Cost benefit analysis of energy efficiency in low cost housing

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Executive summary

This cost-benefit analysis (CBA) was conducted by the Energy and Development Research Centre (EDRC) as part of a larger study on *Environmentally sound energy-efficient low-cost housing study: Evaluation of performance and affordability of intervention technologies.*

This overall study provided critical inputs to the CBA, in particular with regard to the modelling of various interventions, their costs and energy savings. The results of this CBA focus primarily on direct costs, with some consideration of external costs, and should be read in the context of the indirect costs and benefits considered in the overall study, including health, educational and air quality effects.

The five chapters covered in this report are:

- assessment of data/studies on cost savings;
- impact on greenhouse gas emissions;
- cost benefit analysis;
- affordability model;
- model application with focus on low income households.

The consortium which conducted the overall study included the University of the Witwatersrand, University of Pretoria, Peer Africa and EDRC. The larger study is available in the EDRC Library ((ethney@energetic.uct.ac.za). The client for the study was the inter-departmental Environmentally Sound Low Cost Housing Task Team, coordinated by Department of Housing and was funded by USAID

Assessment of data / studies on cost savings

In order to analyse the costs and benefits of interventions promoting energy efficiency in low-cost housing, a number of data sets needed to be collated. Inputs from the housing model produced by the University of Pretoria were combined with data collected on fuel use patterns, fuel prices, housing and other data. The sources of data used are listed in the references to this paper. The key limitations of the data lie in the absence of a data set that disaggregates for all factors simultaneously – region, fuel, income and end use.

This study considered three regions (centered on Cape Town, Johannesburg, Durban), five fuels (electricity, paraffin, wood, coal and gas), five income groups (from <R500 to <R3000 per month) and three end uses (space heating, water heating and lighting).

Overall, the patterns of fuel use show that electricity is commonly used for space heating and lighting and water heating, although there may be some bias towards more established electrified households. In the analysis for water heating and lighting, only electricity is considered, while for space heating all fuels are analysed.

Fuel prices were drawn from the Department of Minerals and Energy for gas, coal and paraffin; from a previous study by EDRC for wood; and from Justice Mavhungu's unpublished Masters thesis for electricity. There is variation in fuel prices across regions, with no fuel prices for rural areas being available separately. Where necessary, older prices were adjusted to 1999 Rands.

Impact on greenhouse gas emissions

This chapter quantifies how energy-efficiency interventions contribute to avoiding direct emissions of greenhouse gases (GHGs), based on South African emissions factors and the energy savings described in Chapter 1 and Chapter 3. The interventions analysed here make a contribution to avoiding greenhouse gas emissions, which is substantial when compared to total residential greenhouse gas emissions even if they are small compared to national totals. The selling points for these mitigation options, however, is their low cost and their significant development benefits – in terms of reduced local household expenditure, improved health and potentially increased employment. These benefits are explored in more depth in the Chapters in section B of the wider study. Suffice to say here that the greenhouse gas benefits of the interventions, combined with their local benefits, make them high priority candidates for project that could attract international climate change linked investment that would support national development priorities.

Cost-benefit analysis

Cost-benefit analysis is a tool for assessing the viability of different investments that takes into account the timing of different costs and benefits. The CBA (including Chapter 3) address two different questions: Is the project in the interests of the country? Is the project in the interests of participating consumers?[1]

Overall, the three packages – ceiling, wall insulation and window size – show substantial positive economic benefit, even without considering externalities. Some of the interventions with positive NPVs have benefits in the same order of magnitude as the investments, i.e. in the thousands of Rands. While from a consumer perspective, few interventions look attractive (Chapter 3), the analysis presented here indicates that most of the interventions warrant investment by society as a whole.

One significant point to note is that the national net benefit for the package of thermal interventions in row houses is economically and environmentally very attractive, but the question of social acceptability must be investigated. While the partitions and roof insulation make sense as part of a package, on their own the incremental energy savings are small. For informal houses, high capital costs make the intervention considered seem expensive. However, research into low-cost insulation should be pursued. Solar water heaters are attractive if we consider local impacts of energy use, and even more so if global impacts are included.

It is difficult to compare the two lighting options, for reasons discussed in Chapter 1. The solar home system (SHS) considered only for lighting does not appear as positive as it might, were all its opportunities explored. If all the considerable costs of SHSs are measured against the benefits of lighting, then it is not surprising that the analysis makes this intervention look unattractive.

We recommend three options for consideration in relation to further study of SHSs – not to include avoided municipal infrastructure costs; to exclude SHS from this study; or to do further, complete analysis of an urban 'energisation' package across all end uses.

Affordability model

While a particular intervention may be attractive from a traditional CBA point of view, it may nonetheless not be affordable for poor households. The basic problem is that poor households have no spare money to invest in energy efficiency. Two simple measures of affordability are chosen for this study are the payback period and the capital subsidy required. These measures connect the interventions and their associated energy savings with the income and expenditure of households of five income groups.

For the 30 m^2 RDP house a capital subsidy of around R1 000 appears to be required to make the package attractive to consumers. In the context of housing subsidies, this appears a modest amount for substantial economic and environmental benefit. It should be remembered that this is not the full capital cost, but a subsidy which would make the intervention attractive to consumers.

Payback periods are relatively long (~10 years) for several interventions – the ceiling, wall insulation, the RDP package and the solar water heater. In no income group can consumers afford to pay for these interventions, at a discount rate of 30%. For informal houses, the payback period exceeds the estimated life of the shack of five years. Only for CFLs is there a fairly short payback period. For some interventions, there is not enough time to make the payments equivalent to energy cost savings in order to repay the capital cost.

What does the affordability model say about different income groups? Variation between income groups on the payback period is not significant. The effect of the consumer discount rate and its associated time preference appears to be the dominant factor here. The variation of

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[1] Because of data limitations on avoided municipal distribution costs analysis at local authority perspective could not be done. This could be an area for further study.

capital grants required for different income groups is not great for most interventions. The exception relates to informal houses, where the capital subsidy required to make the package attractive is about twice as high for the poorest households than for those earning between R2 400 and R3 000 per month. The variation for CFLs is significant in percentage terms, but not in Rands.

Model application with focus on low-income households

This chapter disaggregates the results from Chapter 1 to show how the energy efficiency interventions affect different kinds of households – primarily in different regions of the country. Because climate conditions and fuel use patterns vary considerably, certain interventions could be economic for some groups and not for others. Our analysis shows, however, that the results do not differ significantly by region. This is both because increased energy savings and offset by higher capital cost in thermal efficiency, and because the region with highest energy use also has the lowest electricity prices. Similarly, including avoided external costs contributes to the positive social NPV of most of these interventions, but it is not a decisive factor in determining whether they are economically viable.

If we take the consumer perspective as opposed to a social perspective, few of the energy-efficient interventions modelled in this study look attractive to low-income households. The interventions that have positive NPVs are those which have no incremental capital cost or even capital savings (window size, row house) or where significant capital costs are saved (CFLs saving incandescent bulbs). This does not mean that the other interventions are not good investments for the poor. What it means is that we can not expect poor consumers to pay for them all from their own pocket. As discussed in Chapter 3, the critical question is how government policy can bridge the gap between what is beneficial for society and the constraints that poor households face.

1. STUDIES AND DATA ON COST SAVINGS ANALYSES

1.1 INTRODUCTION

The following five chapters outline the methodology, assumptions, and results of the cost-benefit analysis of interventions for environmentally sound and energy efficient low-cost housing. These chapters are part of a wider study, so that the cost-benefit analysis presented here builds on the previous analysis of possible interventions to develop a coherent economic analysis of these technologies. The structure of the chapters has been adapted to correspond to the study terms of reference as follows:

- Chapter 1 presents the data and assumptions for the cost-benefit analysis, except those issues (greenhouse gases and income levels) that are explicitly covered in other chapters It also defines the scope of the analysis.
- Chapter 2 presents the greenhouse gas reduction impacts of the specific interventions as modelled at a national level, and includes an assessment of the other factors that could impact these results.
- Chapter 3 introduces the overall methodology for the cost-benefit analysis, and the national aggregate results for the different interventions.
- Chapter 4 covers affordability, including the methodology used to evaluate affordability of the interventions and the results of this analysis.
- Chapter 5 presents the household level results for the cost-benefit analysis, disaggregated by climate region and fuel use for each end use.

The remainder of this section describes how the outputs from the housing energy and comfort simulation from Chapter A2 in the wider study (which describes performance assessment of baseline and improved design) were integrated into the cost-benefit analysis, as well as other input data required for the cost-benefit analysis. Some important observations about the scope of the analysis are presented in section 1.2.

1.2 SCOPE OF ANALYSIS

The study team proposed to maximise the value of the analysis by limiting the scope to high priority interventions and those levels of disaggregation that provide the most policy-relevant conclusions. The general scope of the analysis and data sources is presented below, with more detail on particular inputs in the following sections.

In order to analyse the costs and benefits of interventions promoting energy efficiency in low-cost housing, a number of data sets have to be collated. Outputs from the simulations of status quo and modified designs were combined with data collected on fuel use patterns, fuel prices, housing and other data. The fuel-use data was associated with the status quo types and energy savings of the modified designs were assessed relative to consumption and cost of the status quo units. The accuracy and adequacy of this data is analysed below.

To capture the different climatic regimes in South Africa, the study considered three areas based on the three largest metropolitan areas of Cape Town (CT), Durban (Dbn) and Johannesburg (Gauteng). There are significant climatic, economic and cultural differences between these regions, leading to different fuel use patterns and hence potential savings. Beyond fuel consumption, the performance of some interventions for energy efficiency is directly affected by climate as well.

In the aggregation of costs and benefits from the household to the national level, the study assumed that these three regions were reasonable proxies for the whole country. Apart from metropolitan areas representing provinces (Cape Town – Western Cape; Johannesburg – Gauteng; Durban – KwaZulu/Natal), provinces were also grouped as follows:

- Western, Northern and Eastern Cape (region U1);

- Gauteng and Mpumalanga (region U2); and
- KwaZulu Natal, Northern Province, Free State and North West (region U3).

The study had also hoped to consider rural areas; however, due to lack of data on many aspects – most importantly end-use specific consumption – this was not possible. Data collection on fuel patterns in rural areas is recommended as an important area for future research. In all tables in this and subsequent chapters of this part of the study, the headings U1, U2 and U3 refer to the regions described above.

Energy is used for a variety of end-uses. This is the actual service the consumer derives out of the energy consumed. Since the focus of this study was on environmentally sound housing, the study team focused on those end-uses directly related to the shell of the house – *space heating, water heating and lighting.* The rationale here is that government policy within its mass housing programme can have a significant impact on the construction of the housing shell and the provision made within the shell for water heating and lighting. Improving the efficiency of other appliances such as stoves and cool storage, while also important, would require a different strategy such as appliance labelling based on energy efficiency rating or standards. These additional end-uses should be considered in future work.

Along similar lines, this cost-benefit analysis could not include all of the infrastructure savings associated with all of the housing interventions described in the previous chapter. Measures related to efficient use of water, rainwater harvesting, greywater recycling, for example, can not only reduce the consumer's water bill, but also reduce the water infrastructure required to service a community. Similarly, a combination of SHS and safer fuels for heating and cooking (e.g. LPG) would allow semi-autonomous (off grid) urban households, and eliminate the need for distribution infrastructure. Given the relatively high penetration of grid electricity in urban areas (80% or greater at the end of 1998 (NER 1999)) and the political and social priorities for grid electrification, these infrastructure savings may be difficult to achieve. In addition to assessing the whole range of costs and benefits from going 'off grid', one would need to consider all end-uses and how they would be provided for (e.g. cooking with gas, entertainment and cool storage from solar home systems (SHSs), etc). While the cost-benefit analysis in this report focuses mostly on the dwelling itself, an important area of future work should be to package all the resource efficiency interventions and look at the potential of 'self-sufficient' households in urban and rural areas – and not only for low-income households. The energy-use considered was only the *direct energy consumption* to provide energy services – fuel combustion and electricity usage. This does not include the embodied energy of the housing shell or any appliances. Most of the interventions focus on improving *formal, low cost housing*, or what is provided through national government housing subsidy programme. Most of the interventions are based on a 30m^2 standard RDP house, although interventions in a similar size row house and a shack are also described in the next chapter.

1.3 ENERGY SAVINGS AND COST INPUTS

These inputs were derived from the simulation process based on the *Building Toolbox* software as described in Chapter A-1. The inputs for the other interventions – lighting and water heating – come from a combination of the building simulation and other studies, as described below. Most of the interventions analysed in Chapter A-1 were related to thermal efficiency of the housing shell – in other words, the capacity of the building to control heating and cooling (regulate its internal temperature). North orientation and sunshading of north-facing windows in summer were not analysed separately since all the other interventions covered in A-1 assume north orientation of the house as a basic intervention.

1.3.1 Thermal improvements

Thermal simulations in Chapter A-1 of the wider study included a wide variety of interventions such as energy efficiency, water efficiency, and changes in municipal infrastructure usage. To analyse the costs and benefits of particular thermal improvements such as ceilings or exterior wall insulation, it was necessary to disaggregate these costs and the energy savings per specific intervention. This helped to identify not only the energy savings from a single intervention such as a ceiling, but also the savings from putting in a whole suite of interventions. The energy savings of each intervention are obviously not additive (three interventions that each save 50% of space heating energy use on their own do not add up to 150% savings), but the costs are generally additive. In addition, the costs of some interventions vary by region because different scales of an intervention are needed for different climates.

The tables below present the assumptions on incremental capital cost, energy savings and replacement costs, based on the outputs of the thermal simulation. Incremental costs refer to the capital cost of the intervention less any capital savings. For example, the installation of a solar heater nullifies the need for an electric geyser if the solar water heater has electrical backup. Note that here, as with all tables in the cost-benefit analysis chapters, the first 6 interventions refer to modifications to a standard 30m^2 RDP house. The next two refer to a 30m^2 RDP row house, where '*shared wall*' shows only the costs and energy savings associated with moving from a free standing house to a row house design with two shared walls. '*All SH Row*' would include a ceiling, roof insulation, wall insulation, proper window sizing, and interior partitions. '*All SH Inf*' refers to modifications to a shack, which include a ceiling and exterior wall insulation.

Table 1: Incremental capital cost per intervention (Year 2000 Rands)

Intervention	*Region*			*Comments*
	U1 (CT)	*U2 (G)*	*U3 (D)*	
Ceiling	957	957	957	
Roof insulation	419	419	258	Thickness varied by climate
Partition	362	362	362	
Wall insulation	736	1 474	418	Thickness varied by climate
Window	-593	-593	-593	Reduced total window glazing
All SH RDP	1 881	2 619	1 402	Includes all five previous interventions
Shared wall	-1 114	-1 114	-1 114	Reduced need for foundation and roof
All SH row	-105	-18	-380	Includes same as for standard RDP
All SH informal	1 247	1 247	1 247	

Source: Simulation output of this study

Thermal simulation was conducted using a specific notional energy consumption (based on the climate and properties of the building). However, before one can apply this to the typical energy use patterns across regions, one needs to know the percentage of energy savings which can be applied as the typical value across the regions. The required percentages as derived from thermal simulations are presented in Table 2. Note that the combination of thermal improvement interventions were specifically designed to eliminate the need for space heating when used in combination – hence the 100% savings. This may well be overly optimistic, since the use of space heating holds both cultural and social meaning, and is not simply a basic economic and health necessity (Mehlwana & Qase 1999; Melhlwana 1999). This points to the need for long-term monitoring – both social and technical – of how households actually live in more thermally efficient homes.

Table 2: Energy savings per intervention (%)

Intervention	Region			Comments
	U1 (CT)	U2 (G)	U3 (D)	
Ceiling	45	43	69	
Roof insulation	5	8	12	Thickness varied by climate
Partition	7	8	12	
Wall insulation	61	85	30	Thickness varied by climate
Window	6	11	9	Reduced total window glazing
All SH RDP	100	100	100	Includes all five previous
Shared wall	15	25	36	Reduced need for foundation and roof
All SH row	100%	100%	100%	Includes same as for standard RDP
All SH informal	100%	100%	100%	

Source: Simulations output of this study

The thermal simulations and cost-benefit analyses assume that thermal efficiency interventions will last as long as the building itself (50 years), so that there is no need to replace them in the future. The exterior wall insulation and ceiling also provide important benefits on maintenance costs. Exterior insulation can reduce the costs of painting, and more importantly the need to repair cracks that would allow air infiltration. A ceiling reduces interior condensation, which in turn reduces rust and material wear and saves on maintenance. The magnitude of these savings, however, is not clear and, as with many other assumptions, need to be subject to proper field tests and monitoring. What is provided here is an estimate based on the simulations and estimates from Chapter A-1 of the wider study. In the absence of clearly disaggregated data, 50% of the annual savings has been apportioned to ceiling and 50% to the wall insulation in Table 3.

Table 3: Non-energy operating cost savings (R/year)

Ceiling	-93.5
Wall insulation	-93.5
All SH RDP	-187.0
All SH Row	-130.3
All SH Informal	Not applicable

Source: Simulations output of this study

1.3.2 Compact fluorescent lighting (CFL)

Although the initial cost of CFL is considerably higher than that of incandescent lamps, several studies have shown that the resultant energy savings outweigh the additional cost. Such studies include Clark (1997), Spalding-Fecher et al (1999), Praetorius and Spalding-Fecher (1998). The assumptions for this intervention are largely drawn from Spalding-Fecher et al (1999). The CFL that Eskom is promoting in its Efficient Lighting Initiative (ELI – the first large-scale energy efficiency programme in South Africa) has a bulb that can be separated from the ballast and is therefore cheaper to replace. Note that one incandescent bulb would only use 86 kWh per year (3.2 hrs/day x 365 days x 0.075 kW). Houses are assumed to have on average 4 bulbs. All of the costs per bulb and ballast are therefore multiplied by 4 for household net present value (NPV) calculations (Chapter 3). In addition, the avoided expenditure on incandescent bulbs is counted as a benefit from installing CFLs.

Table 4: Lighting assumptions per bulb

	CFL	*Incandescent*	*Comment*
Initial cost (R/bulb)	R27*	R3.00	Bulb and ballast. Price indicated is subsidised price deemed acceptable to customers
Bulb life (hours of use)	8 000	1 000	
Ballast life (hours of use)	40 000	N/a	
Power rating (W)	19	75*	75% energy and demand savings
Hours of use (hours/day)	3.2	3.2	
Bulb life (years)	8	0.86	Based on useful life and usage
Ballast life (years)	34		'
No. replacements (bulb)	6		Over 50 year life of building
No. replacements (ballast)	1		'
Replacement cost (R/bulb)	13		
Replacement cost (R/ballast)	30		

* A 75W bulb here represents a mix of 60W and 100W bulbs

Source: CBA output of this study

1.3.3 Solar water heating (DSWH)

One critical question related to replacing electric storage geysers with DSWH is whether some type of back-up energy source is required to guarantee hot water on demand on cloudy days or when more people are using the home's facilities. Whether 'enough' hot water is available at all times depends on the weather, the size of the collector and storage tank, but also importantly on the lifestyles of the residents. While there are examples of homes that have solar water heating in South Africa with no backup (Holm 2000), other analysts and consultants involved in providing DSWH to low income communities point out that often only 60-70% of the energy needed (and hence hot water) can be provided by solar energy, and so some back-up is necessary to guarantee hot water on demand (Morris 2000; Thorne et al 2000). The study assumes that some backup is needed, and the energy savings are 60%. While the cost savings will vary if the solar water heater backup is non-electric, additional information is needed to quantify these costs.

The up front costs for a 100l indirect DSWH with a 1.8 m^2 collector are taken to be R4 000, while the avoided costs of not having to install an electric geyser are R2 200 (see Chapter A-1).[2] This would provide enough hot water for a typical family of 6. Greater use would increase the use of electrical back-up and so reduce the energy savings. However, it should be noted that the usage patterns for piped hot water in low-income areas (and especially newly electrified ones) is not well understood (Morris 2000).

DSWH are relatively durable, with entire systems lasting for 15 years or more. The tank element for electrical backup might need to be replaced before then. There is limited experience with DSWH over longer time periods. The study assumes that the replacement cost will be about half of the initial cost because of greater efficiency of production in the future and the fact that not all of the system components would need to be replaced.

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[2] Note that this is fairly optimistic. Recent work in the Lwadle community near Cape Town suggested that DSWH with electrical backup might cost R5 500 installed, compared to R1 350 for electric storage geysers, with non-electric backup being even more expensive (Thorne et al 2000).

Table 5: DSWH assumptions

	SWH	*Elec storage*	*Comment*
Initial cost (R)	R4 000	R2 200	Includes cost of back-up
Life (years)	15	15	
Energy savings	60%		
No. replacements	2		Over 50 year life of building
Replacement cost (R)	R2 000		

Source: Simulations output of this study

1.3.4 Solar home systems

An off-grid solar home system (SHS) will provide electricity for three or four lights, a black-and-white television set and/or a radio/hi-fi. Low-power DC appliances (such as a fan or sewing machine) can be powered by medium-sized systems, but these are uncommon in South Africa. With the addition of an inverter (R300 to R 1 500), small AC appliances (colour television, AC sewing machine) can be operated. While refrigeration is possible, it is relatively expensive. LPG- or gas-powered refrigeration is usually more economical for domestic or retail applications (Banks 1998A). Off-grid electrification is not normally used for cooking, space or water heating as it is too expensive to generate and store the large amounts of energy required.

A medium sized system (50W, 100 Ah) has a total capital cost of R2 435, and lifetime maintenance/replacement costs of R2 230 (excluding bulbs) (Banks 1998a). This represents R187 per year in maintenance and replacement costs[3]. SHS is most desirable if it completely replaces the grid connection so that one avoids the cost of readiboard, prepayment meter, and distribution infrastructure. Chapter A-1 of the wider study presents an estimate of R580 and R852 for the costs of a readiboard and prepayment meter respectively. This leaves a net capital cost of approximately R1 000. The costs of connecting new households to the grid varies between R1 300 and R1 800 per household in urban and peri-urban areas (Banks 1998b). To deduct these savings from the capital cost as well, however, would make the net capital cost negative – implying that all urban electrification should have been done with solar home systems. Why is this?

The major difficulty here is that, because SHS are considered as an intervention to save energy used for electric lighting and light appliances. It does not satisfactorily replace other end-uses such as cooking which might utilise grid electricity. A proper analysis of going 'off the grid' must include all major end-uses and how they would be provided with and without the grid. There could be other avoided costs such as coal used for space heating. An 'energisation' package would also include new costs such as access to LPG appliances and the higher cost of LPG per MJ. The negative NPV of SHS in the CBA arises from considering only some of the benefits but counting all direct costs. It should not be taken as an indication that SHS in semi-autonomous urban houses are not viable.

Off-grid electricity has not been considered for urban low-cost housing in South Africa to date. Consumers still show a desire for the option to use high-demand electrical appliances even if they do not use electricity for all end-uses (not to mention the necessity of high electricity usage to pay off the utility and government's investment in the connection). In view of the above, the costs of the readiboard and meter have been deducted, but not those of the grid connection even though in theory these two costs are linked to one another.

There are three options to refine this analysis. One would be not to exclude any of the 'avoided' distribution infrastructure costs – and so assume that the house still has grid electricity for some end-uses. This would be fairly simple analysis, but it would make the intervention even more expensive and unrealistic. The second option would be not to include the SHS in

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[3] The original life-cycle costs in Banks (1999) were estimated using a 15% discount rate and 10% escalation.

this study at all – because there is no adequate data on the whole range of energy-uses by households.

Opportunities to explore the full benefits of these systems in urban areas should be explored. One possibility would be to do a complete analysis of an urban 'energisation' package – across all end uses, including any additional operating costs, and ensuring an equivalent level of service as grid electricity. This would be very useful in terms of understanding the barriers to renewable energy systems and the implicit costs of a political decision for grid electrification. The most useful analysis at this stage would seek to address the question whether the additional costs of an urban 'off grid' home could be offset at all by climate change-linked funding (see Chapters 3 and C-2 in the wider study which covers information gaps for further research)

1.4 FUEL-USE PATTERNS IN URBAN SOUTH AFRICA

Data on cost savings on low-cost housing is available from a number of sources. Simmonds and Mammon (1996) is a key source for the data used in the CBA process of the study. The study collated findings of several other studies on energy services in low-income urban households. Afrane-Okese (1998) constitutes another significant data source used in the CBA. All the data from Simmonds and Mammon (1996) was derived from various sources including the 1993 country-wide survey by South African Labour and Development Research Unit (SALDRU) on living standards in South Africa. Data from the National Electricity Regulator (NER 1998) was important for understanding the proportions of electrified and non-electrified households per province.

The fuels considered in this study were electricity, paraffin, wood, coal and gas. Other fuels which were not considered were candles, gensets (petrol and diesel) and lead-acid batteries. End uses not covered include cooking and refrigeration, as these do not relate directly to the housing shell design.

There is no current data set that combines fuels by end-use, by income group and by province. Although the energy-related data from SA Focus (Eskom 1998) is the most recent data available, it expresses energy consumption as an expenditure across all end-uses and not by end-use. This could not be used for analysing particular end-uses.

The analysis of fuel-use patterns combined information on household consumption by fuel-type with the share of homes using particular fuels. Simmonds and Mammon (1996) show household consumption profiles by fuel-type and region, represented by Cape Town, Durban and Johannesburg. They also show percentage estimates of how much fuel is used per particular end-use. Consumption figures for each end-use were then obtained by multiplying the consumption of each fuel in homes that used it with the percentage of homes using that fuel for a particular end-use. These monthly figures were converted into annual consumption, assuming that households need space heating for four months in a year. The study assumes that lighting and water heating is required throughout the year.

The fuel-use patterns and percentage share of households using particular fuels for different end-uses are shown in the tables below, with space heating in Tables 6 and 7.

Table 6: Annual consumption for space heating by region and fuel

	U1 (CT)	*U2 (Jhb)*	*U3 (Dbn)*	*Units*
Electricity	387.8	358.4	387.1	KWh
Coal	371.7	743.4	247.8	Kg
Wood	0	0	0	Kg
Paraffin	49.2	21.0	22.8	Litre
Gas	6.9	2.0	2.7	Kg

Source: CBA output of this study based on Simmonds and Mammon (1996: 70, 73-6)

Table 7: Share of houses using fuel for space heating by province

	U1 (CT) (%)	*U2 (Jhb) (%)*	*U3 (Dbn) (%)*
Electricity	75	69	54
Coal	2	5	3
Wood	0	0	0
Paraffin	19	23	38
Gas	2	1	0

Source: CBA output of this study based on Simmonds and Mammon (1996: 70, 73-6) and NER (1999: 16)

Given that coal is primarily available inexpensively in Gauteng and Mpumalanga, and the climate is considerably colder, it is understandable that the coal consumption figures are highest for this region. Both Cape Town and Durban have higher levels of paraffin usage than Johannesburg. The low percentage of homes using coal for space heating in Johannesburg is, however, surprising. In a review of the SADLRU (1993) survey, Simmond and Mammon (1996) observe that the survey focused more on established households. Such households are more likely to use proportionately more electricity. In addition, the study considered households living in formal housing and not in shacks. In many cases the move from informal to formal housing also stimulates additional electricity use, although this process is by no means comprehensively understood. Finally, electrification levels are highest in Cape Town, which also explains the higher use of electricity in those households.

Obviously, no households use coal or wood for lighting. One can note that the electricity consumption for lighting does not vary significantly across regions, but paraffin consumption does. Durban has a lower share of homes using electricity and paraffin for lighting (54% and 9% of total households respectively). A closer observation shows that the remaining percentage of households use candles for lighting, however candles are not included in this cost-benefit analysis.

The difference in paraffin prices between regions is due to different fuel use patterns between regions, with Gauteng and Kwa Zulu Natal using less than Cape Town (Simmonds & Mammon 1996). By contrast, coal-use in Gauteng is higher than for other regions. Paraffin is cheaper at the coast than inland and that is possibly why less of it would be used for lighting in Gauteng. The use of alternative sources of lighting not included in the study, notably candles, further explains the variation.

Table 8: Consumption on lighting by province and fuel

	U1 (CT)	*U2 (Jhb)*	*U3 (Dbn)*	*Units*
Electricity	332.4	307.2	331.8	KWh
Coal	-	-	-	-
Wood	-	-	-	-
Paraffin	123	52.5	57	litres
Gas	-	-	-	-

Source: CBA output of this study based on Simmonds and Mammon (1996: 73-4)

Table 9: Share of houses using fuel for lighting by province

Baseline	*U1 (CT) (%)*	*U2 (Jhb) (%)*	*U3 (Dbn) (%)*
Electricity	80	72	54
Coal	0	0	0
Wood	0	0	0
Paraffin	16	6	9
Gas	0.4	0.3	0

Source: CBA output of this study based on Simmonds and Mammon (1996: 73-4) and NER (1999: 16)

Tables 10 and 11 present water heating energy use and share of households using particular fuels. The consumption figures on water heating are high. They are based on low consumption level averages rather than consumption in well-established homes (Simmonds & Mammon 1996). Low monthly consumption for all end-uses is 345 kWh per month. Annualised and multiplied by 40% of consumption used for water heating (Simmonds & Mammon 1996: Tables 5.9 and 5.5).

Table 10: Consumption on water heating by province and fuel (kWh)

	U1 (CT)	*U2 (Jhb)*	*U3 (Dbn)*	*Units*
Electricity	1.656	1.656	1.656	KWh

Source: CBA output of this study based on Simmonds and Mammon (1996: 74-6)

Table 11: Share of houses using fuel for water heating by province

	U1 (CT) (%)	*U2 (Jhb) (%)*	*U3 (Dbn) (%)*
Electricity	74	68	31
Coal	0	5	4
Wood	3	1	28
Paraffin	17	23	19
Gas	5	1	2

Source: CBA output of this study based on Simmonds and Mammon (1996: 44), Afrane-Okese (1998: 119) and NER (1999: 16)

Overall, the patterns of fuel use show that electricity is commonly used for space heating and lighting and water heating but not exclusively. In the calculations for the cost-benefit analysis, only electricity is considered for water heating and lighting – because the interventions deal with alternative electricity supply. All fuels are included in space heating component of CBA.

1.5 FUEL PRICES

Fuel price data were drawn from the following sources:

1. Gas, coal and paraffin: From Department of Minerals and Energy (DME 1999)
2. Wood: From Simmonds and Mammon (1996)
3. Electricity: From Mavhungu (2000)

The studies indicate that there exists significant variation in fuel prices across regions. No fuel prices are available specifically for rural areas. Where necessary, prices were adjusted to 1999 Rands.

Regional variation in fuel prices is pronounced between the coast and inland regions. For example, while a litre of paraffin costs R2.05 retail in both Cape Town and Durban, the equivalent cost in Johannesburg is about R2.20. This is mainly due to distribution costs from the main refineries in Durban and Cape Town. Such variation are captured in the different fuel prices applied in this study. The CBA model applied disaggregated data by region and fuel type. Average electricity prices from Mavhungu (2000) also reflect significant regional variations as shown in Table 12.

Table 12: The average price of electricity by province

Province	*Gauteng*	*Durban*	*Western Cape*
Average electricity price in c/kWh	19	21	26

Source: Mavhungu (2000: 31)

DME (1999) contained valuable price data for paraffin, gas and coal. For all the fuel prices from the DME, the coastal price was taken as the price in Durban and Cape Town and the Reef price for Johannesburg. In the absence of separate rural prices, we have assumed a price higher than the Reef price for rural areas. Due to the South African system of determining fuel prices by the global crude oil market, the figures for paraffin may have changed this year with the major swings in oil prices even though the government attempts to minimise the volatility of local prices. Table 14 shows both the coastal and the Reef prices of LPG. Retail prices were used in all cases since the CBA focuses on the economics at household level.

Table 13: Prices of paraffin (Rands /litre)

Fuel	*Mth/year*	*Coast price*	*Reef price*
Paraffin	08/1999	2.05	2.20

Source: DME (1999)

Table 14: LPG (gas) fuel price

Fuel	*Year*	*Coastal price*	*Reef price*
LPG – R/kg			
Average price	04/99	3.32/kg (wholesale) 6.60/kg (retail price)	3.69/kg (wholesale) 7.07/kg (retail price)

Source: DME (1999)

Coal price data were derived from two sources: Simmonds and Mammon (1996) and DME (1999). The first source cover Cape Town and Johannesburg and shows the price in Johannesburg to be about half the price in Cape Town. This is possibly because coal is more readily available inland. The price of coal in Durban was assumed to be similar to that in Cape Town. Since no price was available for the rural areas, the current DME price was used (DME 1999). Table 15 shows the retail price for domestic coal.

Table15: Local coal prices

Domestic coal	*Year*	*Coastal*	*Reef*
Retail price in R/kg	1996	0.53	0.23

Source: DME (1999)

Simmonds and Mammon (1996) provide retail coal-prices for Johannesburg and Cape Town as well as prices for wood. Since wood price data for the Cape Town region were not available, the average of Durban and Johannesburg prices was used.

Using the above sources, the most recent and accurate fuel-prices were identified. Prices that were not in 1999 Rands were adjusted, using figures based on the South African Reserve Bank Quarterly Bulletin. For this reason, prices in the table below may differ from the raw data in the tables above. The final table of fuel prices as used in the spreadsheet is presented as Table 17.

Table 16: Prices for fuels used by low-income households in Johannesburg, Durban and Cape Town

Fuel type	*Price by area*		
	Johannesburg	*Durban*	*Cape Town*
Electricity (R/kWh)	0.19 – 0.27	0.24 – 0.27	0.22 – 0.27
Coal (R/kg)	0.23		0.50 – 0.55
Paraffin (R/litre)	1.67	1.40 – 1.66	1.04 – 1.50
Wood (R/kg)	*	1.27 – 1.46	0.43 – 0.45
Gas (R/kg)	3.78	2.45-3.15	1.66-3.66

Source: Simmonds and Mammon (1996: 68)

Table 17: Fuel prices as used in the cost-benefit analysis

Region	*Elec (R/kWh)*	*Coal (R/kg)*	*Wood (R/kg)*	*Paraffin (R/l)*	*Gas (R/kg)*
U1 (CT)	0.26	0.65	1.47	2.05	6.06
U2 (Jhb)	0.19	0.28	1.24	2.20	6.06
U3 (Dbn)	0.21	0.65	1.70	2.05	6.06

Sources: CBA output of this study based on Simmonds and Mammon (1996), Mavhungu (2000) and DME (1999)

1.6 EXTERNAL COSTS OF ENERGY USE

The external costs of energy supply reflect the environmental and other social costs associated with their use. These costs can be especially difficult to quantify in monetary terms and are usually expressed as ranges rather than precise figures. Previous research on external costs of energy supply in South Africa relates to environmental costs of electricity generation, costs of fires and burns associated with paraffin use in the home, and the costs of illness and death caused by indoor air pollution from coal and wood burning (van Horen 1996a and 1996b). This analysis distinguishes between the *global* external costs associated with greenhouse gases and the *local* environmental impacts that reflect immediate health impacts, for example, from indoor air pollution. The total external cost is applied in the derivation of social benefits, while the cost of local impacts is applied in the derivation of the cost of avoided greenhouse gas emissions. The results are presented in Chapter 3 with and without external costs to illustrate the impact they have on the results.

Local external costs are taken from van Horen's study of household external impacts and impacts of electricity generation (van Horen 1996a). The damage cost of greenhouse gases is based on the work of Fankhauser and Pearce for the IPCC and reported in Pearce (1995). The study recommends a damage cost of US\$22 per ton of carbon, or US\$6 per ton of CO_2. This translates to R37/t at 6.2 R/US\$ (reported in Pearce 1995). The external cost assumptions are summarised in Table 18. For more detail on the calculations see Spalding-Fecher et al (1999).

Table 18: External cost assumptions by fuel (1999 Rands)

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

* No research available on local impacts of LPG

Source: Spalding-Fecher et al (1999: 35); van Horen (1996a: 170); IPCC (1996) and Pearce (1995)

1.7 HOUSING STOCK AND BACKLOG

Low-cost housing was interpreted as costing between R7 500 – R 17 250 and fully funded by government subsidy (Hendler 2000). Housing data were drawn primarily from Hendler (2000) whose data are based on primary research with developers as well secondary sources such as SAIRR (1980), Hendler (1993) and Department of Housing (DoH 1999). Additional information on housing backlog was obtained from the Department of Housing (DoH, 2000). The data for low-cost houses built between 1 April 1997 and 31 March 2000 was available on a provincial basis.

National estimates data were available for 1994-97. The data wwas converted to provincial figures using the same percentage breakdown as the period 1997-2000. The data on the number of houses built between 1994-97 varies considerably between the two sources cited above. Hendler (2000) gives a total of 450 876 houses while DoH (1999) estimates show 86 700 units. Assuming that that the real number lies somewhere between the two, a simple average was taken for this analysis. This is logical given that it is lower than the houses completed between 1997 and 2000, when the mass housing drive accelerated. In addition, the 1997-2000 data has the highest level of accuracy as it is based on primary research with developers as well as secondary sources. This total number of houses was then allocated to each province using the same breakdown as for the 1997-2000 period.

Totals for houses built in urban areas from 1960 to 1977 were obtained, and were similarly apportioned by province. Very few low-cost houses were built during the 1977-94 period. Consequently, no additions to housing stock from this period have been included. The urban fraction for 1994-2000 is assumed to be the same as the share of subsidy allocation to urban areas in the last few years (Hendler 2000). Totals for the existing housing stock were calculated by adding the urban fraction of housing stock for the periods 1960-77, 1994-97 and 1997-2000 for each province.

Totals of housing backlogs per province were provided in Hendler (2000) which draws on data from the Department of Housing as quoted in SAIRR (2000) The total number of houses that needed to be built as of June 1998 was 2 603 717. These data are comparable with the latest estimate by the DoH of 2 784 193 for June 2000 (Bosch 2000).

To estimate the proportion of the housing backlog in the urban areas, the study assumed that three-quarters of the housing would still be built in urban areas and only one quarter in rural areas. The Department of Housing and the Energy Development Group were consulted for their views, but no accurate percentage breakdown could be obtained. Given the new commitment to a rural bias in government, this breakdown might change in future. However, this change is recent, and much housing in rural areas is not provided by government. The most recent data available on informal houses was from the 1996 Census (Statistics SA 1996).

In order to aggregate findings for households in the three regions, the study assumed that these regions are proxies for parts of the whole country. The study therefore combined the provincial data for housing stock, backlog and informal houses for different provinces as follows: Region U1 combines the Western, Northern and Eastern Cape; U2 is Gauteng and Mpumalanga; and U3 is KwaZulu Natal, Free State, North West and Northern Provinces. The consolidated figures are shown in the Table 19.

Table 19: Number of houses in target group for each intervention per region (000s)

	RDP 30 m^2 house – space heating						*Row house – space heating*		*Informal house*	*Lighting*		*Water heating*
	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
U1 (CT)	658	658	430	658	430	430	430	430	334	658	430	430
U2 (Jhb)	916	916	709	916	709	709	709	709	562	916	709	709
U3 (Dbn)	1 078	1 078	812	1 078	812	812	812	812	555	1 078	812	812

Source: CBA output of this study

Some interventions can be applied to existing housing stock and new houses (i.e. the backlog), while others (e.g. window sizing and partitions) are only applicable to new houses. Thermal improvements in informal housing are taken as one comprehensive intervention.

In order to aggregate results from the household to national level, the number of houses in the target group for each intervention needed to be defined. Only newly constructed housing (based on housing backlog data) was taken as the target group for the partition, window size, all packages of thermal improvements in all formal houses, the shared wall in the row house, the SHS and the DSWH. For the following interventions, both existing housing stock and new houses constituted the target group for ceiling, roof insulation, wall insulation and compact fluorescent lights. For the thermal interventions in informal housing, the number of informal houses was used as the target figure.

1.8 OTHER GENERAL ASSUMPTIONS

1.8.1 Discount rates – consumer and social

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

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

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

1.8.2 Inflation/choice of currency year

All currency values are in constant 1999 Rands. Where figures (e.g. fuel prices) were given in Rands for other years, the appropriate conversion factors were used to reflect inflation. The inflation factors, based on the gross value added deflator, are shown in Table 20.

Table 20: Adjustment factors for conversion to 1999 prices

Year	*Inflation rate*	*Deflator (multiply by this factor to get 1999 prices)*
1988		
1989	16.1	2.8
1990	16.3	2.4
1991	16.44	2.1
1992	14.5	1.8
1993	12.0	1.6
1994	9.3	1.5
1995	10.3	1.3
1996	8.0	1.24
1997	8.0	1.15
1998	7.6	1.06
1999	6.5	1

Source: Adapted from SA Reserve Bank (1999)

1.9 RECOMMENDATIONS

The major challenge in collecting the input data for the CBA is the level of disaggregation – i.e. by region, fuel, income group and end-use. No single data set exists which considers all the above factors at once. It was therefore necessary to combine data from a number of different sources to approximate the desired level of detail. In some instances, this limitation lies in the fact that data is simply not recorded or analysed at this level of disaggregation in national studies. For example, attempts to gain more recent detailed data from SA Focus were limited by the absence of consumption data. At the same time, one should understand that data will remain limited for two major reasons:

1. Considering four or five different breakdowns simultaneously quickly generates complex tables and becomes difficult to communicate to relevant stakeholders.
2. There is a limit to what can be feasibly quantifiable and measurable. For example where data is gathered through household survey, information on what part of fuel consumption can be attributed to a particular end-use will not be known by respondents. Most consumers do not know how much of their expenditure on say gas goes to space heating, water heating or cooking.

From the above, the study recommends that data sets that combine data on energy-use (especially fuel patterns) with demographics (especially income) should receive further attention. Another area for further study would be to determine a reliable attribution of fuel consumption to end-use. Such studies should consider how these patterns vary regionally and by income group.

Another major uncertainty is the actual energy savings achievable through these interventions. While simulation software are powerful tools, they may not incorporate a range of behavioural issues that also impact on actual energy savings. This study may probably be overly optimistic in terms of the savings achievable as it mainly focused on what is technically possible rather than what actually happens when one combines the technical and user systems. There is an urgent need to systematically monitor the impacts of housing and energy efficiency interventions. This is particularly true in a policy environment where large amounts of public money are at stake, either through the housing or the electrification subsidies and public funding for research (particularly in the energy sector) is on the decline. It is crucial to understand the social and cultural variable that determine the effectiveness of energy efficient housing interventions in order to design good policy. This is only possible through social as well as technical monitoring of the impacts of demonstration and large scale housing interventions.

2. POTENTIAL CONTRIBUTION TO SOUTH AFRICA'S CLIMATE-CHANGE AGENDA

2.1 INTRODUCTION AND METHODOLOGY

The objective of this chapter is to quantitatively assess the contribution of the specific interventions in the CBA to the mitigation of greenhouse gas emission. While there is some overlap with the more general discussion in Chapter C-2 (covering information gaps for further study in the wider study), this chapter focuses only on the interventions included in the CBA, their impact on annual emissions of carbon dioxide in South Africa as well as their cost effectiveness.

The scope of this analysis covers the carbon dioxide emissions from the combustion of fossil fuels both in homes and at electricity generation stations. In addition, the coal bed methane emissions associated with coal mining and coal-fired power production have also been included in the emissions factor for electricity (see Praetorius and Spalding-Fecher 1998). This study only covers direct emissions from combustion. 'Embodied emissions' (emissions that are a product of embodied energy) arising from production, distribution and site-related operations for building materials used in low cost homes are not included.

As with the economic benefit calculations presented in Chapter 3 the national totals were built up from household level analysis. Avoided emissions per household were based on avoided energy-use and South Africa-specific emissions factors per delivered unit of energy as shown in Table 21.

Table 21: CO_2 emission factors for South Africa compared to IPCC default factors

	South Africa		*IPCC default factors**
Energy source	kg CO_2 /GJ	Kg CO_2/unit	kg CO_2 /GJ
Coal**	104	2.81/kg	94.6
Paraffin	71.5	2.72/litre	71.3
Gas	56.1	2.79/kg	56.1
Electricity delivered**	287.4	1.03/kWh	N/a
Wood	0	0	n/a

Source: Davis & Horvei (1995); IPCC (1996); Praetorius & Spalding-Fecher (1998: 37)

* IPCC default CO_2 emission factors for comparison.
** Includes CO_2 equivalent for methane emissions related to coal mining.
*** Excludes losses in transmission and distribution (T&D).

The emission factor for electricity was calculated based on the coal burned in Eskom's power stations for electricity generation in 1996. In that year, Eskom burned 85.4milion tons (mt) of coal which led to an emission of 157mt CO_2 or 266 kg CO_2/GJ electricity generated in coal-fired power stations. When applied to the total electricity generated by Eskom, this amounts to 243 kg CO_2/GJ. A 10% loss is assumed for transmission and distribution (T&D).

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

Avoided GHG emissions are calculated for each household by multiplying the annual energy savings (unit energy / year) by the emissions factor (kg CO_2/unit energy) for each fuel. Avoided emissions by fuel and region (tonnes CO_2/year) is derived by aggregating household values by the number of households using the relevant fuels in the different regions. These are then aggregated across regions for each fuel (tonnes CO_2 / year). Finally, a national figure of GHG emissions avoided is calculated by combining the results from all fuels (tonnes CO_2/year). (Chapters 3 and 4 provide more details on the aggregation process).

2.2 GHG-EMISSION SAVINGS AND COSTS BY INTERVENTION

Figure 1 shows the total annual avoided emissions for each intervention. Not surprisingly, the interventions that save the most energy (e.g. ceilings, wall insulation, solar water heating) also save the greatest amount of emissions.

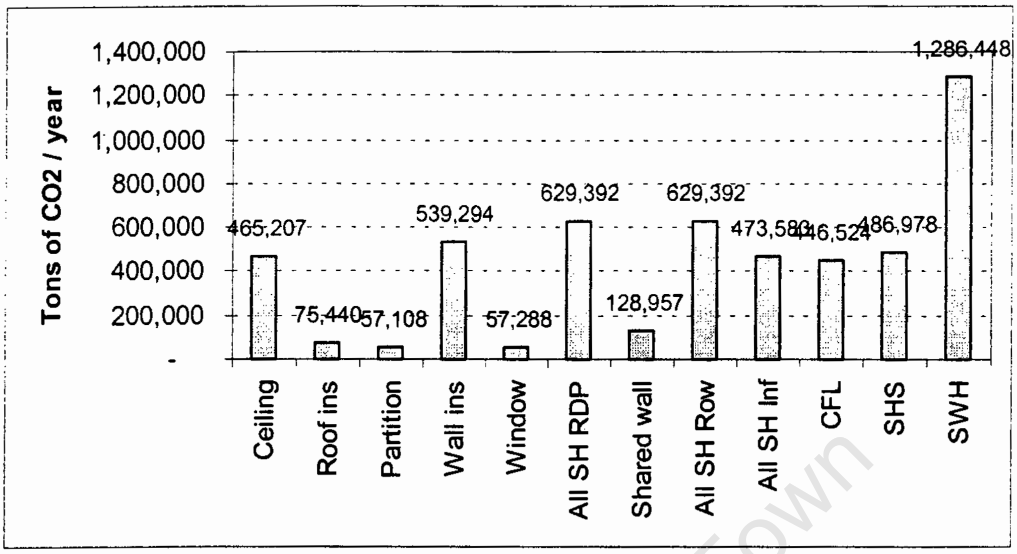

Figure 1: Avoided emissions (t CO_2 /yr) for each intervention nationally
Source: CBA output of this study

The avoided emissions should be understood in the context of total emissions of 373mt of CO_2-equivalent (mt(CO_2)) in 1990, with the energy sector contributing 89% of the total (van der Merwe and Scholes 1998). In 1990, the residential sector contributed approximately 10mt of CO_2-equivalent (De Villiers & Matibe 2000). The interventions analysed here show potential GHG reduction ranging between 0.05 and 0.6 mt(CO_2) per year which is 0.1%-6% of the residential total. While this is a small amount compared to national emission level, it is significant considering that the study only covers low-income households and not all households. Perhaps more importantly, at an international market price of $10/t of CO_2 (65 R/t), 3mt[4] of CO_2 is worth roughly R200 million per year – a substantial contribution to local development projects.

Having calculated a national total of avoided emissions, the cost of avoiding emissions (or cost of mitigation) can be derived. This is done by dividing annualised social NPV for the intervention by its annual avoided emissions (t CO_2) to give a cost per tonne (R/t CO_2). To avoid double counting of economic benefits, we have only included avoided external cost in the NPV – not global. Table 22 shows the resulting costs in Rands.

Table 22: Cost of avoided emissions per tonne of CO_2 for each intervention

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Share d wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
Including local externalities	-391	732	679	-393	-1 879	-375	-362	-730	635	-220	450	-6
No externalities	-327	796	743	-336	-1 819	-314	-350	-668	696	-211	459	3

Source: CBA output of this study

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[4] It would be incorrect to simply sum the avoided emissions across all interventions, since many are not mutually exclusive.

The interventions that are already cost-effective before considering the global environmental benefits have a negative cost of mitigation – in other words, reducing emissions saves money rather than increasing costs to the economy. These are often called 'no regrets' or 'win-win' climate change mitigation projects. Clearly many of the energy efficiency interventions are 'no regrets' options. The higher costs for roof insulation, partitions, informal houses and SHS are discussed in detail in Chapter 3, and relate to relationship between additional capital costs and incremental energy savings as well as the services provided.

The global attractiveness of intervention projects as mitigation options within mechanisms such as the Clean Development Mechanism (CDM) and the Global Environmental Facility (GEF) depends on how they compare to global estimates of marginal abatement costs for CO_2. No industrialised-country investor would invest in a South African project if the cost per tonne of carbon were higher than they would have paid in their own country or on an international 'spot market' for carbon credits. A number of studies have tried to estimate this 'market price' for carbon, and have been collated by Vrolijk (1999). Mitigation costs per tonne of CO_2 are projected to be in the range of US$13-$42/tC or $3.5 to $11.5/t$CO_2$ (Vrolijk 1999). For comparison, the values above are also presented in US$, assuming an exchange rate of R6.80 / $1.00.

Table 23: Cost (US$/t CO_2) of avoided emissions for each intervention.

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
Including local externalities	-58	108	100	-58	-276	-55	-53	-107	93	-32	66	-1
No externalities	-48	117	109	-49	-268	-46	-51	-98	102	-31	67	0

Source: CBA output of this study

In the context of international negotiations on CDM and the increasing interest in South Africa as a host for projects, it is important to remember that the cost of a project for a CDM investor is not the same as the cost to the country. One of the major differences in analysing CDM projects versus GHG mitigation options is that the financing arrangements do not necessarily coincide with the changes in economic costs. In other words, in 'traditional' mitigation analysis one would basically compare the life-cycle costs and GHG emissions with and without the intervention while taking into account as much as possible, full economic costs, appropriate (social) discount rates among other factors. One would then compare these two to get the incremental life-cycle cost which, if divided by the total emissions savings, gives a measure of cost effectiveness. The GEF operational guidelines refer to this increment as the market barrier removal (reduction) costs.

CDM investors are not interested in market barriers or the future local savings *per se*. Instead, they would be interested in realising profits out of such investment. This would mainly depend how many credits they can generate per dollar invested in the project. This may not bear much resemblance to the cost per ton identified in the mitigation study for a variety of reasons (e.g. rules on sharing of credits, financing mechanisms, equity partnerships, etc). Analysing how CDM investors might see these particular interventions is beyond the scope of this study. However, as part of the information gaps identified in this study, Chapter C-2 provides a discussion of the necessary policy and legal framework required for South Africa to become a competitive player in this field for low-cost housing market. Thorne et al (2000) provides further details on the international dynamics of this market.

2.3 CONCLUSIONS

The interventions analysed here make a contribution to avoiding greenhouse gas emissions, which is substantial when compared to total residential greenhouse gas emissions even if they are small compared to national totals. The selling point for these mitigation options, however, is their low cost of mitigation and their significant development benefits – in terms of reduced local household expenditure, improved health and potentially increased employment. These benefits are explored in more details in Part B of the wider study which deals with indirect cost savings. The low GHG-related cost-potential of the interventions combined with their local socio-economic benefits, make them attractive for international climate-change linked investment that would support national development priorities.

3. COST-BENEFIT ANAYSES OF IMPLEMENTATION AND UTILISATION OF INTERVENTIONS

3.1 INTRODUCTION

All of the interventions described in this report are ways in which energy can be used more *efficiently* to provide a higher level of service at reduced cost. The international energy policy literature has numerous examples of how energy efficiency is often the least-cost path towards providing sustainable energy service (see for example Lovins and Lovins (1991), Reddy and Goldemberg (1990); Gadgil and Jannuzzi (1991) and Kats (1992)). In countries where the gap between *access* to affordable energy and the *demand* for clean energy is very large, such as South Africa, energy efficiency has the potential to accomplish multiple social and economic objectives.

Previous South African studies have shown that significant potential for energy efficiency exists across a range of sectors but the costs are not well understood (Thorne 1995). The impacts of energy efficiency on the low-income residential sector are particularly important, because of the social priorities for upliftment and empowerment of the poor. A series of research papers from EDRC have applied traditional CBA to some energy efficiency interventions for the urban poor at a national level (Spalding-Fecher et al (1999); van Horen and Simmonds (1998); Simmonds (1997); Clark (1997); Thorne (1996)). This analysis takes such studies a step further by including a wider range of interventions and a disaggregated analysis at the household level. The basic methodology, however, remains the same.

3.2 METHODOLOGY FOR COST-BENEFIT ANALYSIS

Cost-benefit analysis is a tool for assessing the viability of different investments while taking into account future realisation of different costs and benefits. In general, the appraisal of capital investment projects is undertaken using discounted cash flow analysis. This approach is adopted in the methodology described here. In this sense, evaluating an investment in energy efficient or environmentally sound housing is no different from evaluating any other type of capital project (see Davis and Horvei 1995). However, this study has extended the analysis, to cover both the national and consumer perspective as well as including a wider range of costs than in a traditional financial analysis. The study has also looked at impacts with respect to specific income groups as described in detail in Chapter 3

Two different ways of posing the viability-question for a project are:

1. Is the project in the interests of the country?
2. Is the project in the interests of participating consumers?

The first question addresses the *economic viability* of the project. Does the project result in net economic benefits for the country as a whole? This involves a discounted cash flow analysis of all of the *financial and social costs* associated with the intervention. The *integrated energy planning* (IEP) approach terms this as *the total resource cost test* and involves calculating the total cost of providing energy services with and without the project in question (CEC 1987). The CBA task of the study is mainly based on incremental cost which is the change in capital cost or energy cost in each year arising from the intervention being analysed. When one intervention replaces some existing costs (for example DSWH replacing an electric storage geyser), the net additional cost in the cash flow analysis is used instead of the absolute cost.

Costs must be projected over a suitable lifetime and discounted to calculate the present value of these costs. This is the most appropriate and standard way of dealing with costs incurred unevenly over a period of time. The discount rate used in this case is the social discount rate which reflects the opportunity cost of capital to society as a whole rather than to individuals or specific institutions. With respect to the housing interventions covered in Chapter A-1, the costs would refer to the following:

- capital and replacement costs

- costs in energy
- external environmental costs of fuels (both local and global)

All interventions are considered over 50 years as this is assumed to be the standard economic life of a low cost house. If the intervention must be replaced before 50 years, those future replacement costs are also included in the analysis. An intervention passes the *total resource cost test* if the present value of all of the benefits such as savings in energy expenditure or health costs exceed the present value (PV) of all the costs such as additional capital required, replacements cost or operational/running costs. The result of this test may be different, depending on whether external costs are taken into account or not.

One can also look at the net economic benefit at different levels such as for individual households, regions, or the nation as a whole from a particular intervention. This disaggregation is important because many of the costs and benefits vary depending on fuel use patterns and local prices of energy and construction materials, on top of the climatic variations in different regions.

The second question examines the attractiveness of the project to the consumers who benefit from the intervention. The simplest technique to use is to do the discounted cash flow analysis using a *consumer* discount rate and only those costs that the consumer actually pays. This would exclude most external costs. In electricity efficiency analysis this is typically called the *consumer revenue test* (CEC 1987).

For this part of the analysis, the study has considered all capital, energy and other operating costs in the consumer perspective, but not any external costs. The study does not include municipal infrastructure savings, since they do not accrue to the consumer. While the consumer perspective is reported in the aggregate results in this chapter, it is even more useful to look at the perspective of individual households, as discussed in Chapter 5 RESULTS FROM THE NATIONAL PERSPECTIVE

To determine whether energy-efficiency programmes are in the interest of the country the study derived the net present value (NPV) for each intervention separately. The national NPV is calculated by taking the NPV at the household level and multiplying by the number of houses in the target group. These figures are derived from the analysis of benefit at the household level (see chapter 4) and the housing data (see chapter A-1 section 8). For the national level, the study considered the *social* NPV, i.e. using a discount rate of 8%. The social NPV is calculated per household including externalities, without externalities and with only local externalities. This breakdown is repeated at the aggregate level. The analysis to this point has also been disaggregated across five fuels and three regions. The national figure is calculated by summing first across fuels and then over regions. These calculations were performed for each intervention in the relevant worksheet and summarised for all interventions in the worksheet reproduced below as Table 24.

Another external parameter (other than the discount rate) affecting these values is the life of the house. For informal housing, present values are calculated over five years. For formal housing, it is averaged over an expected life of 50 years as assumed at the simulation stage of this study (see Chapter A-1)

Table 24: National NPV per intervention at social discount rate (in 1999 R millions)

	RDP 30 m^2 house – space heating						*Row house – space heating*		*Informal house*	*Lighting*		*Water heating*
	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
NPV including externalities	2 437	-641	-449	2 838	1 343	3 174	581	5 904	-1 130	1 407	-1 972	686
NPV without externalities	1 858	-734	-519	2 219	1 275	2 414	552	5 144	-1 315	1 154	-2 193	-43
NPV with local externalities only	2 227	-676	-474	2 594	1 317	2 890	571	5 620	-1 200	1 203	-2 150	100

Source: CBA output of the study

3.2.1 Discussion

The three packages – ceiling, wall insulation and window size – show substantial positive economic benefit, even without considering externalities. This means that they are relatively low-cost (including capital savings for the window), with significant energy savings over the life of the building. While the partitions and roof insulation make sense as part of a package, their specific incremental energy savings are small. On their own, they do not appear economically viable. An advantage of packaging several interventions together is that those with large net benefits can 'carry' those with costs which are relatively small.

The shared-wall intervention has positive economic benefit, because one saves on the cost of the housing shell, as well as energy consumption. The national net benefit for the package of thermal interventions in row houses is the highest discrete intervention analysed. The savings on building costs are significant, adding to the energy cost savings. However, the social acceptability of this intervention is still under assessment. While there is little doubt that densified housing is economically and environmentally beneficial, it tends to be associated with public housing and hostels. The question here may be more on acceptability than affordability.

Interventions in informal housing appear costly from a national perspective. This is due in large part to the much shorter life assumed for shacks (five years against 50 years for formal housing). This short life is not simply a technical or engineering assumption, but could also be due to lack of security of tenure and low desirability of continuing to live in shacks. This means that the stream of benefits is for a shorter time and the present value of savings is lower. High capital costs are prohibitive for upgrading, but research into low-cost insulation should be continued.

It is difficult to compare the two lighting options, for reasons discussed in Chapter 1 already. The major difficulty here is that, because SHSs are considered as an intervention to save only energy use for electric lighting and light duty appliances, it cannot be assumed to serve as substitute for other end-uses such as cooking which may require grid electricity. If all the considerable costs of SHSs are measured against the benefits of light-duty end-uses, then it is not surprising that the analysis makes this intervention look unattractive. A proper analysis of going 'off the grid' must include *all* major end uses and how they would be provided with and without the grid. There could be other avoided costs such as coal used for space heating. An 'energisation' package would also include new costs such as access to LPG appliances and the higher cost of LPG per MJ.

DSWH are attractive if one considers local impacts of energy use, and even more so if global impacts are included. The local avoided external costs are not very large since the geysers they would replace are electric and the incremental capital cost (including the back up) are high.

3.2.2 Comparison of interventions

Besides the analysis of each intervention in isolation, the study also analysed packages of interventions as suggested at the thermal simulation stage. The sum of benefits of the separate interventions is greater than the benefit of the package, since savings achieved by one intervention may affect another. The simulation findings suggest that 100% of energy for space heating can be saved for all the house types analysed (RDP house, row house and

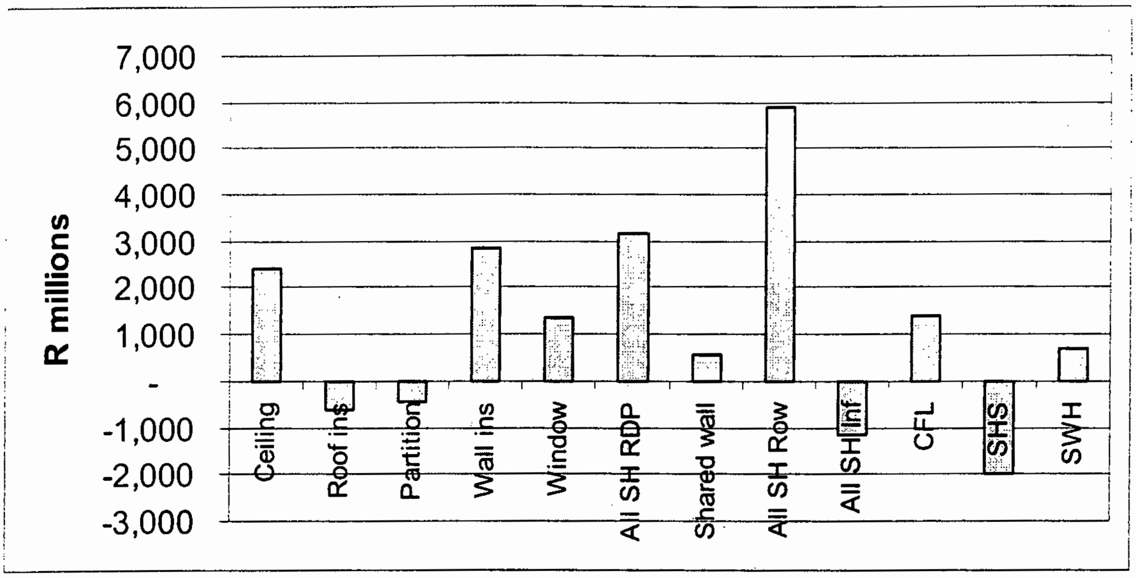


Figure 2: NPV of energy efficiency interventions nationally, assuming social discount rate and including externalities
Source: CBA output of the study

informal shack). The comparison of different interventions as well as the comprehensive packages is illustrated graphically in Figure 2 for NPVs *with external costs.* The effects of excluding external costs from the analysis or including only local external costs are also illustrated in Figure 3. The comparison of interventions in this analysis may differ somewhat from that discussed for the national results in Table 25. The differences arise from the fact that the number of households in the target groups varies for different interventions (see 1). While the numbers differ, the overall ranking is largely consistent.

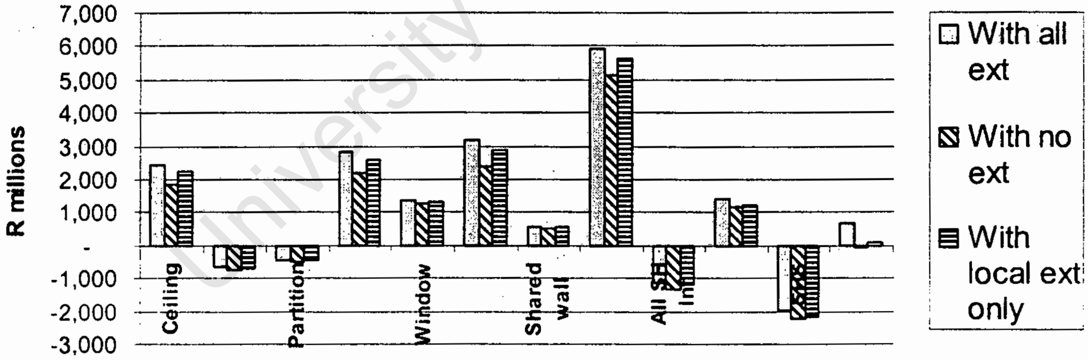


Figure 3: NPV of interventions at national level and the implications of local externalities
Sources: CBA output of the study

Table 25: NPV per household for each intervention averaged across regions (1999 Rands)

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
NPV including externalities	881	-232	-230	1 026	688	1 625	298	3 023	-778	509	-1 010	351

Source: CBA output of the study

3.3 CONCLUSIONS / RECOMMENDATIONS

Overall, the three packages – ceiling, wall insulation and window size – show substantial positive economic benefit, even without considering externalities. In overview, some of the interventions with positive NPVs have benefits in the same order of magnitude as the investments, i.e. in the thousands of Rands. Although only a few interventions look attractive from a consumer's point of view, the analyses presented here indicates that most of the interventions warrant investment by society as a whole.

The national net benefit for the package of thermal interventions in row houses is very attractive both economically and environmentally. This provides a strong argument for the study of social acceptability of this house type possibly involving actual demonstration units. While the partitions and roof insulation make sense as part of a package, on their specific incremental energy savings are negligible.

It is difficult to compare the two lighting options, for reasons discussed in chapter 1. The negative NPV of SHS in the CBA is precisely the result of taking into account only some benefits, but all direct costs. It should not be taken to mean that SHS in semi-autonomous urban houses are not viable. Further studies should investigate the full costs and benefits of an urban semi-autonomous house. The study considered three options on how to treat SHS benefits in this analysis:

1. Exclude avoided municipal infrastructure costs from the analyses,
2. Exclude SHS from such analyses
3. Undertake comprehensive analysis of an urban 'energisation' package across all end-uses.

The first option was applied. The DSWH intervention is attractive if we consider local impacts of energy use, and even more so if global impacts are included. For informal houses, high capital costs make the intervention considered seem expensive in view of their short life cycle. However, research into low-cost insulation alternatives should be pursued.

4. AFFORDABILITY ASSESSMENT

4.1 INTRODUCTION

While a particular intervention may be attractive from a traditional (CBA) point of view, it may nonetheless be unaffordable for the target households. Since this study focuses on low-cost housing, it is important to consider the issue of affordability.

The basic problem is that poor households have negligible savings to invest in decent shelter incorporating energy efficiency modifications. Given the immediate pressing needs of the present, poor households will not easily invest in interventions that will cost a lot now, but save money in future. In economic terms, they have a high discount rate. The cost profile of different alternatives influence affordability of interventions by poor households. Energy-efficient technologies typically have high initial costs followed by low recurring costs while less efficient technologies often cost less up front but become more expensive through higher cumulative operating costs.

This issue can be illustrated as follows: A poor household would ask why it should replace an incandescent light bulb that costs R3.00 with one that costs R65.00. A household with a total monthly income of R500.00 can be expected to perceive such an intervention as unaffordable. The challenge for this chapter is to find a relatively simple way of expressing this dilemma in quantitative terms.

4.2 METHODOLOGY

What is required for this cost-benefit analysis is a measure that is useful in ranking interventions by their affordability for different interest groups. The key measures of affordability chosen for this study are the payback period and the capital subsidy required. These measures connect the interventions and their associated energy savings with the income and expenditure of households of different income groups.

The payback period connects energy savings for the household with the capital cost of the intervention, calculating the number of years required to repay the capital with the cost savings generated through the intervention. The longer the payback period, the less the economic attractiveness of the intervention to the consumer. This should not be taken as a suggestion that households should pay for all or any of these interventions. Indeed, from a low-income-household's perspective, many of the interventions are not attractive (see chapter 4) for further discussion of this issue).

The capital subsidy explicitly approaches affordability from a social perspective in that it establishes the capital subsidy required to make the intervention attractive. The incremental capital cost less the PV of energy savings gives the required value. The exact nature of the payment vehicle for either energy savings or capital subsidy is beyond the scope of this CBA and the study in general. This brings out the need for further studies on the most optimum way of raising the required capital through public and private sector initiatives. Chapter C-2 explores the critical gaps to be addressed with respect to the global climate change mechanisms such as the CDM. Issues of greenbond financing and how to channel household savings to the repayment of bulk loan facilities would require detailed study through pilot projects.

4.3 INCOME GROUPS

In South Africa, households earning R3 500 or less per month are eligible for housing subsidy. At the moment there are about 6.7 million households in this category (DoH 1999). SA focus (1998) subdivides the households into the following categories:

1. R0 – 99,
2. R100 – 199,
3. R200 – 299,
4. R300 – 399,

5. R400 – 499,
6. R500 – 799
7. R800 – 1 400,
8. R1 401 – 2 000,
9. R2 001 – 3 000,
10. R3 001- 4 000.

The survey provides no details on how the income categories were derived. Afrane-Okese (1998) used expenditure levels to determine income levels based on the assumption that household expenditure and income have a direct relationship. The income categories applied in this study were based on per capita total household expenditure derived by dividing total household expenditure by the particular household size.

Simmonds and Mammon (1996) report that the average household size in poor households is 5.9. Household expenditure (R100/month per capita) reported in the 1993 SALDRU study and quoted in Afrene-Okese (1999) was used as the difference between the successive income groups. Data from the above sources were synthesised into the energy-expenditure data by income group as shown in Table 26.

Table 26: Energy expenditure by household expenditure/income groups

	Income group by per capita expenditure (R/month)	*Total household expenditure (R/month)*	*Total fuel expenditure (R/month)*	*Fuel expenditure as a % of total HH expenditure per month*
less than	100	586	82.08	11
less than	200	1 041	71.26	6
less than	300	1 286	87.31	5
less than	400	1 526	88.80	5
less than	500	1 727	96.05	4
more than	500	3 150	144.87	4

Source: Mammon and Simmonds (1996, Table 2.11)

Note that the income groups reported here are for income *per person per month*. For the affordability analysis, the above data were converted to household income using a factor of six and then further adjusted to derive annual figures used in the analysis. From Table 3.1 it is clear that there is no substantial variation in fuel expenditure between the different income groups except in the highest income category in electrified households. This is supported by several studies such as Simmonds and Mammon (1996) and Afrene-Okese (1998) which show that as household income increases the demand for fuels particularly electricity and fuelwood increases at a proportionally lower rate. Demand for other fuels is reported to be income inelastic.

4.4 END-USE FUEL EXPENDITURE

In order to assess affordability of an intervention, the expenditure on a particular fuel for a given end-use was required. For example, one needs to know how much a household in Durban might spend per month on electricity for space heating. Although none of the available data sets provides this information in Rands, Simmonds and Mammon (1996, Table 2.11) provides data on total fuel expenditure for different income groups. The data was adjusted to reflect 1999 prices.

Expenditure per fuel on a particular end-use was derived with the assumption that 25% is spent on space heating, 40% on water heating and 5% on lighting (Simmonds & Mammon 1996, Table 5.5). More refined estimates of energy consumption by end-use and climatic region should be addressed through further studies. Multiplying the fuel expenditure per end use and income group (in R/mth) by the savings for a particular intervention, the annual savings on expenditure per intervention on one end-use were derived. Based on these calculations, the payback period and the capital subsidy required were derived.

4.5 RESULTS OF THE AFFORDABILITY MODEL

The capital subsidy was computed by first establishing the PV of the fuel cost savings at the consumer discount rate over 50 years. The PV was then deducted from the incremental capital cost of the intervention to arrive at the capital subsidy required. Since both the energy savings and the capital costs differ regionally (at least for some interventions), it was necessary to differentiate results for the three regions. The study applies the U1 (Johannesburg) region as an example to illustrate the capital subsidy required as an incentive for households to implement the various interventions.

4.5.1 Capital subsidy required

The following two tables present the PV and incremental capital subsidy using the example of the Johannesburg region. Table 27 presents the PV of the intervention for consumers. These values are then deducted from the incremental capital cost (see Table A-1-1) to give the capital subsidy required as presented in Table 28. One should note that the initial incremental capital costs would have to be advanced to households due to lack of household-savings to invest in such interventions. The previous two tables have used the example of one region to illustrate the calculation of PV and capital subsidy in one region. The average capital subsidies that are required at the national level are presented in Table 29 which shows the values averaged over regions.

Table 27: PV per intervention for consumers at 30% discount rate for Johannesburg

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
< R 600/m	355.11	67.81	65.15	698.72	89.48	820.77	209.24	820.77	820.77	123.12	164.15	787.94
< R1 200/m	308.31	58.87	56.57	606.64	77.69	712.60	181.67	712.60	712.60	106.89	142.52	684.10
< R1 800/m	377.76	72.13	69.31	743.28	95.18	873.12	222.59	873.12	873.12	130.97	174.62	838.20
< R2 400/m	384.18	73.36	70.49	755.92	96.80	887.97	226.38	887.97	887.97	133.20	177.59	852.45
< R3 000/m	415.56	79.35	76.25	817.66	104.71	960.49	244.87	960.49	960.49	144.07	192.10	922.07

Source: CBA output of this study

Table 28: Capital subsidy required per household-income category and intervention at 30% discount rate for Johannesburg (Rands)

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
<R600/m	601.89	351.19	296.85	37.28	-682.48	1 060.23	-1 323.24	-925.77	426.23	-20.52	549.85	1 017.06
<R1 200/m	648.69	360.13	305.43	129.36	-670.69	1 168.40	-1 295.67	-817.60	534.40	-4.29	571.48	1 120.90
<R1 800/m	579.24	346.87	292.69	-7.28	-688.18	1 007.88	-1 336.59	-978.12	373.88	-28.37	539.38	966.80
<R2 400/m	572.82	345.64	291.51	-19.92	-689.80	993.03	-1 340.38	-992.97	359.03	-30.60	536.41	952.55
<R3 000/m	541.44	339.65	285.75	-81.66	-697.71	920.51	-1 358.87	-1 065.49	286.51	-41.47	521.90	882.93

Source: CBA output of this study

Table 29: National average capital grant required per household for an income group and per intervention (in Rands)

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
<R600/m	526.91	351.08	288.43	255.01	-664.14	1 060.23	-1 322.90	-925.77	426.23	-20.52	549.85	1 017.06
<R1 200/m	583.59	360.03	298.13	318.40	-654.76	1 168.40	-1 295.37	-817.60	534.40	-4.29	571.48	1 120.90
<R1 800/m	499.48	346.75	283.74	224.33	-668.68	1 007.88	-1 336.23	-978.12	373.88	-28.37	539.38	966.80
<R2 400/m	491.70	345.52	282.41	215.63	-669.96	993.03	-1 340.01	-992.97	359.03	-30.60	536.41	952.55
<R3 000/m	453.69	339.52	275.91	173.13	-676.25	920.51	-1 358.46	-1 065.49	286.51	-41.47	521.90	882.93

Source: CBA output of this study

The variation of capital grants required for different income groups is not great for most interventions. The exception relates to informal houses, where the capital subsidy required to make the package attractive is about twice as high for the poorest households than for those earning between R2 4000 and R3 000 per month. The variation for CFLs is significant in percentage terms, but not in Rands. Capital subsidies are not required for interventions where initial capital is saved. Unsurprisingly, windows, CFLs and the two interventions in the row house, all have a negative subsidy requirement. These are economically attractive discrete interventions, even at a consumer discount rate.

For the 30m^2 RDP house a capital subsidy of around R1 000 appears to be required to make the package attractive to households. In the context of housing subsidies, this would be a modest amount in view of the substantial economic and environmental benefits. It should be remembered that this is not the full incremental capital cost, but a subsidy which would make the intervention attractive to households. Mechanisms for financing the incremental capital cost (over and above the status quo subsidy) as well as the capital subsidy should be a subject for further studies.

SHS and ceilings have relatively large subsidies due to their relatively high incremental capital cost. One should note that wall insulation requires a modest subsidy, which would differ by region. For example, capital costs in Johannesburg are about double those in Cape Town and more than three times those in Durban.

4.5.2 Payback period

The payback period was calculated as the number of periods required to pay back the incremental capital cost of the intervention, using the fuel cost savings as payment. This might be the case where a municipality or utility, for example, pays for the intervention upfront, but continues charging present fuel costs and repays the capital over a period. Here, we assumed that the interest rate was 8%, which would imply that the capital was provided by an institution with a significantly lower discount rate than that of the consumer.

Table 30: Average payback period per income group and intervention (in years)

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
<R600/m	13.12	N/A	N/A	8.36	-15.53	14.97	-12.17	-0.67	6.75	3.27	N/A	12.26
<R1 200/m	17.58	N/A	N/A	10.33	-16.83	25.45	-13.30	-0.77	8.17	3.84	N/A	15.80
<R1 800/m	11.76	N/A	N/A	7.66	-14.98	13.09	-11.69	-0.64	6.23	3.04	N/A	11.10
<R2 400/m	11.43	N/A	N/A	7.49	-14.83	12.66	-11.57	-0.63	6.10	2.99	N/A	10.81
<R3 000/m	10.07	N/A	N/A	6.73	-14.15	10.96	-10.98	-0.58	5.52	2.74	61.43	9.59

Note: 'N/A' indicates that the capital amount cannot be repaid in the life of the investment at that discount rate.

Source: CBA output of this study

Variation between income groups on the payback period is not significant. The effect of the consumer discount rate and its associated time preference appears to be the dominant factor here. The table shows clearly that several interventions have long payback periods (~10 years for the ceiling, wall insulation, the RDP package and the DSWH). In no income group can consumers afford to pay for these interventions, at a discount rate of 30%. For informal houses, the payback period exceeds the estimated life of the shack of five years. Only CFLs show a fairly short payback period.

For some interventions, there is not enough time to make the payments equivalent to energy cost savings in order to repay the capital cost. This is true of roof and wall insulation, as well as SHS. The 'negative years' reported in the table have no real-life meaning, but apply to interventions which save on building costs (window and row house). An anomaly should be noted that the lowest income group generally has a lower PV and shorter payback period than the second lowest. This result is probably due to the small sample on which the data in Simmonds and Mammon (1996) is based.

Payback period allows different interventions to be compared in simple terms – how long does it take to pay back the capital cost. This comparison can be made graphically. Fig A-6-1 shows a comparison of payback periods for region U3 (Durban) for the various interventions, for one income group. In the cases where the payback period is negative, this indicates that the capital cost was negative. In other words, there was saving on the initial payment on capital.

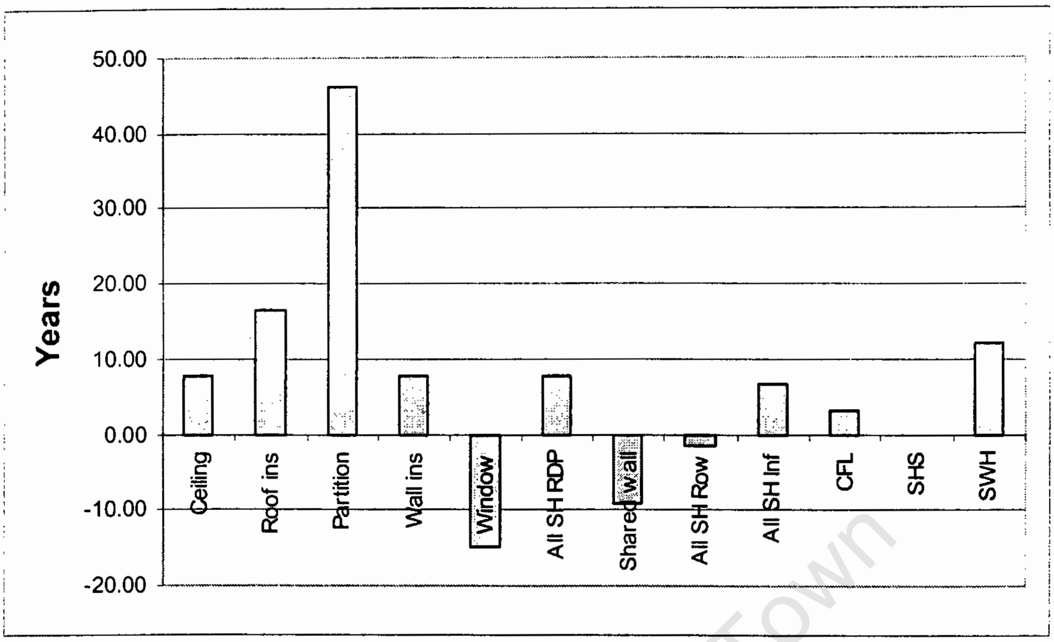


Figure 4: Payback periods for interventions in Durban for income group < R600/mth
Source: CBA output of this study

4.6 CONCLUSIONS AND RECOMMENDATIONS

Capital subsidies are not required for interventions where initial capital is saved. Unsurprisingly, therefore, windows and the two interventions in the row house, all have a negative subsidy requirement. These are economically attractive discrete interventions, even at a consumer discount rate.

For the 30m^2 RDP house a capital subsidy of around R1 000 would be required to make the package attractive to consumers. In the context of housing subsidies, this would be a modest amount in view of the substantial economic and environmental benefits of the most of the interventions. It should be remembered that this is not the full capital cost, but a subsidy which would make the intervention attractive to households.

SHS and ceilings have relatively large subsidies, relating to the relatively high incremental capital cost.

Payback periods are relatively long (~10 years) for several interventions – the ceiling, wall insulation, the RDP package and DSWH. In no income group can consumers afford to pay for these interventions, at a discount rate of 30%. For informal houses, the payback period exceeds the estimated life of the shack of 5 years. Only CFLs show a fairly short payback period. For some interventions, there is not enough time to make the payments equivalent to energy cost savings in order to repay the capital cost. This is true of roof and wall insulation, as well as SHS.

What does this say about different income groups? Variation between income groups on the payback period is not significant. The effect of the consumer discount rate and its associated time preference appears to be the dominant factor. The variation of capital grants required for different income groups is not great for most interventions. The exception relates to informal houses, where the capital subsidy required to make the package attractive is about twice as high for the poorest households than for those earning between R2 4000 and R3 000 per month. The variation for CFLs is significant in percentage terms, but not in Rands.

In order to take the analysis on affordability further, data collection is required on fuel expenditure on end-uses by region. The work done in this CBA might enable some figures to be back-calculated, although the ideal would be survey data. Further economic analysis could be done based on the concept of income elasticity where the study could calculate the fuel expenditure for various income groups as a percentage of the average and then multiply this by the income elasticity. This would more accurately reflect regional variation in fuel use patterns. It would also incorporate the different proportions that households in various income groups would spend on fuel for an end-use given some additional income in the form of savings.

5. APPLICATION OF AFFORDABILITY ASSESSMENT TO LOW-INCOME HOUSEHOLDS

5.1 INTRODUCTION

This chapter disaggregates the results from Chapter 2 so as to show how the energy efficiency interventions affect different kinds of households in different regions of the country. Because climate conditions and fuel-use patterns vary considerably, certain interventions could be economic for some groups and not for others. The methodologies used for the cost-benefit analysis are the same as in Chapter 2. The national results in Chapter 2 are the aggregated results from the household level that are presented here.

5.2 COSTS AND BENEFITS FOR POOR HOUSEHOLDS IN DIFFERENT REGIONS

The value of each intervention per household can be measured in terms of NPV as explained in chapter 3.

5.2.1 Calculating NPV per household

The inputs from the housing model, data gathered on fuel use patterns and fuel prices constitutes the basis of this CBA. Fuel consumption figures were collected by region, fuel and end-use, as described in Chapter A-1 These consumption figures were multiplied by the energy savings factor for the various interventions simulated in Chapter A-1 in the wider study to derive energy-saving (kWh, kg or l per year). Energy savings are converted into Rands using respective fuel prices by region. Avoided external costs for the respective intervention are also calculated based on energy savings at the household level.

The *benefits* to the household are found by taking the present value of both the energy savings and the avoided local external costs (PV 1999Rands). *Costs* are composed of the incremental capital cost (costs of the intervention, less any avoided costs such as that of an electric geyser), replacement costs and any increased operational costs (such as maintenance requirements) other than fuel costs as described in Chapter A-1).

The NPV for the households adds together the benefits (energy savings and avoided external costs) and deducts the costs (capital, replacement, operational). The present values are calculated at the social discount rate of 8% to provide the social NPV. The consumer NPV is also computed at the consumer discount rate of 30%. Both household level NPVs are disaggregated by 5 fuels and 3 regions.

5.2.2 Variation by region/climatic zone

Because of variations in climate and fuel use patterns throughout the country, it is important to examine how the economic benefits vary by region. This value was calculated based on the household NPV for homes using different fuels in each region, weighted by the share of homes using that fuel in each region. Figure 5 and Table 31 below illustrates this variation for each intervention. No external costs are included.

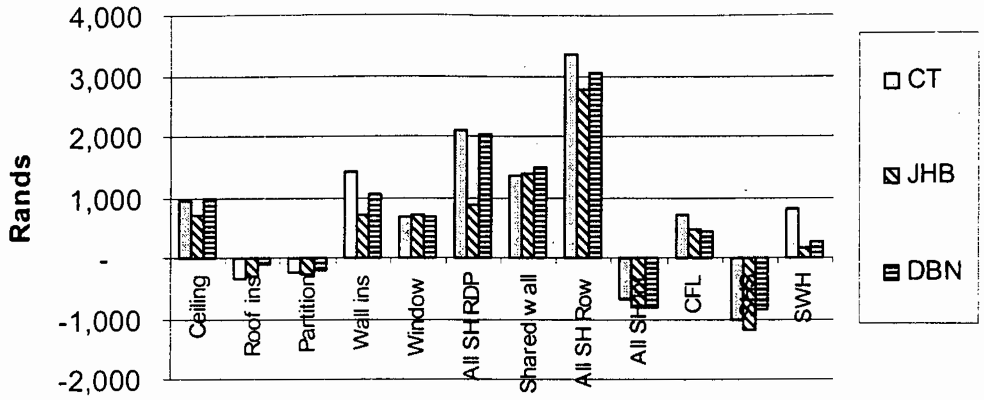


Figure 5: Weighted average regional NPV per household (1999 Rands) including external costs and aggregating across fuel types
Source: CBA output of this study

Perhaps the most interesting result is how little the NPV varies across regions. This is partly because the regions with the coldest climate, and hence the largest energy savings (Johannesburg), is also in some cases the region with the highest capital costs (e.g. because thicker insulation is required). Part of the variation is also due to the lower prices for electricity in Johannesburg – whose municipalities are closer to the sources of generation and have more industrial customers who can cross-subsidise residential tariffs. This is most evident in the analysis of solar water heaters, where the present value of electricity savings, and hence the NPV varies by as much as R600 across regions. In no cases, however, are there interventions that make sense in one region that do not make sense in another.

5.2.3 Effect of external costs

Table 32 and Figure 6 show the impact of external costs on the results. While the interventions clearly have the most economic benefit when we take the external costs of energy into account, the difference is relatively minor, except where the benefit is relatively small (as in DSWH). This is understandable because the majority of the energy savings from these interventions are electricity savings: previous research on external costs of energy has attributed much higher health and environmental impacts to non-electric household fuels than to electricity (Van Horen 1996a; 1996b).

Table 31: Weighted average regional NPV per household (1999 Rands), including external costs and aggregating across fuel types

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
U1 (CT)	950	-329	-240	1 426	687	2 091	1 349	3 362	-675	704	-1 031	818
U2 (Jhb)	708	-308	-256	714	710	893	1 395	2 787	-818	460	-1 174	166
U3 (Dbn)	985	-108	-201	1 043	668	2 018	1 480	3 051	-799	429	-855	265

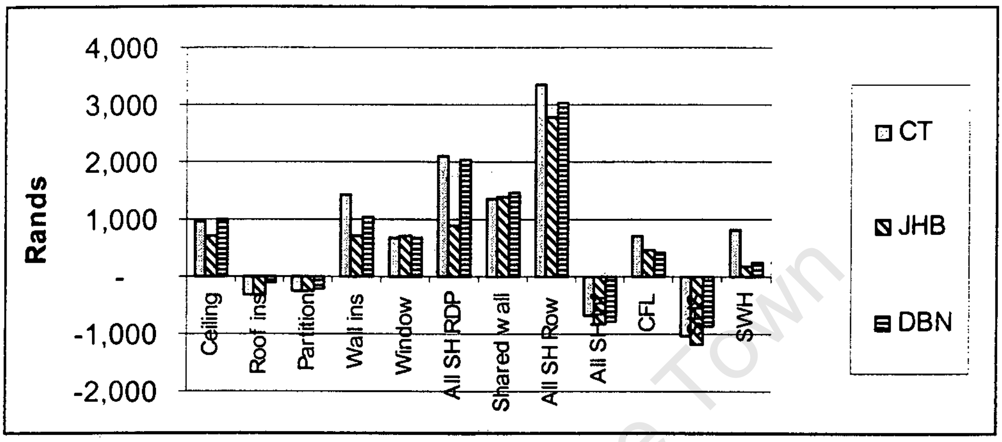
Source: CBA output of this study

Table 32: Household Net Benefit/Cost with, without and with only local external costs, for each intervention and aggregating across regions (NPV in 1999 Rands)

	Ceiling	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
Including all externalities	881	-232	-230	1,026	688	1 625	298	3 023	-778	509	-1 010	351
No externalities	672	-266	-266	802	653	1 236	283	2 634	-905	417	-1 123	-22
Local externalities only	805	-244	-243	938	674	1 480	292	2 878	-826	435	-1 101	51

Source: CBA output of this study

Figure 6: Weighted average NPV per household with all, without and with only local external costs (1999 Rands), aggregating across regions



Source: CBA output of this study

5.2.4 Consumer perspective

From a consumer perspective, a higher discount rate should be applied to calculate present values. Where the study addresses the national perspective, a social discount rate (one which reflects both a low risk cost of capital and a social time preference for longer-term investments) is used. This assumes that the future benefits, and even the interests of future generations, are taken into account more strongly than at higher discount rates. If, however, the perspective of the consumer is considered, then the time preference for money (the discount rate) will be higher. In particular, among low-income households where financial resources are extremely limited, the effective discount rate is likely to be much higher – as much as 30% or more (Banks 1999). In plain language, low-income households cannot afford to wait for future benefits and therefore strongly prefer money now to money later. The NPV for households at this discount rate differ substantially from those reported at the social discount rate, above.

Table 33: NPV per household at the consumer discount rate (30%) for each intervention and region (in 1999 Rands)

Consumer discount rate	*Ceiling*	*Roof ins*	*Partition*	*Wall ins*	*Window*	*All SH RDP*	*Shared wall*	*All SH Row*	*All SH Inf*	*CFL*	*SHS*	*SWH*
U1 (CT)	-481	-395	-333	-212	604	-898	1 146	870	-979	114	-748	-729
U2 (Jhb)	-530	-389	-335	-938	603	-1 716	1 143	669	-1 048	57	-759	-827
U3 (Dbn)	-461	-219	-317	-35	583	-518	1,136	994	-1 022	60	-580	-621

Source: CBA output of this study

Not surprisingly, most of the interventions do not yield a net benefit when a 30% discount rate is assumed – the future energy savings simply have much less value to consumers with high discount rates. In addition, the study has not included external costs in this calculation because these are not attributable to individual households. The reason that changing window size, a shared wall, and the row house still have a positive NPV is that they do not require additional up-front costs – but in fact save money when the house is built. Compact fluorescent lamps, if purchased at the bulk prices that Eskom is projecting for its Efficient Lighting Initiative, are also cost effective even at high discount rate.

5.3 CONCLUSIONS / RECOMMENDATIONS

The analysis of the impacts of energy efficiency interventions on particular household groups shows that the results do not differ significantly by region. This is mainly due to the fact that increased energy savings are offset by higher capital cost in thermal efficiency. An additional reason could be that regions with highest energy-use also have the lowest electricity prices. Similarly, including avoided external costs contributes to the positive social NPV of most of these interventions, but this is not a decisive factor in determining whether they are economically viable, despite the fact that some local extemal costs are attributable to individual households.

If we take the consumer perspective as opposed to a social perspective, few of the energy-efficient interventions analysed in this study appear to be economically attractive to low-income households. The interventions that have positive NPVs are those which have no incremental capital cost or even capital savings (window size, row house) or where significant capital costs are saved (CFLs saving incandescent bulbs). This does not mean that the other interventions are not good investments for the poor. What it means is that one cannot expect low-income households to afford them from their limited incomes. As discussed in Chapter 4, the critical question is how govemment policy can bridge the gap between what is beneficial for society and the constraints that poor households face. An important extension of this analysis, and that in Chapter 3 would be to test the sensitivity of the results to different assumptions about discount rates and energy savings.

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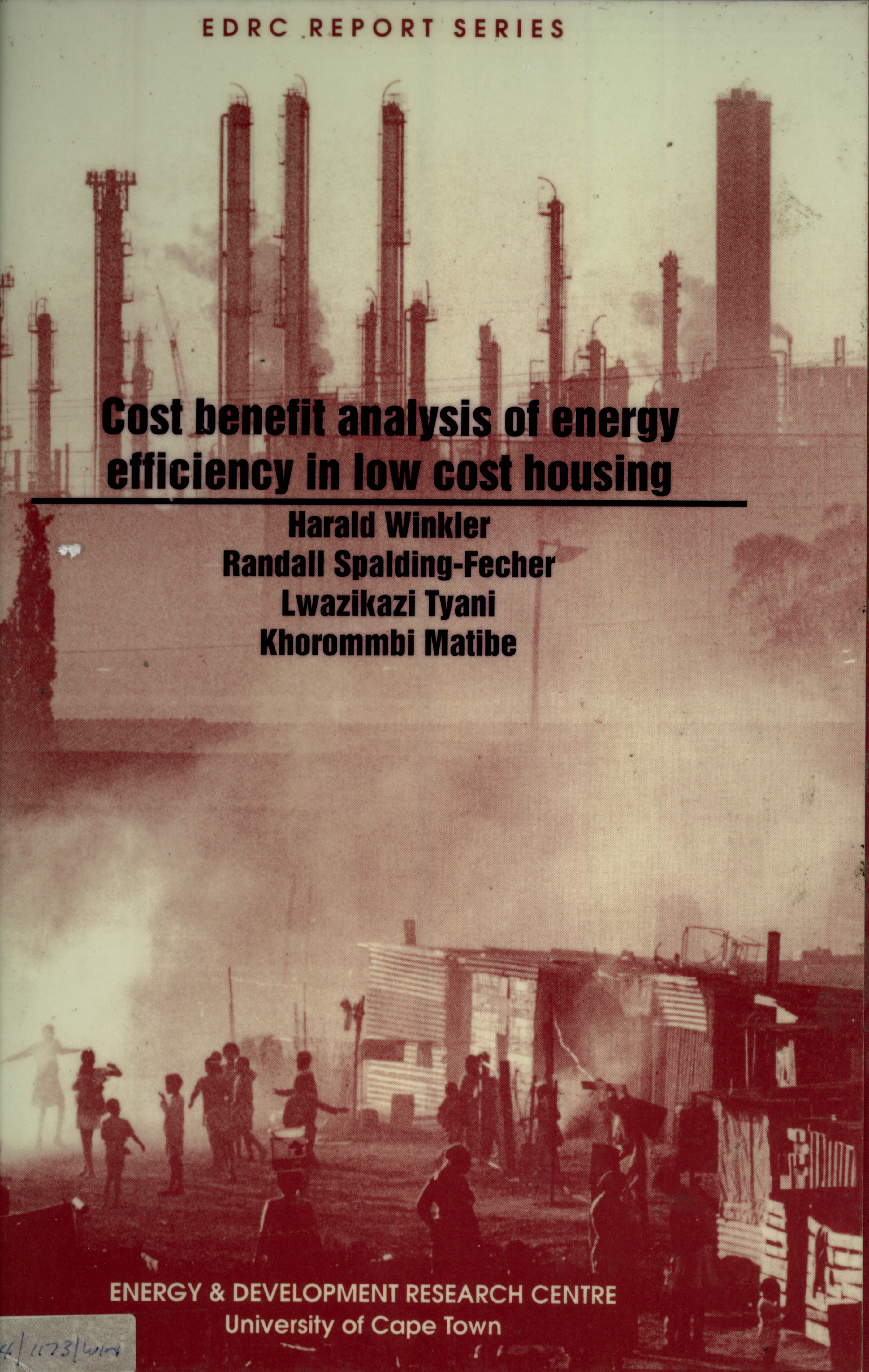

Cost benefit analysis of energy efficiency in low cost housing

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