hours per day. If houses use twice this much energy for water heating, because having a geyser and hot water system makes it more convenient, then the CCE would come down to 1 c/kWh.

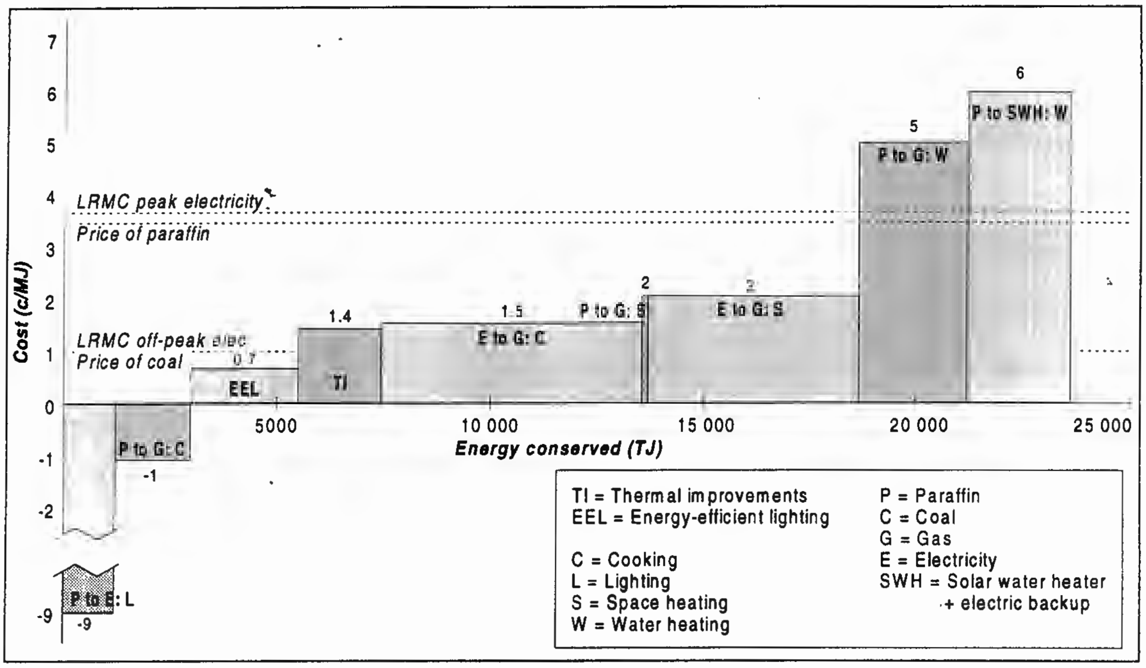


Figure 1. Cost of conserving energy (c/MJ)

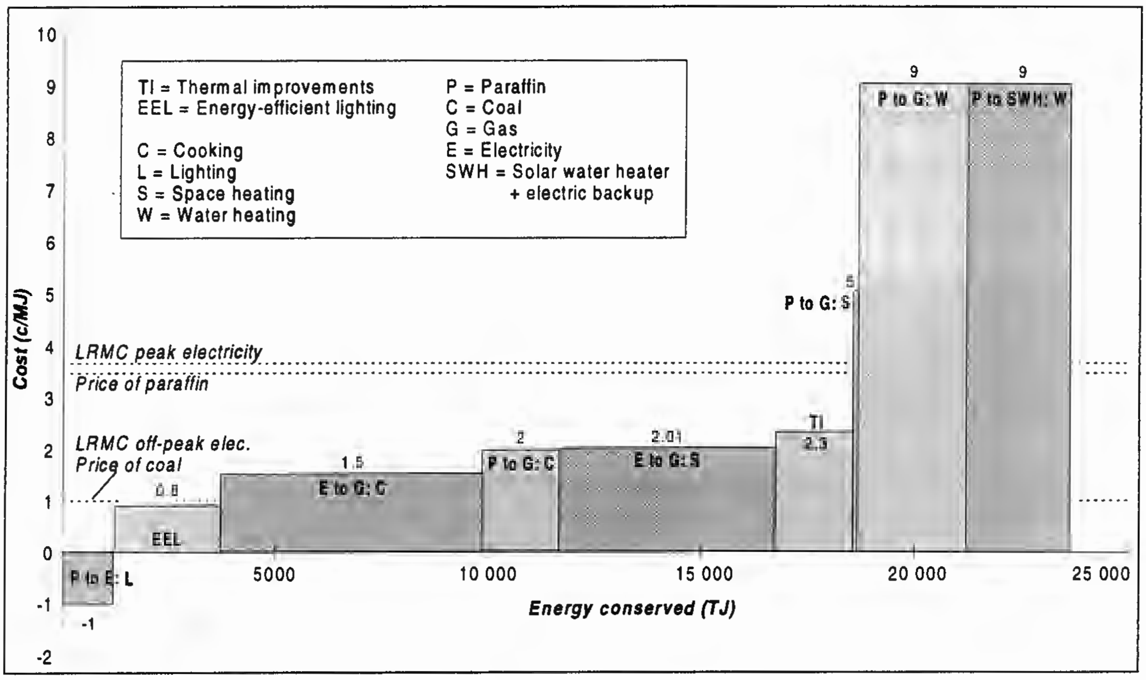
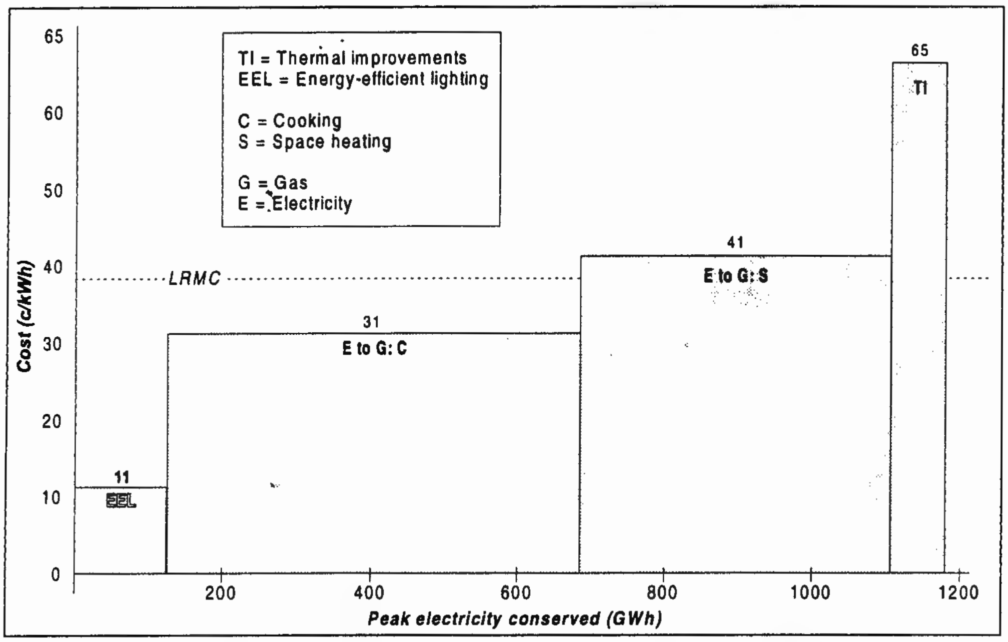


Figure 2: Cost of conserving energy (c/MJ) excluding externalities



Note: Paraffin and candles to electricity for lighting increases electricity use slightly (~80GWh but also at highly negative cost – that is, high benefits.

Figure 3: Cost of conserving peak electricity (c/kWh)

The cost of conserving peak electricity for two of the interventions that save electricity is well below the cost of new peak electricity. Switching to gas for space heating is on par with the cost of new peak electricity. Thermal improvements appears to be much higher than the cost of peak electricity, but this is because not all homes that receive a ceiling use electricity for space heating. This implies that thermal improvements should be implemented to deal with a broad range of fuel use and environmental problems, rather than only to save electricity. Still, as demonstrated in Figure 4 on CAPIC, this intervention is still much less expensive than new peak power plants.

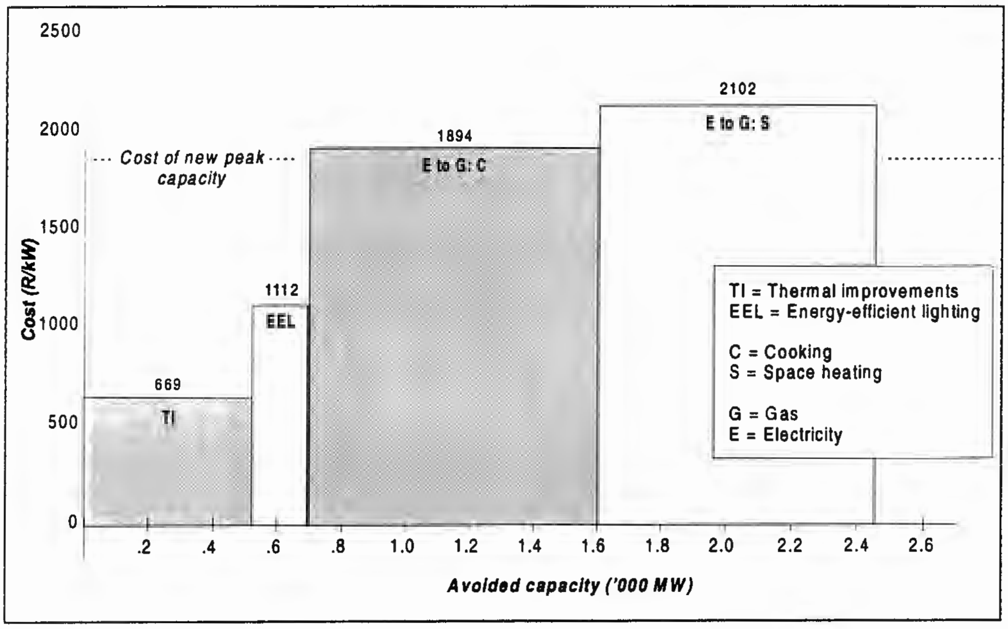


Figure 4: Cost of avoided peak installed capacity (R/kW)

Figure 4 shows that the CAPIC for energy efficiency lighting and thermal improvements are well below the cost of building new plants. Both of the fuel switches are close to the cost of a new plant, so that cost to society of the avoiding the plant is roughly the same as that of building the plant. Note, however, that

CAPIC overestimates the cost of avoiding capacity because all of the costs of put on peak capacity avoided, even though the interventions avoid base load capacity as well.

A more important question is why the fuel switching CCE can be lower than the cost of electricity per kWh but the CAPIC be higher than the cost of a peak plant. This is because the benchmarks for CCE and CAPIC are not based on precisely the same source. The LRMC of peak electricity is based on projections of full costs to the consumer, while the cost of peak capacity is only the cost of a typical peak plant (in this case a pump storage facility). To derive both benchmarks from the same data, we would need projected capital costs, operating costs, and load factors for pump storage generation, and the same information for marginal transmission and distribution investments.

9.2 Sensitivity analysis for national costs

9.2.1 Cost of conserving energy

The most important question in each sensitivity analysis section is whether, over a wide range of key variables, the CCE is less than the cost of new energy supply. The benchmark values (in c/MJ primary energy) again are roughly 3.7 c for peak electricity, 4 c for gas, 3.5 c for paraffin, 1 c for off-peak electricity and 1 c for coal (see section 3.2.3). For all interventions, external costs, discount rate, appliance efficiency and appliance cost are important components of the CCE calculation. Thorne (1997) also identified these as key variables for sensitivity analysis.

External costs form a large component of some of the economic savings for fuel switching interventions. Table 15 shows the CCE without including *any* external costs. Two results are notable: thermal improvements is now on par with the weighted average electricity cost, while still lower than other fuel costs except coal. Secondly, switching from paraffin to gas for space heating is now above the cost of paraffin. This is understandable because one of the main reasons for fuel switching is to get away from the use of fuels that have a high external cost, due to burns and fires for example. Despite the uncertainty around external costs, however, they are a crucial to the national perspective – the social needs for alternative fuels to paraffin are based on the dangers associated with paraffin use.

The ranges for the other input variables are derived from the survey analysis in Thorne's (1997) work on the costs of energy services. Thorne found that, given the limited information available on appliance efficiency in South Africa, and the influence of user behaviour on efficiency, appliance efficiency could easily range 10-20% around the average. A range of plus or minus 20% for appliance efficiency is used for the results presented in Table 17. The range of appliance cost is even greater, again because of the wide variety in new and second-hand appliances available. To be conservative, a range of plus or minus 50% of the old appliance cost is used here (ie if switching from a hot plate to a gas ring, plus or minus 50% of the cost of hot plate). Since there a two fuels and appliance involved in fuel switching, only the old fuel and appliance cost is varied to simplify the analysis. In the calculation of energy savings, increasing the old appliance efficiency by 20% is, of course, roughly equivalent to increasing it by 10% while decreasing the efficiency of the new appliance by 10%. Note that appliance cost for thermal improvements is the cost of the ceiling, and for energy-efficient lighting, the CFL.

The analysis presented in Tables 16 and 17 shows that, while CCE is sensitive to some of these variables, the changes would not push the CCE above the cost of new energy. The water heating switches are already relatively costly for the reasons explained above. If the cost of a ceiling rose by 50%, thermal improvements would cost 2.5 c/MJ, which is slightly higher than the weighted average cost of electricity (see Table 2). In addition, if the efficiency of gas stoves is 20% less than the base case (ie 30% instead of 50%), then switching from electricity to gas becomes more expensive than new electricity. The same is true for space heating. The likelihood of gas appliances working so poorly, however, is small.

Because most of the fuel switches are to gas, and gas prices vary significantly throughout the country (Thorne 1996), CCE sensitivity to gas cost is also shown in Table 17. An increase of 50% in the cost of gas could push most of these interventions above the cost of new energy, which points to the need to understand the true economic costs of gas rather than using prices as a proxy.

CCE (c/MJ)*		*Discount rate*			*Old appliance cost*		
Intervention	*End-use*	*6%*	*8%*	*10%*	*- 50%*	*Middle*	*+50%*
Thermal efficiency	Space heating	1.1	1.4	1.7	0.2	1.4	2.5
Energy-efficient lighting	Lighting	0.6	0.7	0.9	0	0.7	1.4
Elec. to gas	Space heating	1.9	2.0	2.0	2.0	2.0	1.9
Elec. to gas	Cooking	1.5	1.5	1.5	1.6	1.5	1.4
Paraffin to elec.	Lighting	-9	-9	-9	-8	-9	-10
Paraffin to SWH	Water heating	5	6	7	6	6	6
Candle to elec.	Lighting	-13	-13	-13	-9	-13	-17
Paraffin to gas	Space heating	2	2	3	3	2	2
Paraffin to gas	Cooking	-1	-1	-1	-1	-1	-1
Paraffin to gas	Water heating	4	5	6	5	5	5

* CCE includes external costs

Table 16: Sensitivity of CCE to discount rate and appliance cost

CCE (c/MJ)*		*New appliance efficiency*			*Gas cost*		
Intervention	*End-use*	*-20%*	*Middle*	*+20%*	*- 50%*	*Base*	*+ 50%*
Thermal efficiency	Space heating	N/A	1.4	N/A	N/A	1.4	N/A
Energy-efficient lighting	Lighting	N/A	0.7	N/A	N/A	0.7	N/A
Elec. to gas	Space heating	2.6	2.0	1.6	1.1	2.0	2.8
Elec. to gas	Cooking	2.6	1.5	1	0.7	1.5	2.3
Paraffin to elec.	Lighting	-9	-9	-9	N/A	-9	N/A
Paraffin to SWH	Water heating	6	6	6	N/A	6	N/A
Candle to elec.	Lighting	-13	-13	-13	N/A	-13	N/A
Paraffin to gas	Space heating	4	2	2	1	2	4
Paraffin to gas	Cooking	1	-1	-2	-2	-1	0
Paraffin to gas	Water heating	7	5	4	4	5	6

* CCE includes external costs.

Table 17: Sensitivity of CCE (c/MJ) to appliance efficiency and gas cost

9.2.2 Cost of avoided peak installed capacity

For CAPIC, the benchmark is R1800/kW (Surtees 1997). The sensitivity analysis will test whether interventions that appear to be less expensive than new capacity are still less expensive if key inputs change. The relevant inputs covered are external costs, discount rate, appliance cost, and peak coincidence of power use. Only the interventions that actually avoid peak installed capacity are analysed.

If we calculate CAPIC without including external costs (see Table 15), the costs for fuel switching rise above the cost of new capacity, while the other two interventions remain well below the cost of a new plant (ie about half the cost).

CAPIC is more sensitive to the discount rate than CCE because with CAPIC we take the present value of annual cost over 30 years. As shown in Table 18, lower discount rates would make the fuel switching interventions considerably more expensive (ie because the future stream of annual costs adds up to a larger total incremental cost). Appliance cost has a much greater impact on energy efficient lighting and thermal improvements than the other two interventions. Given that new bulbs are already being introduced in South Africa that are less than R40, the high cost scenario for energy efficient lighting is very unlikely. Finally, a lower peak coincidence of demand would drive up CAPIC significantly as well, pointing to the need to investigate demand and use patterns for cooking and space heating.

CAPIC (R/kW)		*Discount rate*			*Old appliance cost*		
Intervention	*End-use*	*6%*	*8%*	*10%*	*-50%*	*Middle*	*+50%*
Thermal efficiency	Space heating	624	669	702	117	669	1222
Energy-eff. lighting	Lighting	1126	1112	1097	33	1112	2190
Elec. to gas	Space heating	2538	2102	1782	2143	2102	2061
Elec. to gas	Cooking	2313	1894	1588	1982	1894	1806

Table 18: Sensitivity of CAPIC to discount rate and appliance cost

CAPIC (R/kW)	*Peak coincidence*			
Intervention	*End-use*	*- 10%*	*Middle*	*+ 10%*
Thermal efficiency	Space heating	753	669	603
Energy-efficient lighting	Lighting	1297	1112	973
Elec. to gas	Space heating	2365	2102	1892
Elec. to gas	Cooking	2210	1894	1657

Table 19: Sensitivity of CAPIC to peak coincidence

9.3 Eskom curves

Figure 5 shows Eskom's costs of avoiding peak capacity while subsidising the interventions. For all four interventions, at 50% subsidy Eskom is better off investing in efficiency rather than a new plant.

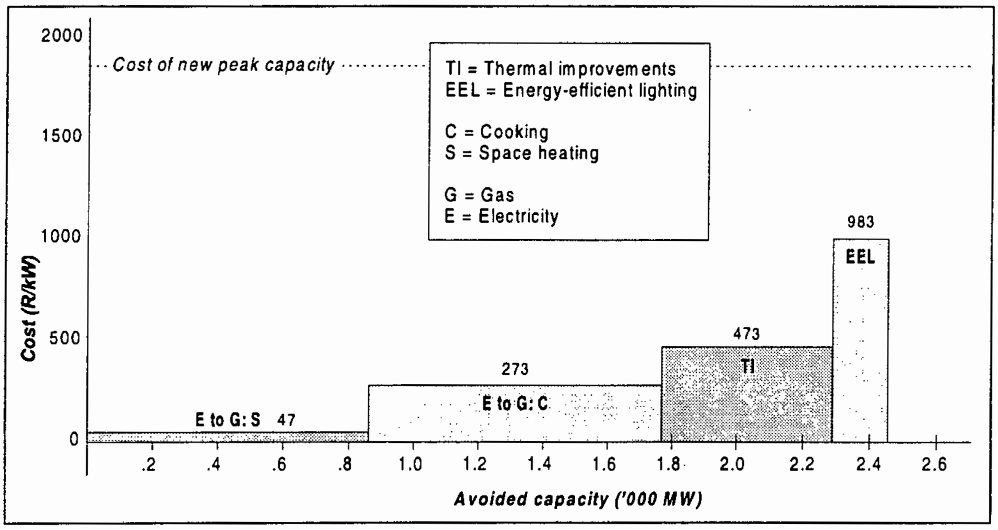


Figure 5: Eskom cost of avoided peak installed capacity (with 50% Eskom subsidy)

9.4 Sensitivity analysis for Eskom costs

Sensitivity for Eskom's CAPIC is quite different for Net Annual Benefit. Because CAPIC only deals with capital cost and avoided capacity, the key variables are the capital cost of the intervention and the peak coincidence of that end use. Table 19 shows the sensitivity of CAPIC to changes in these two variables. Because Eskom's CAPIC does not include external costs, no sensitivity analysis for that variable is presented.

Net Annual Benefit includes an avoided electricity cost, so the cost of electricity is important. In particular, what share of peak and off-peak electricity an end use requires (Peak Electricity Use) is critical because peak electricity is so much more expensive to produce. Table 20 shows the sensitivity of Eskom's Net Annual Benefit to changes in peak electricity use by project.

As shown in Table 19, although Eskom's CAPIC is sensitive to changes in peak coincidence and appliance cost, CAPIC is still below the cost of a new plant in all cases when Eskom pays for 50% of the capital cost. For Net Annual Benefit, shown in Table 20, the interventions still lose money for Eskom (assuming 50% subsidy) regardless of the change in peak electricity use. This shows that the cost-benefit to Eskom is more related to how they make surpluses (ie margins on each kWh) than to percentage peak electricity use.

CAPIC (R/kW)*		*Peak coincidence*			*Old appliance cost*		
Intervention	*End-use*	*- 10%*	*Middle*	*+ 10%*	*- 50%*	*Middle*	*+ 50%*
Thermal efficiency	Space heating	532	473	426	237	473	710
Energy-eff. lighting	Lighting	1147	983	860	492	983	1475
Elec. to gas	Space heating	307	273	246	N/A	273	N/A
Elec. to gas	Cooking	54	47	41	N/A	47	N/A

* Assuming 50% Eskom subsidy; cost of ceiling for thermal improvements, CLF for lighting

Table 19: Sensitivity of Eskom CAPIC to peak coincidence and appliance cost

NAB (R per household)*		*PEU*		
Intervention	*End-use*	*- 10%*	*Middle*	*+ 10%*
Thermal efficiency	Space heating	-24	-22	-20
Energy-efficient lighting**	Lighting	-3	-2	-1
Elec. to gas	Space heating	-111	-73	-36
Elec. to gas	Cooking	-103	-57	-10

* Assuming 50% Eskom subsidy
** per bulb

Table 20: Sensitivity of Eskom Net Annual Benefit to peak electricity use

10. Conclusions

This sample of the potential energy efficiency interventions in low-income urban households shows that significant economic benefits can be achieved while saving energy and avoiding generation capacity investments. Eight of the ten interventions that save energy for low-income households are less expensive than the cost of new energy supply, and the other two will also be less expensive if the use of household hot water rises with access to running hot water. Avoided environmental and health risks play a major role in these benefits, but are by no means the only source of savings. Economic benefits are also apparent from Eskom's perspective, as all four interventions avoid new peak generation capacity at a lower cost than building new plants, even if Eskom subsidises the intervention heavily. This is not the case, however, with the net benefit *to Eskom.*

Using CCE as a measure to compare energy efficiency interventions with new supply, all but two of the interventions are below the benchmark values for the cost of paraffin, gas and electricity. The CCE for thermal improvements is slightly higher than the cost of new coal, but provides other comfort and health benefits. Switching from paraffin to solar hot water heating with electric backup will also be economically attractive if household hot water use rises: the same will also make switching from paraffin to gas for water heating more attractive.

For the electricity sector, thermal improvements, energy-efficient lighting, and switching to gas for cooking and space heating can avoid peak capacity at or significantly below that of new plants. While switching to electric lighting from paraffin and candles will increase capacity requirements somewhat, this is small in comparison to the savings from the first four interventions. If solar hot water heaters have an electric geyser for backup, however, there is the potential for a large peak load (particularly in winter), even though annual electricity use will be small: gas or paraffin backup should be explored instead given the low cost of solar water heating.

Although calculations of the cost of conserving energy are affected by changes in key input variables such as appliance cost and efficiency, the cost of conserving energy generally remains below the cost of new supply. A significant increase in the cost of a ceiling would make thermal improvements somewhat expensive, as would highly inefficiency gas appliance for switching from electricity to gas, but both of these scenarios are unlikely. The effect on CAPIC from changes in appliance cost, discount rate and peak coincidence is much more significant. If the peak coincidence of power use for electric cooking and space heating were 10% lower than assumed here, the fuel switching interventions would be more expensive that a new peak power plant.

To understand the magnitude of the energy saving interventions, it is useful to compare them to total national energy use. Total domestic electricity consumption in 1996 was nearly 4 800 GWh (Eskom 1996b). Just thermal improvements and energy-efficient lighting would save 210 GWh, or 5% of current consumption – and this is only looking at the low-income urban sector. Of course, this is electricity saved in 2007 – by which time baseline consumption could easily reach 6 000 GWh. Because we are focusing on peak electricity, it is also useful to compare the savings to electricity generated by peaking pump storage stations. Total electricity sent out from Eskom's pump storage stations in 1996 was 2 220 GWh (Eskom 1996b). In other words, just these two interventions could theoretically save a 10% of all of the electricity produced by peak capacity in 1995, with economic benefits for every kilowatt hour saved. The total energy savings from all interventions, including paraffin, coal and other fuel savings, comes to over 2 300 *GWh* equivalent in 2007 – almost half the total domestic electricity consumption of the entire country today.

Comparing installed capacity to avoided peak capacity is even more striking. Eskom's current pump storage facilities have a net maximum capacity of 1 400 MW. Without a concerted strategy for demand-side management and energy efficiency, that capacity will necessarily increase dramatically after currently mothballed plants are brought back on line, and as domestic power use during peak hours climbs. The four interventions outlined in this report that avoided peak capacity would, however, eliminate the need for over 2 400 MW of peak capacity in 2007 – more than is currently in place. Again, it is important to recognise that these are all savings from the low-income urban sector – middle- and upper-income households are not included. In addition, the significant savings of base-load power have not been included in this analysis. Further research is needed on the implications for domestic gas markets of switching to gas for cooking and space heating on a large scale.

As important as the specific results of this analysis is the methodology presented, which compares demand- and supply-side options for energy services on an equal basis. Analysts and stakeholders in the energy sector may disagree over the assumptions used, particularly the long run marginal cost of energy. The methodology, however, is robust enough to incorporate changes in these assumptions. In fact, this approach provides a tool for weighing up different options from a national perspective over a range of assumptions, to facilitate better allocation of national resources. The methodology is probably best suited, however, to interventions that only involve one fuel, because the calculations become more complex and less straight-forward for fuel switching. Other analytical tools should be explored to understand what kinds of fuel switches are beneficial for consumers and the nation.

The analysis from Eskom's perspective also raises important questions about the methodology as well as the regulatory structure of the electricity industry. The calculation of CAPIC from Eskom's perspective shows that all of the electricity saving interventions are at or well below the cost of new supply. Eskom might argue, however, that the relevant measure is not CAPIC but the Net Annual Benefit, which includes revenue losses as well as avoided electricity costs. From a net benefit perspective, none of the interventions is attractive to Eskom. In an environment where Eskom generates profits through a margin on each kWh sold, energy efficiency will almost never be attractive for the utility even if it is economically beneficial for the country. This is why many countries have moved to "rate of return" regulation for public utilities, where utilities make a return on capital regardless of how much electricity is sold. Including energy efficiency investments in the rate base, in some cases even with a higher rate of return than for supply-side capital, provides economic and financial incentives for utilities to invest in efficiency programmes that are good for the country. The South African government and National Electricity Regulator would do well to consider these issues in the current debates on the future structure and regulatory framework for the industry.

Energy efficiency and fuel switching interventions in low-income urban households can provide significant economic, environmental and energy saving benefits. The interventions presented here are good examples of 'low hanging fruit' – savings that produce 'win-win' results for communities and the nation. If South African policy makers, industry, and community organisations do not move forward with energy efficiency strategies for the poor, they will be foregoing a golden opportunity to meet the national goals of economic efficiency, environmental sustainability, and equity. In an era where the decisions of South-African policy-makers are complicated by a constant barrage of conflicting priorities and insufficient analysis, one thing is clear: it is generally cheaper to save energy than to produce it.

References

Borchers, M 1997. Institutional and financial implications of fuel switching. Energy and Development Research Centre, University of Cape Town.

Clark, A 1997. Economic analysis of Eskom's energy-efficient lighting programme for low-income households. Energy and Development Research Centre, University of Cape Town.

Cowan, W D, M L Borchers, A A Eberhard, G J Morris and C de V Purcell 1992. *RAPS Design Manual*. Cape Town: Energy and Development Research Centre, University of Cape Town.

Craemer, T. SA power utility aims to save 5000 MW. *Engineering News*. July 25-31 1997. P. 9.

Davis, M 1996. Electricity consumption growth in newly electrified settlements. Energy and Development Research Centre, University of Cape Town.

Davis, M and T Horvei 1995. *Handbook for economic analysis of energy projects*. Johannesburg: Development Bank of Southern Africa.

Eskom 1996a. *Annual Report*. Eskom: Sandton.

Eskom 1996b. *Statistical Yearbook*. Eskom: Sandton.

Eskom 1996c. Summary of IEP5. Eskom: Sandton.

Eskom 1997. IEP6. Volume 3: Demand side management. Eskom: Sandton.

Swisher, J N, G de M Jannuzzi and R Y Redlinger 1997. *Tools and Methods for Integrated Resource Planning: Improving Energy Efficiency and the Environment*. UNEP Collaborating Centre on Energy and Environment, Riso National Laboratory: Roskilde, Denmark.

Koomey, J, A H Rosenfeld and A Gadgil 1990. Conservation screening curves to compare efficiency investments to power plants. *Energy policy 18 (8)*. October. Pp. 774-782.

Marbeck Resource Consultants 1996. Appliance Energy Labelling Program: Activity 1 Report. February 19, 1996.

NER 1996. Electricity supply statistics for south Africa. National Electricity Regulator: Sandton.

Pabot, J L 1998. Chief Engineer, Power Systems Support, Eskom Transmission Group. Personal communication.

Pearce, D W and J J Warford. 1993. *World without End: Economics, environment and sustainable development*. Oxford University Press: Oxford. Chapter 3: 'Fairness and Time'.

Perrings, C 1991. Reserved rationality and the precautionary principle: Technological change, time, and uncertainty in environmental decision making. In Krishnan, R., Harris, J. M. and N. R. Goodwin (eds) *A Survey of Ecological Economics*. Island Press: Washington. 1995.

Simmonds, G 1997. Financial and economic implications of thermal improvements. Energy and Development Research Centre, University of Cape Town.

Simmonds, G and Clark, A 1998. Energy strategies for the urban poor. Energy and Development Research Centre, University of Cape Town.

Simmonds, G and N Mammond 1996. Energy services in low-income urban South Africa: A quantitative assessment. Energy and Development Research Centre, University of Cape Town.

Surtees, R 1998. *Journal of Energy in Southern Africa*. ##

Surtees, R 1997. Eskom Residential Demand Side Management Manager. Personal communication.

Thorne, S 1996. Financial costs of household energy services in four South African cities. Energy and Development Research Centre, University of Cape Town.

Thorne, S 1997. Economic costs of household energy services in South Africa. Energy and Development Research Centre, University of Cape Town.

APPENDIX

Detailed calculations for all interventions

Summary: Cost of Conserving Energy and Capacity

	Thermal Improvement	Energy Efficie Lighting	Elec to Gas Spc Htg	Elec to Gas: Cooking	Par to Elec: Lighting	Par to SWH Water Htg	Candle to E Lighting	Par to Gas: Spc Htg	Par to Gas: Cooking	Par to Gas: Water Htg	Par to Elec Cooking
Energy Savings in yr 10 (TJ)	1,980	2,624	4,884	6,096	1,227	2,613	715	107	1,688	2,523	(1,390)
Cost of conserving energy (R/MJ)	0.014	0.0073	0.0195	0.015	-0.09	0.06	-0.13	0.02	-0.01	0.05	
Peak Elec Savings in yr 10 (GWh)	41	175	395	485	(20)		(19)				
Cost of conserving peak elec (R/kWh	0.649	0.110	0.409	0.312							
Avoided peak capacity in yr 10 (MW)	467	194	867	899		(899)					
Cost of Avoided Peak Cap (R/kW)	669	1,112	2102	1894							

NB: peak elec savings at the plant, not the socket

Variables in sensitivity analysis

Discount Rate	8%	**Old appliance cost (except CFLs and tl**	+ - 50%
Peak coincidence	*+ - 10%*	Ceiling	450
Cooking	0.7	CFL	50
Water Heating	0.7	Electric heater	52
Space Heating	0.9	Electric hot plate	104
Refrigeration	0.9	Paraffin pressure lamp	192
Lighting	0.7	Paraffin flame stove (water/cooking)	107
Diversified Load Factor	*+ - 10%*	Candles	0.4
Cooking	0.5	Paraffin heater	31
Water Heating (also affects switching)	0.5	**New Appliance Efficiency**	+ - 20%
Space Heating	0.5	Gas heater	75
Refrigeration	0.3	Gas ring	50
Lighting (also affects fuel switching)	0.7	SWH with elec backup	234
	+ - 50%	Gas geyser	84
Gas cost (R/kg)	2.0		

Eskom Summary

Thermal Improvements		CAPIC	Net Ann Benefit
Cost of avoided capacity kW		R/kW	R/HH
-no subsidy	467	-	(3)
-50% subsidy		473	(22)
-100% subsidy		946	(42)
Energy Efficient Lighting			R/bulb
Cost of avoided capacity kW		R/kW	
-no subsidy	194	-	1
-50% subsidy		983	(2)
-100% subsidy		1,967	(6)
Electricity to Gas: Space Heating			R/HH
Cost of avoided capacity kW		R/kW	
-no subsidy	867	-	(40)
-50% subsidy		273	(73)
-100% subsidy		546	(106)
Electricity to Gas: Cooking			R/HH
Cost of avoided capacity kW		R/kW	
-no subsidy	899	-	(49)
-50% subsidy		47	(57)
-100% subsidy		93	(64)

	Water Heating	0.5	Water He	0.7			
	Space Heating	0.5	Space He	0.9			
	Refrigeration	0.3	Refrigerat	0.9			
	Lighting	0.7	Lighting	0.7			
(percentage of peak electricity used)			*(percentage chance that appliance is on during peak)*				
Externality costs by fuel (excl CO2) 1994							
	Per GJ		low	central	high		
	Electricity generation	mills/kWh	5.2	7.23	9.1	Van Horen 96b:118	
	Coal pollution	R/GJ delive	1.6	3.6	6.5	Van Horen 96b:170	
	Wood pollution	R/GJ	4.4	19.8	53.8	Van Horen 96b:170	
	Paraffin poisoning	R/GJ	3.5	14.2	52.0	Van Horen 96b:170	
	Fires/burns: Paraffin					adjust for space heat	
	-lighting	R/GJ	8.75	67.68	126.90	Adjusted from Van H	
	-other	R/GJ	1.75	13.54	25.38	Borchers 97 (spread	
	Tot paraffin-lighting	R/GJ	12.24	81.86	178.85		
	Tot paraffin-other	R/GJ	5.24	27.72	77.33		
	Fires/burns: Candles	R/GJ	8.16	63.17	118.4	Note: 70% of Van H	
	Gas	R/GJ	0.0	0.0	0.0		
	Per Unit		low	central	high		
	Electricity generation	R/kWh	0.005	0.007	0.009	calculated from calor	
	Coal pollution	R/kg	0.043	0.097	0.174	values given below	
	Wood pollution	R/kg	0.069	0.307	0.833		
	Total paraffin	R/l	0.199	1.1	2.939		
	Paraffin poisoning	R/l	0.133	0.539	1.974		
	Fires/burns: paraffin						
	-lighting	R/l	0.332	2.572	4.822		
	-other	R/l	0.066	0.514	0.964		
	Fires/burns: Candles	R/candle					
	Gas	R/kg					
Calorific Values							
	Coal	MJ/kg	27.0	Davis and Horvei 95:6.21			
	Parrafin	MJ/l	38.0	Davis and Horvei 95:6.21			
	Gas	MJ/kg	49.8	Davis and Horvei 95:6.21			
	Wood (20%)	MJ/kg	15.5	Davis and Horvei 95:6:21			

Assumptions for All Interventions							
Conversions							
	kWh/MJ	0.278					
	MJ/kWh	3.6					
Discount Rate		Units					
	-Social		8%	Davis and Horvei 95:5.6			
	-Household		30%				
	-Eskom		6%	Yafele, pers comm			
Economic energy costs by fuel (except electri				c/MJ			
Coal		R/kg	0.244	0.90	Simmond	(Davis and Horvei 9	
Paraffin		R/l	1.3	3.45	Simmonds 97:11		
Gas		R/kg	2.0	4.0	Simmonds 97:10		
Wood		R/kg	0.5	3.1	Simmonds 97:11		
Candles		R/candle	0.5	14.5	Simmonds and Mammon 96: 6		
Capital adjustment factor calculation							
	discount rate	levelized ann cost			*This is used to convert capital c*		
	8%	8.22	years	30	*Eskoms discount rate into natio*		
	6%	6.9	capital	100	*using a national discount rate*		
Economic costs for electricity							
Electricity generation							
	Off-Peak (LRMC)	c/kWh					
Electricity total		*per kWh sent out*		/MJ elec	/MJ primary		
	Peak (LRMC)	c/kWh	38.5	11	3.7	*Adjust 80% capital p*	
	Off-Peak (LRMC)	c/kWh	9.2	3	0.9	*Adjust 50% capital p*	
Electricity total		*per kWh delivered*					
	Peak (LRMC)	c/kWh	42.7		*cost per kWh sent out /*		
	Off-Peak (LRMC)	c/kWh	10.2		*T&D efficiency*		
Cost per MJ of primary energy							
	Peak	c/MJ	3.7		*multiply by generation efficienc*		
	Off-Peak	c/MJ	0.9				
Eskom Rates/Costs							
	Avg Residential tarriff	c/kWh	26				
		per kWh sent out					
	Peak LRMC		33	*delivered cost x T&D efficiency*			
	Off-peak gen LRMC	c/kWh	6.0	Davis and Horvei 95:6.8			
	Off-peak total LRMC	c/kWh	8.3	*includes cost of T&D based on load factor*			
		per kWh delivered					
	Peak LRMC	c/kWh	37	Surtees 1997, pers comm (Res peak TOU			
	Off-peak total LRMC	c/kWh	9.3	*sent out cost / T&D efficiency*			
Electricity capacity capital cost							
	New peak (pump st)	R/kW	1,800	Surtees 1997, pers comm			
	New off peak (coal)	R/kW	2,750	Surtees 1997, pers comm			
	Transmission	R/kW-yr	132	Davis and Horvei 95			
Peak plant life		yr	30				
Reserve Margin							
	Plant availability fact	%	0.9	Eskom 96:17			
Fuel cycle efficiencies							
Electricity							
	Generation (avg)	34.4	Eskom 95:8				
	Generation (new)	34.3	Kendal (Eskom 95:12)				
	T&D	0.9	Based on 10% technical losses (Davis 96:3)				
		30.87	Eskom 95:70 gives 6% for T losses only				
Peak electricity use			**Peak coincidence of power use**				
	Cooking	0.5	Cooking	0.7			

Energy Efficient Lighting Model

Assumptions

Cost of CFL	R	50	
Cost of incandescents	R/yr	3	*assumes 750 hr life and 3 hr/day*
Wattage of CFL	W	15	
Wattage avoided at end-	W	45	*assumes replacement of 60W bulb*
Reserve margin		1	
Peak coincidence of power use		70%	
Peak wattage at plant	W	31.50	*avoided watts x peak coinc*
Avoided peak cap	W	38.89	*includes reserve margin & T&D losses*
Peak plant life	yr	30	
Price of electricity	c/kWh	27	*weighted by peak/off-peak*
Life of CFL	yr	10	
Discount Rate		8%	
Ann electricity savings	kWh deliver	45	*assumes 1000 hrs use per year*
Ann electricity savings	kWh sent o	*50*	*wattage diff x T&D efficiency*
Ann peak elec savings	kWh sent o	*35*	
Ann primary energy savi	MJ	523	*includes gen losses*

Household/Single Bulb Model

Cost of conserving energy

Amort cost of CFL	R/yr	7.5	
less avoided incandesce	R/yr	3.25	
less avoided external co	R/yr	0.36	
Incremental cost	R/yr	3.84	
CCE	R/kWh total	0.077	*Incremental cost/energy savings*
CCE	R/kWh pea	0.110	
CCE	R/MJ	0.007	*divided by primary energy savings*
Avoided capacity in yr 10	(kW)	0.039	*includes reserve margin & T&D losses*
Incremental cost 30 yrs	R	43.2	
CAPIC	R/kW	1,112	

Eskom Perspective

Tariff		0.26		
Cost of electricity (deliver		0.29	*weighted by peak/off-peak*	
Ann revenue lost	R/yr		11.7	
Ann avoided generation c	R/yr		12.9	
Capital cost	R		50	
Amort capital cost	R/yr		6.8	

Capital Subsidy level	100%	50%	0%	
Subsidy over plant life	76.48	38.24	0.00	
CAPIC (R/kW)	1,967	983	-	*only includes subsidy*
CCE (R/kWh)	0.14	0.07	0.00	
CCE peak (R/kWh peak)	0.19	0.10	0.00	
Net ann benefit (R/yr)	(5.6)	(2.2)	1.2	*avoided generation - capital -*
Benefit over plant life (R)	-63.45	-25.21	13.03	

Programme Model

Bulbs		Totals	1	2	3
Bulbs installed per year	*(must keep replacing bulbs to*		500,000	500,000	500,000
Cummulative bulbs	*avoid capacity investment)*		500,000	1,000,000	1,500,000
Annual electricity savings					
- MJ total	*installed bulbs x ann svgs*		90,000,000	180,000,000	270,000,000
-kWh total			25,000,000	50,000,000	75,000,000
-kWh peak			17,500,000	35,000,000	52,500,000
Annual energy savings in yr 10					
- MJ electricity		900,000,000			

Cce7	CFL	
- MJ primary energy	2,623,906,706	
- kWh total	250,000,000	
- kWh peak	175,000,000	
Avoided peak capacity in yr 10		
Avoided capacity	194444	*including reserve margin & T&D losses*

Thermal Improvements to Low-Cost Housing

Assumptions

Cost of ceiling	R	450		
Peak coincidence of electricity use		50%	*used to weight cost electricity*	
Peak coindidence of power use		90%	*est based on load profile*	
Wattage of electric appliance		1.5	kW	*also used in fuel switching calculations*
Peak wattage		1.35	kW	
Discount Rate		8%		
Life of ceiling (yrs)		20		
Peak plant life	yr	30		

Single House model

Cost of conserving energy

Amort cost of ceiling	R/yr	45.8	
less avoided external c	R/yr	18.1	
Incremental cost	R/yr	27.8	
average elec savings	kWh/yr	86	*Note that not all houses are using electricity*
average peak elec svs	kWh/yr	43	*for space heating; includes T&D losses*
average energy svs	MJ/yr	1995	*for all fuels combined*
CCE	R/kWh total	0.324	*NB: only electricity*
CCE	R/kWh peak	0.649	*savings included in these two*
CCE	R/MJ	0.014	*cost/total energy savings from all fuels*
Share of hse using elec (in yr 10)		28%	
Avoided capacity in yr 10 (kW)		0.467	*includes reserve margin & T&D losses and*
Incremental cost 30 yr	R	312	*takes into account share of houses using*
CAPIC	R/kW	669	*electricity for heating*

Eskom Perspective

Tariff		0.26		
Cost of electricity		0.23	*delivered; weighted by peak/off-peak*	
Ann revenue lost	R/yr		22.2	
Ann avoided generatio	R/yr		19.7	
Capital cost	R		450	
Amort capital cost	R/yr		39	

Capital Subsidy level	100%	50%	0%	
Subsidy over plant life	441.68	220.84	0.00	
CAPIC (R/kW)	946	473	-	
CCE (R/kWh)	0.46	0.23	0.00	
CCE peak (R/kWh pea	0.92	0.46	0.00	
Net ann benefit (R/yr)	(42)	(22)	(3)	*avoided generation - rev loss - capital*
Benefit over plant life (	(575)	(305)	(35)	

For single home Fuel type	**Ann Energy sav** (units)	**Ann Energy sav** (MJ)	
electricity	294	1058	*elec delivered*
coal	98	2646	
wood	155	2403	

gas 30 1494

Programme Model

Cummulative Number of Houses by Fuel Type			Year								
Fuel type				1	2	3	4	5	6	10	20
Electricity				32,000	64,000	96,000	128,000	160,000	180,000	280,000	480,000
Coal				32,000	64,000	96,000	128,000	160,000	155,000	130,000	80,000
Wood				24,000	48,000	72,000	96,000	120,000	115,000	90,000	40,000
Paraffin				72,000	144,000	216,000	288,000	360,000	350,000	300,000	200,000
Gas				2,000	4,000	6,000	8,000	10,000	10,000	10,000	10,000
None				38,000	76,000	114,000	152,000	190,000	190,000	190,000	190,000
Total				200,000	400,000	600,000	800,000	1,000,000	1,000,000	1,000,000	1,000,000
Annual Energy Savings (Units)			Year								
Fuel type		Units		1	2	3	4	5	6	10	20
electricity	***Energy savings X***	kWh delivered		9,408,000	18,816,000	28,224,000	37,632,000	47,040,000	52,920,000	82,320,000	141,120,000
coal	***Number of house***	kg		3,136,000	6,272,000	9,408,000	12,544,000	15,680,000	15,190,000	12,740,000	7,840,000
wood	***using that fuel***	kg		3,720,000	7,440,000	11,160,000	14,880,000	18,600,000	17,825,000	13,950,000	6,200,000
paraffin		litre		2,808,000	5,616,000	8,424,000	11,232,000	14,040,000	13,650,000	11,700,000	7,800,000
gas		kg		60,000	120,000	180,000	240,000	300,000	300,000	300,000	300,000
avg elec savings over all houses			86	47	47	47	47	47	53	82	141
Annual elec savings in yr 10		kWh		82,320,000							
Annual peal elec savings in yr 10		kWh		41,160,000							
Annual Energy Savings (MJ)											
Fuel type											
electricity	***Ann energy savings***			109,714,286	219,428,571	329,142,857	438,857,143	#########	#########	#########	1,645,714,286
coal	***x MJ/unit***			84,672,000	169,344,000	254,016,000	338,688,000	#########	#########	#########	211,680,000
wood	***(for elec, divide by***			57,660,000	115,320,000	172,980,000	230,640,000	#########	#########	#########	96,100,000
paraffin	***gen, T&D efficiency)***			106,704,000	213,408,000	320,112,000	426,816,000	#########	#########	#########	296,400,000
gas				2,988,000	5,976,000	8,964,000	11,952,000	14,940,000	14,940,000	14,940,000	14,940,000
average per house			1995	1809	1809	1809	1809	1809	1837	1980	2265
Annual energy savings in yr 10			1979745000								
		in yr 10									
Avoided peak capacity (kW)			466,667	53333	106667	160000	213333	266667	300000	466667	800000
	includes reserve margin & T&D losses										
Avoided external costs (R)				1	2	3	4	5	6	10	20
electricity				68020	136040	204060	272079	340099	382612	595174	1020298
coal	***External costs per unit X***			305666	611332	916998	1222664	1528330	1480569	1241768	764165
wood	***Annual energy savings***			1141668	2283336	3425004	4566672	5708340	5470493	4281255	1902780
paraffin	*(using central estimate)*			2957408	5914816	8872224	11829632	14787040	14376289	12322534	8215022
gas	*(external costs in assumptions page)*										
average per house			18.1	22.4	22	22	22	22	22	18	12

Fuel Switching model | Social Discount R | 8% | 30 plant life (yrs)

1. From Paraffin to Gas for Cooking

End use	Cooking		
	From	To	
	Paraffin wick	Gas ring	
Primary energy cost (R/MJ)	0.034	0.040	

Single Household Model

appliance cost (R)	107.0	35.1	
appliance life (yr)	3.0	4.8	
amort appl cost/year (R/yr)	41.5	9.1	
access cost (R)	0.0	78.4	*half of bottle deposit*
access life (yr)	0.0	30.0	
amort access cost/year (R/yr)	0.0	7.0	
access maint cost (R/yr)	0.0	0.0	
external costs (R/yr)	224.9	0.0	*assumptions x energy use*
new fuel cost (R/yr)		178.3	*new cons x cost/MJ*
Total new cost (R/yr)		194.4	*new appliance, access, maint & external cost*
less old cost (R/yr)		266.4	*old appliance, external (accessand connection*
Incremental cost (R/yr)		-72.0	*mait is sunk cost)*
appliance use (hr/day)	4.5		
fuel consumption (unit/hr)	0.1		
conversion (MJ/unit)	38.0		
annual old fuel use (MJ)	8,114.0		*hr/day x units/hr x MJ/unit x 365*
useful energy	2,231.3	2,231.3	*new appliance must match useful energy of old one*
appliance efficiency	28%	50%	
annual new fuel use (MJ)		4,462.7	*useful energy / new appliance efficiency*
net energy savings (MJ/yr)		3,651.3	*annual old fuel use - annual new fuel use*
CCE (R/MJ OLD FUEL)		-0.01	*NB: divide by old fuel not net savings*

Programme Model

Programme number of houses				1	2	3
Total low-income using paraffin '96		non-elec				
(share from GS,NM 96:49)	0.8	924,529				
Penetration over 10 yrs	0.5					
Houses converting per year				46,226	46,226	46,226
Cumulative houses				46,226	92,453	138,679
Annual energy savings (MJ)		In year 10				
(cum houses x ann savings per hse)		1,687,855,603		168,785,560	337,571,121	506,356,681

2. Paraffin to Electricity for lighting

End use	Cooking		
	From	60.0	
	Paraffin pres	60W Incandescent	
Peak Electricity Use		0.7	
Peak coinc of power use		0.7	
Primary energy cost (R/MJ)	0.034	0.028	Elec is weighted for peak/offpeak

Single Household Model

appliance cost (R)	192.0	2.1	
appliance life (yr)	4.4	0.8	
amort appl cost/year (R/yr)	53.6	2.9	
access cost (R)	0.0	32.6	*7.5% of connection cost divided*
access life (yr)	0.0	30.0	*by 5 bulbs*
amort access cost/year (R/yr)	0.0	2.9	
access maint cost (R/yr)	0.0	4.5	*7.5% of maint cost / 5 bulbs*
external costs (R/yr)	336.1	0.9	*assumptions x energy use*
new fuel cost (R/yr)		12.7	*new cons x cost/MJ*
Total new cost (R/yr)		23.9	*new appliance, access, maint & external cost*
less old cost (R/yr)		389.8	*old appliance, external (accessand connection*
Incremental cost (R/yr)		-365.9	*maint is sunk cost)*
Incremental cost (30 yrs)		-4,448.8	
energy use (kWh/1000 lhrs)	0.8	0.1	
delivered energy use (MJ/1000 lhrs)	3.0	0.3	
avg daily home lighting (1000 lhrs)	3.8	3.8	*new lighting service must match old service*
annual lighting use (1000 lhrs)	1,368.8	1,368.8	
avg daily primary energy use (MJ)	11.3	1.2	
ann old fuel use (MJ)	4,106.3		
annual new fuel use (MJ) (primary energy)		448.0	*for equivalent light output*
generation efficiency		34%	
T&D Efficiency		90%	
Primary energy at plant (MJ)		1,451.1	
net energy savings (MJ/yr)		2,655.2	*annual old fuel use - annual new fuel use*
CCE (R/MJ OLD FUEL)		-0.09	***NB: divide by old fuel not net savings***
Increased capacity (kW)		0.052	includes reserve margin and T&D losses

Programme Model

Programme number of houses		-		1	2	3
Total low-income non-elec using paraffin '96						

Houses converting per year		46,226	46,226	46,226
Cumulative houses		46,226	92,453	138,679
Annual energy savings (MJ)	In year 10			
(cum houses x savings per house)	1,227,381,358	122,738,136	245,476,272	368,214,408
New annual electricity use (kWh)	In year 10			
(cum houses x new electricity use)	19,729,497	1,972,950	3,945,899	5,918,849
New annual peak electricity use (kWh)	In year 10			
(cum house x ann elec/hse x peak use)	13,810,648	1,381,065	2,762,130	4,143,194
Additional peak capacity (kW)	In year 10			
(cum house x increased cap per hse)	23,969	2,397	4,794	7,191

3. Paraffin to Gas for Space Heating

End use	Space Heating From Paraffin	To Gas	
Primary energy cost (R/MJ)	0.034	0.040	
Single Household Model			
appliance cost (R)	30.7	245.8	
appliance life (yr)	5.5	3.0	
amort appl cost/year (R/yr)	7.1	95.4	
access cost (R)	0.0	78.4	*half of bottle deposit*
access life (yr)	0.0	30.0	
amort access cost/year (R/yr)	0.0	7.0	
external costs (R/yr)	192.2	0.0	*assumptions x energy use*
new fuel cost (R/yr)		267.9	*new cons x cost/MJ*
Total new cost (R/yr)		370.2	*new appliance, access, maint & external cost*
less old cost (R/yr)		199.3	*old appliance & external*
Incremental cost (R/yr)		170.9	
appliance use (hr/day)	2.5		
fuel consumption (unit/hr)	0.2		
conversion (MJ/unit)	38.0		
annual old fuel use (MJ)	6,935.0		*hr/day x units/hr x MJ/unit x 365*
appliance efficiency	0.73	0.75	
useful energy	5,027.9	5,027.9	
annual new fuel use (MJ)		6,703.8	*useful energy / new appliance efficiency*
net energy savings (MJ/yr)		231.2	*annual old fuel use - annual new fuel use*
CCE (R/MJ OLD FUEL)		0.02	***NB: divide by old fuel not net savings***

Programme Model

Programme number of houses			1	2	3
Total low-income using paraffin '96					
(share from GS,NM 96:49)		elec			
Penetration over 10 yrs	0.8	924,528.8			
Houses converting per year	0.5		46,226	46,226	46,226
Cumulative houses			46,226	92,453	138,679
Annual energy savings (MJ)		In year 10			
(cum houses x ann savings per hse)		106,860,120	10,686,012	21,372,024	32,058,036

4. Paraffin to Gas for Water Heating

End use	Space Heating From Paraffin wick/pot	To Gas geyser	
Primary energy cost (R/MJ)		0.040	
Single Household Model			
appliance cost (R)	107.0	4,298.2	
appliance life (yr)	3.0	21.9	
amort appl cost/year (R/yr)	41.5	422.0	
access cost (R)	0.0	78.4	*portion of connection cost weighted by power use*
access life (yr)	0.0	30.0	
amort access cost/year (R/yr)	0.0	7.0	
external costs (R/yr)	224.9	0.0	*assumptions x energy use*
new fuel cost (R/yr)		106.1	*new cons x cost/MJ*
Total new cost (R/yr)		535.1	*new appliance, access, maint & external cost*
less old cost (R/yr)		266.4	*old appliance & external*
Incremental cost (R/yr)		268.7	
appliance use (hr/day)	4.5		*Need 4.5 hrs on paraffin stove to*
fuel consumption (unit/hr)	0.1		*heat equivalent of 1.5 hrs of gas use*
conversion (MJ/unit)	38.0		
annual old fuel use (MJ)	8,114.0		*hr/day x units/hr x MJ/unit x 365*
appliance efficiency	28%	84%	
useful energy	2,231.3	2,231.3	
annual new fuel use (MJ)		2,656.4	*useful energy / new appliance efficiency*
energy savings (MJ/yr)		5,457.6	*annual old fuel use - annual new fuel use*
CCE (R/MJ OLD FUEL)		0.049	***NB: divide by old fuel not net savings***

Programme Model

Programme number of houses			1	2	3
Total low-income using para '96		non-elec			
(share from GS,NM 96:49)	0.8	924,528.8			

Penetration over 10 yrs	0.5				
Houses converting per year			46,226	46,226	46,226
Cumulative houses			46,226	92,453	138,679
Annual energy savings (MJ)		In year 10			
(cum houses x ann savings per hse)		2,522,852,951	252,285,295	504,570,590	756,855,885

5. Paraffin to SHW mix for Water Heating

End use	Water Heating From Paraffin wick/pot	To SWH w/backup	
Primary energy cost (R/MJ)	0.034	0.028	Elec is weighted for peak/offpeak
Single Household Model			
Peak Coinc of elec use			
Peak-coinc of power use			
Wattage of elec appl		2.0	kW
appliance cost (R)	107.0	4,766.9	
appliance life (yr)	3.0	15.0	
amort appl cost/year (R/yr)	41.5	556.9	
access cost (R)	0.0	434.0	*portion of connection cost weighted by power use*
access life (yr)	0.0	30.0	
amort access cost/year (R/yr)	0.0	38.6	
access maint cost (R/yr)	0.0	60.0	*portion of elec connection maint. weighted by power use*
external costs (R/yr)	224.9	0.0	*assumptions x energy use*
new fuel cost (R/yr)		87.6	*new cons x cost/MJ*
Total new cost (R/yr)		743.1	*new appliance, access, maint & external cost*
less old cost (R/yr)		266.4	*old appliance, external (accessand connection*
Incremental cost (R/yr)		476.7	*mait is sunk cost)*
appliance use (hr/day)	4.5		*Need 4.5 hrs on paraffin stove to*
fuel consumption (unit/hr)	0.13		*match 1.75 hrs from solar/elec mix*
conversion (MJ/unit)	38.0		
annual old fuel use (MJ)	8,114.0		*hr/day x units/hr x MJ/unit x 365*
Appliance Efficiency	28%	234%	ST (mid)
Generation efficiency		34%	
T&D efficiency		90%	
Total efficiency		72%	
useful energy	2,231.3	2,231.3	*new appliance must match useful energy service of old*
annual new fuel use in house (MJ)		953.6	*useful energy / new appliance efficiency*
primaryenergy at plant (MJ)		3,089.0	*new fuel use / elec gen and T&D efficiencies*
Net energy savings (MJ/yr)		5,025.0	*annual old fuel use - new primary energy*
CCE (R/MJ OLD FUEL)		0.06	***NB: divide by old fuel not net savings***

Programme Model

Programme number of houses			1	2	3
Total low-income using elec '96		elec + non-elec			
(share from GS,NM 96:49)	0.9	1,040,094.9			
Penetration over 10 yrs	0.5				
Houses converting per year			52,005	52,005	52,005
Cummulative houses			52,005	104,009	156,014
Annual energy savings (MJ)		In year 10			
(cumm houses x ann savings per hse)		2,613,232,313	261,323,231	522,646,463	783,969,694
New capacity needed		In year 10			
cumm hse x wattage x peak coinc / (T&D eff. X reserve m		898,847	89885	179769	269654

6. Candles to Electricity for Lighting

End use	Lighting From Candles	To Inc 60W	*Lighting wattage and peak coincidence* *from par-elec switch*
Primary energy cost (R/MJ)	0.145	0.028	Elec is weighted for peak/offpeak
Single Household Model	**for 5 candles**	60.0	
appliance cost (R)	2.0	2.1	
appliance life (yr)	0.009	0.8	
amort appl cost/year (R/yr)	227.7	2.9	
access cost (R)	0.0	32.6	*7.5% of connection cost divided*
access life (yr)	0.0	30.0	*by 5 bulbs*
amort access cost/year (R/yr)	0.0	2.9	
access maint cost (R/yr)	0.0	4.5	*7.5% of maint cost / 5 bulbs*
external costs (R/yr)	186.8	0.6	
new fuel cost (R/yr)		25.4	*new cons x cost/MJ*
Total new cost (R/yr)		36.2	*new appliance, access, maint & external cost*
less old cost (R/yr)		414.5	*old appliance, external*
Incremental cost (R/yr)		-378.3	
energy use (kWh/1000 lhrs)	5.0	0.09	
energy use (MJ/1000 lhrs)	18.0	0.33	
avg daily lighting (1000 lhrs) (5 candl	*0.5*	*2.3*	*Switch will dramatically improve*
avg daily energy use (MJ)	8.1	0.8	*lighting service (lhrs)*
annual old lighting use (1000 lhrs) (5	164.3	843.2	
ann old fuel use (MJ)	2,956.5		
annual new fuel use at house (MJ)		275.9	
Generation Efficiency		34%	
T&D Efficiency		90%	

(primary energy at plant (MJ))	893.9	
Net energy savings (MJ/yr)	2,062.6	*annual old fuel use - new primary energy*
CCE (R/MJ OLD FUEL)	-0.13	***NB: divide by old fuel not net savings***

Programme Model

Programme number of houses			1	2	3
Total low-income non-elec using candles '96					
(share from GS,NM 96:49)	0.6	693,396.6			
Penetration over 10 yrs	0.5				
Houses converting per year			34,670	34,670	34,670
Cumulative houses			34,670	69,340	104,009
Annual energy savings (MJ)		In year 10			
cum houses x savings per hse		715,107,697	71,510,770	143,021,539	-214,532,309
Annual new electricity use (kWh)					
cum hse x elec/hse					
Annual new peak electricity use (kWh)		In year 10			
cum hse x elec/hse x DLF		18,602,097	1,860,210	3,720,419	5,580,629
Additional peak capacity (kW)		In year 10			
(cum house x increased cap per hse [see switch #2])		17,977	1,798	3,595	5,393

7. Electricity to Gas for Space Heating

End use	Space Heating		
	From	To	
	Elec. Radiant	Gas heater	
Primary energy cost (R/MJ)	0.023	0.040	Elec is weighted for peak/offpeak

Household Model

Peak Electricity Use	50%	
Peak coinc of power use	90%	
Wattage of elec appl	1.5	kW

CCE

appliance cost (R)	52.0	245.8	
appliance life (yr)	5.5	4.8	
amort appl cost/year (R/yr)	12.1	63.7	
access cost (R)	379.8	78.4	*portion of connection cost weighted by power use*
access life (yr)	30.0	30.0	
amort access cost/year (R/yr)	33.7	7.0	
access maint cost (R/yr)	52.5	0.0	*portion of elec connection maint. weighted by power use*
external costs (R/yr)	9.9	0.0	*assumptions x energy use*
new fuel cost (R/yr)		262.5	*new cons x cost/MJ*
New cost (R/yr)		333.2	*new appliance, access, maint & external cost*
less old cost (R/yr)		22.0	*old appliance, external (accessand connection*
incremental cost (R/yr)		311.2	*mait is sunk cost)*
Incremental cost (30 yrs)		3,503.1	
Appliance Efficiency	1.0	0.8	ST (mid)
Generation Efficiency	0.3		
T&D Efficiency	0.9		
appliance use (hr/day)	2.5		
fuel consumption (unit/hr)	1.5		
conversion (MJ/unit)	3.6		
annual old elec use (kWh)	1,368.8		*at the socket*
annual old fuel use (MJ)	4,927.5		*hr/day x units/hr x MJ/unit x 365*
(primary energy at plant MJ)	15,962.1		*old fuel use / elec generation and T&D efficiency*
useful energy	4,927.5	4,927.5	*new appliance must match useful energy service of old*
annual new fuel use (MJ)		6,570.0	*useful energy / new appliance efficiency*
net energy savings (MJ/yr)		9,392.1	*annual old fuel use - annual new fuel use*
electricity savings (kWh/yr)	1,520.8		*at the plant*
Cost of conserving energy (R/MJ)		0.019	INC COST / TOTAL OLD MJ
Cost of conserving elec (R/kWh sent out)		0.205	INC COST / ELEC SENT OUT
Cost of conserving peak elec (R/kWh sent out)		0.409	INC COST / PEAK ELEC SENT OUT

Avoided capacity in yr 10 (kW)	1.67	*includes reserve margin and T&D losses*
Cost of avoided peak capacity	2,101.9	

Eskom Perspective

Tariff		0.26			
Cost of electricity (delivered)		0.23			*weighted by peak/off-peak*
Ann revenue lost	R/yr		355.9		
Ann avoided generation cost	R/yr		315.6		
Capital cost	R		324.2		*appliance and access*
Amort capital cost	R/yr		66.1		*appl and access amort over different lives*
Capital Subsidy level		100%	50%	0%	
Subsidy over plant life		910.4	455.2	0%	
CAPIC (R/kW)		546.2	273.1	-	
Net ann benefit (R/yr)		-106.4	-73.3	(40)	*avoided generation - rev loss - subsidy*
Benefit over plant life (R)		-1,464.4	-1,009.3	-554.1	

Programme Model

Programme number of houses			1	2	3
Total low-income using elec '96		elec			
(share from GS 6/97:9)	0.9	1,040,094.9 -			
Penetration over 10 yrs	0.5				
Houses converting per year			52,005	52,005	52,005

Cumulative houses		52,005	104,009	156,014
Annual energy savings (MJ)	In year 10			
(cum. houses x ann savings per hse)	4,884,337,200	488,433,720	976,867,440	1,465,301,160
Annual peak electricity savings (kWh)	In year 10			
(cum hse x ann elec/hse x peak use)	395,452,748	39,545,275	79,090,550	118,635,825
Avoided capacity (kW)	In year 10			
cumm hse x avoided cap per hse	866,746	86,675	173,349	260,024

---

8. Electricity to Gas for Cooking

End use	Cooking From Elec Hot Plt	To Gas ring	
Primary energy cost (R/MJ)	0.023	0.040	Elec is weighted for peak/offpeak
Single Household Model			
Peak Electricity Use	50%		
Peak coinc of power use	70%		
Wattage of elec appl	2.0 kW		
appliance cost (R)	104.0	35.1	
appliance life (yr)	4.8	4.8	
amort appl cost/year (R/yr)	27.1	9.1	
access cost (R)	596.8	78.4	*portion of connection cost weighted by power use*
access life (yr)	30.0	30.0	
amort access cost/year (R/yr)	53.0	7.0	
access maint cost (R/yr)	82.5	0.0	*portion of elec connection maint. weighted by power use*
external costs (R/yr)	12.1	0.0	*assumptions x energy use*
new fuel cost (R/yr)		314.0	*new cons x cost/MJ*
Total new cost (R/yr)		330.0	*new appliance, access, maint & external cost*
less old cost (R/yr)		39.2	*old appliance, external (accessand connection*
Incremental cost (R/yr)		290.8	*mait is sunk cost)*
Incremental cost (30 yrs)		3,273.8	
Appliance Efficiency	0.7	0.5	ST (mid)
Generation Efficiency	0.3		
T&D Efficiency	0.9		
appliance use (hr/day)	2.3		
fuel consumption (unit/hr)	2.0		
conversion (MJ/unit)	3.6		
annual old fuel use (kWh)	1,679.0		*at the socket*
annual old fuel use (MJ)	6,044.4		*hr/day x units/hr x MJ/unit x 365*
(primary energy at plant MJ)	19,580.2		*old fuel use / elec generation and T&D efficiency*
useful energy	3,928.9	3,928.9	*new appliance must match useful energy service of old*
annual new fuel use (MJ)		7,857.7	*useful energy / new appliance efficiency*
net energy savings (MJ/yr)		11,722.5	*annual old fuel use - annual new fuel use*
electricity saved (kWh/yr)	1,865.6		*At the plant*
Avoided capacity in yr 10 (kW)		1.728	*includes reserve margin and T&D losses*
Cost of conserving energy (R/MJ)		0.015	INC COST / OLD PRIMARY MJ
Cost of conserving elec (R/kWh sent out)		0.156	INC COST / ELEC SENT OUT
Cost of conserving peak elec (R/kWh sent out)		0.312	INC COST / PEAK ELEC SENT OUT
Cost of avoided peak capacity (R/kW)		1,894.1	

Eskom Perspective

Tariff		0.26			
Cost of electricity (delivered)		0.23	*weighted by peak/off-peak*		
Ann revenue lost	R/yr		436.5		
Ann avoided generation cost	R/yr		387.2		
Capital cost	R		113.5		*appliance and access*
Amort capital cost	R/yr		14.3		*appl and access amort over different lives*
Capital Subsidy level		100%	50%	0%	
Subsidy over plant life		161.2	80.6	0.0	
CAPIC (R/kW)		93.3	46.6	0.0	
Net ann benefit (R/yr)		-63.7	-56.5	(49)	*avoided generation - rev loss - subsidy*
Benefit over plant life (R)		-876.8	-778.2	-679.7	

Programme Model

Programme number of houses			1	2	3
Total low-income using elec '96	elec				
(share from GS,NM 96:49)	0.9	1,040,094.9			
Penetration over 10 yrs	0.5				
Houses converting per year		520,047.5	52,005	52,005	52,005
Cummulative houses			52,005	104,009	156,014
Annual energy savings (MJ)	In year 10				
(cumm houses x ann savings per hse)		6,096,232,793	609,623,279	1,219,246,559	1,828,869,838
Annual peak electricity savings (kWh)	In year 10				
cumm hse x elec/hse x peak use		485,088,705	48,508,870	97,017,741	145,526,611
Avoided capacity (kW)	In year 10				
cumm hse x avoided cap per hse		898,847	89,885	179,769	269,654

9. Paraffin to Electricity for Cooking

End use	Cooking From Paraffin wick/pot	To Elec hotplate	
Power useage (kW)		2.0	
Peak coincidence of elec use		0.5	
Peak coincidence of power use		0.5	
Primary energy cost (R/MJ)	0.034	0.023	Elec is weighted for peak/offpeak
Single Household Model			
appliance cost (R)	107.0	104.0	
appliance life (yr)	3.0	4.0	
amort appl cost/year (R/yr)	41.5	31.4	
access cost (R)	0.0	596.8	*portion of connection cost weighted by power use*
access life (yr)	0.0	30.0	
amort access cost/year (R/yr)	0.0	53.0	
access maint cost (R/yr)	0.0	82.5	*portion of elec connection maint. weighted by power use*
external costs (R/yr)	224.9	6.9	*assumptions x energy use*
new fuel cost (R/yr)		253.2	*new cons x cost/MJ*
Total new cost (R/yr)		427.0	*new appliance, access, maint & external cost*
less old cost (R/yr)		266.4	*old appliance, external*
Incremental cost (R/yr)		160.5	
appliance use (hr/day)	4.5		
fuel consumption (unit/hr)	0.1		
conversion (MJ/unit)	38.0		
annual old fuel use (MJ)	8,114.0		*hr/day x units/hr x MJ/unit x 365*
useful energy	2,231.3	2,231.3	*new appliance must match useful energy service of old*
Appliance Efficiency	28%	65%	ST (mid)
Generation Efficiency		0.3	
T&D Efficiency		0.9	
annual new fuel use (MJ)		3,432.8	*useful energy / new appliance efficiency*
primary energy at plant (MJ)		11,120.3	*new fuel use / elec gen and T&D efficiencies*
net energy savings (MJ/yr)		-3,006.3	*annual old fuel use - input energy at plant*

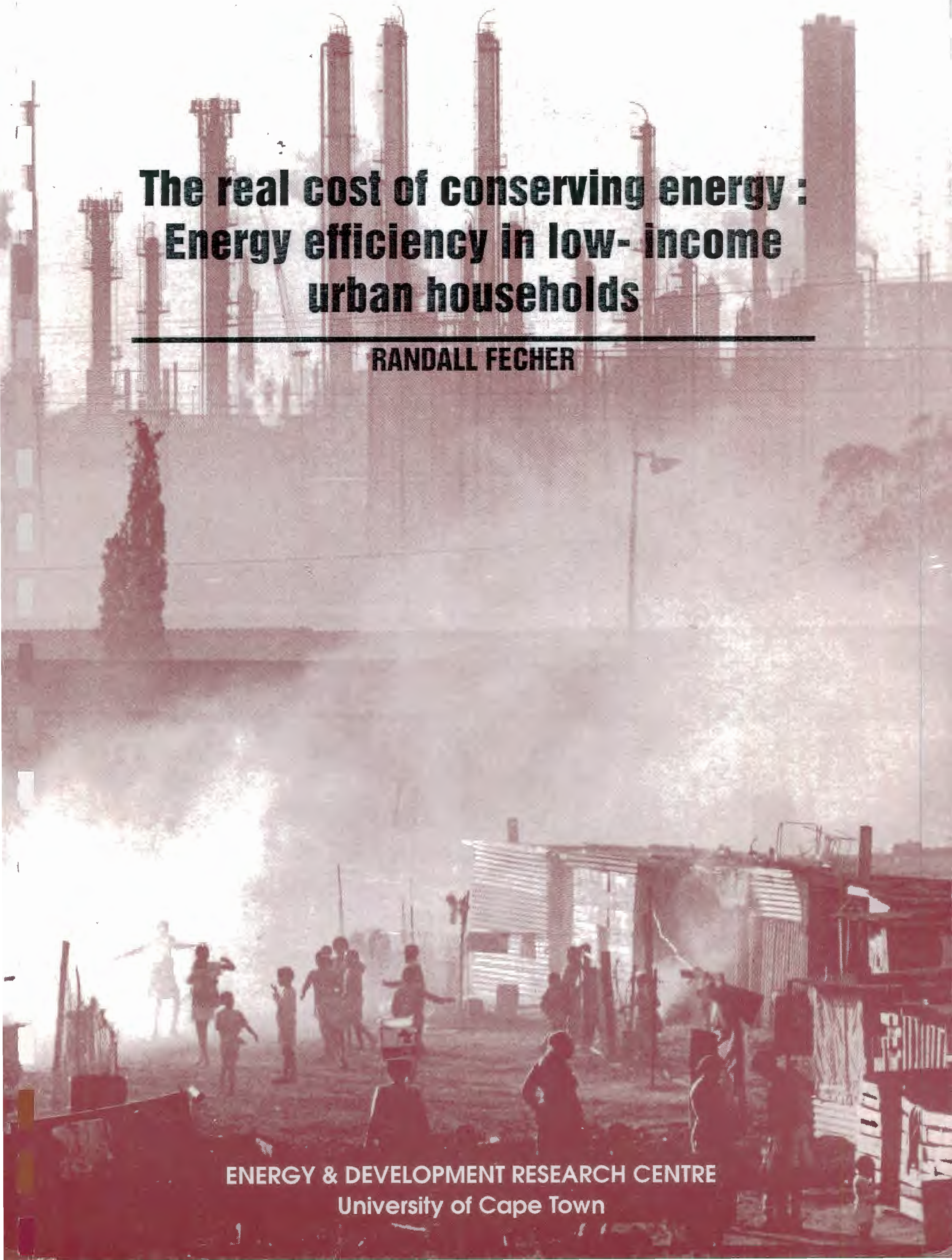
Programme Model

Programme number of houses			1	2	3
Total low-income non-elec using paraffin '96	elec				
(share from GS,NM 96:49)	0.8	924,528.8			
Penetration over 10 yrs	0.5				
Houses converting per year			46,226	46,226	46,226
Cumulative houses			46,226	92,453	138,679
Annual energy savings (MJ)	In year 10				
cum houses x savings per hse		-1,389,711,193	-138,971,119	-277,942,239	-416,913,358
Annual new peak electricity demand (kWh)	In year 10				
cum hse x elec/hse x peak coinc. elec use		220,398,998	22,039,900	44,079,800	66,119,700

EDRC REPORT SERIES

The real cost of conserving energy : Energy efficiency in low- income urban households

RANDALL FECHER



ENERGY & DEVELOPMENT RESEARCH CENTRE
University of Cape Town