Economic costs of energy services in South African cities

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EXECUTIVE SUMMARY

The paper describes the process of estimating the economic costs of fuels and appliances currently used to fulfill energy service needs in low-income urban households. Energy services examined included cooking, water- and space-heating, refrigeration and lighting. Initial steps involved the estimation of the economic cost of fuels in which the taxes and subsidies on the fuels were removed from the price and environmental, health, social and other externalities added. In the case of the appliances, the economic costs were approximated by removing the value added tax from empirical retail prices. The life-cycle costs were estimated using a 10% discount rate and an average of the cost range. The average costs were compared with the financial life-cycle costs on the basis of an amortised 10 Megajoules of useful energy (for the thermal services), per 1000 lumenhours and per day (for refrigeration).

General conclusions are that the cost of paraffin makes it the least efficient of the fuel options, without exception. Electricity is the preferable least-cost option for lighting and refrigeration (and heatpumping of thermal energy, although this is clearly not a low-income solution unless multiple family housing is included), solar for water-heating and coal for cooking and space-heating. Gas (LPG) emerges as a competitive fuel for cooking. Wood was not considered, as the dual economies of collected and bought wood make an average LCC estimate meaningless.

The life-cycle estimates were tested for sensitivity to a number of variables, including fuel and appliance cost and energy efficiency, (which were tested across the real cost range), durability of the appliance and the discount rate (which were tested at 20% and 4% increments respectively. The cost estimates were most sensitive to fuel and appliance cost changes and the energy efficiency of the appliances.

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1. Introduction

This short paper examines the cost to the economy of using a range of fuel and appliance combinations to fulfill domestic energy services. It draws on work described in the previous paper (report no. 5) in the series: 'Financial cost of energy services in four South African cities'.

In essence, the economic costs are based on the cost of production and distribution of fuels and appliances. From these, subsidies and/or taxes are removed, and externalities, such as environmental and social costs, are included. The process approximates the real costs absorbed by the economy of providing an energy service, but is flawed in that only costs which have been quantified can be included/excluded. That only quantified costs can be included in the approximations implies that fuels which have been studied in depth are likely to have more comprehensive externality baggage. So, for example, electricity externalities are likely to be better understood that those pertaining to, for example, liquefied petroleum gas (LPG). Further uncertainty is experienced when an estimate of the cost of carbon dioxide emissions is made – while the debate on the possibilities and effects of global warming rages on. The contribution of this externality to the cost is small compared to the others.

In addition to the externalities, the costs of providing the fuels and appliances have to be estimated, and here too there is a margin of uncertainty. The cost of paraffin demonstrates this. According to the oil industry, the paraffin cut of the barrel can be changed according to demand; therefore the cost of producing paraffin is not fixed. To further complicate the economic cost estimation, the price of paraffin is set using an arbitrary in-bond landed cost (IBLC) methodology – a figure established using a formula that draws on the cost of the refined product from refineries in the Persian Gulf and Singapore. The cost of electricity has similar complexities. The choice of using the long- or short-run marginal costs has to be made, and the options are numerous, as both of these cost are related to time. A clear illustration of the cost and time relationship is faced when confronting the cost implications of whether the electrical energy is being consumed during system peak or not.

The externality costs used in this study were drawn from van Horen (1996a&b), who explains in detail the approach taken in making the estimates of the range in size of externalities. The method employed classifies the impacts with respect to how serious they are and the possibility of quantifying them. In estimating the effect, the damage function approach was utilised for Class One externalities – those which are serious and can be quantified.

Chapter Two of this paper explains the methodologies employed in the economic cost analysis. Chapter Three estimates the economic costs of the fuel and appliance combinations, and Chapter Four tests the sensitivity of the estimates to assumptions and parameters used in the estimates. Conclusions are drawn in Chapter Five.

2. Methodologies and sources of data

In estimating the economic costs of urban energy services, the life-cycle cost analysis methodology is used (see Appendix A). There are limitations to the use of the estimates in that the parameters employed are frequently disparate. For example, fuel and appliance costs range widely, as do efficiencies, and in the case of appliance durability there is no empirical data.

The life-cycle costs are estimated by amortising the net present value of all the identifiable costs associated with the specific energy service over the life of the appliance. The estimate of costs is limited to costs to society of providing energy services, and requires estimates of health, environmental, social and any other identifiable taxes or subsidies. The prices associated with the end-users' cost estimates are stripped of taxes and subsidies, and the social and environmental costs associated with the production and use of appliances are added. The Net Present Values (NPV) of all the identifiable and quantifiable costs are amortised, and brought to 10 MJ useful energy for thermal energy services (cooking, water- and space-heating), 1000 lumenhours for lighting, and Rands per day for refrigeration. The costs are ranked and compared to the average financial costs.

A summary of the methodology employed in the costing of these externalities are outlined below. The full impact pathway methodology for each of these types of externalities can be found in van Horen (1996a&b). The impact pathway or damage function approach, which has been used in most major international externality studies, in summary entails:

> identification and quantification of environmental and other damages arising at each stage in the in the fuel cycle: from the extraction of raw materials... to their transport and processing, to their consumption..., to the impacts of waste products ..., and their impacts on human health and amenity, and on the physical and natural environments. (van Horen 1996b: 63)

By way of example, Van Horen (1996b: 62) describes the damage approach as having five steps when applied to power station emissions:

- emission and resource impacts;
- changes in environmental quality;
- environmental and social impacts;
- changes in well-being or damages in economic terms;
- aggregation of damage across effects, individuals and time.

The damage function approach was used to estimate the cost of externalities. Those which were employed in the economic analysis include:

- the respiratory health effects (morbidity and mortality) of direct domestic burning of coal and wood;
- the effects of the ingestion of paraffin;
- the costs of fires and burns associated with the use of candles and paraffin in households;
- effects of wood gathering on the social environment;
- the global effects of the burning of LPG, paraffin, coal (for electricity), coal and wood directly burned;
- water consumption in the generation of electricity; and
- the cost of occupational health in the coal mining operation (for electricity only).

The economic costs are tested for their sensitivity to variables. Amongst these are the costs of fuels and appliances, discount rates, appliance durability, and efficiency in transforming the fuel into useful energy for appliances. The sensitivity to economic costs is arithmetic and undertaken by freezing the variables and changing one variable within the range of real costs. The discount rate and the appliance durability are varied using arbitrary but realistic increments.

2.1 Sources of data

Most of the financial data on fuel and appliance costs and energy efficiency in this paper derives from `The financial costs of household energy services in four South African cities' (Thorne 1996)

The South African Petroleum Industry Association (SAPIA) provides price build-up data for paraffin and LPG. For solid and liquid fuels, estimates of the external costs of mortalities and morbidity associated with direct use, such as the health effects of exposure to smoke, ingestion of paraffin and burns, are sourced and/or derived from data presented by Dickson et al (1995) and van Horen (1996b). Fatalities associated with mining of coal for electricity can also be taken from van Horen's (1996a) work. Van Horen (1996a&b) also gives cautious indications of the costs of greenhouse gas emissions for electricity, paraffin, and coal. Emissions associated with LPG are estimated using the stoichiometric carbon content of the butane and propane constituents of LPG and assuming complete combustion, and the costs associated with these emissions are included in the economic cost evaluation.

3. Economic cost analysis of fuel and appliance combinations

3.1 Introduction

The results of an economic cost analysis can be used to compare various fuel and appliance combinations in fulfilling the energy service requirements of low-income urban households. Such analysis provides information that will allow the appliance and fuel combinations to be ranked according to the cost to the national economy of providing comparable services. A first step to informing a cost-benefit comparison is an economic cost analysis.

The economic cost analysis centres around an estimate of net present value (NPV) of economic costs of candidate appliance/fuel combinations. The methodology entails the manipulation of economic cost data – where the result is indicative of an effect to the national economy. Because taxes have been removed and some previously excluded social and environmental costs added, the result of this analysis differs from the financial life-cycle costs in which only the financial costs of energy services as seen from the end-users' perspective are considered (Thorne 1996).

The first step in the economic analysis is to strip the financial price of fuels and appliances of all but the cost of producing and distributing the fuels. In addition to the economic costs, other quantifiable costs incurred by society – externalities, or costs associated with the environmental or health damage – are added. There are additional classes of externality costs that (though identifiable) are unquantifiable. One such cost in South Africa is that deriving from damage caused by acid rain: this cost is not estimated because of the lack of useful data on acid rain's effects on the economy.

To complete the costing analysis, costs incurred in upstream production, such as the operational and capital cost incurred in the drilling for oil in Nigeria or Kuwait, should be factored in. These upstream activities are assumed to be implicit in the price of the landed fuel but that price is unlikely to reflect the externality cost associated with the production. The costing methodology employed in this project does not draw its system boundary to include costs so far back in the oil production chain. Instead it uses an estimate of the in-bond landed price of the refined products, adding on only externalities which are associated with paraffin, candles and LPG in use.

3.2 Externalities and the cost to the national economy

> If the welfare of future generations is a public good, members of the present generation might be better off by government intervention to promote conservation and reduce the anticipated drag on growth. For that matter the government might intervene to promote intergenerational equity even if the market were allocating resources efficiently from the standpoint of the present generation ... [A]n inquiry into the prospects of resource exhaustion need not be without interest. (Fisher 1990: 90)

An understanding of the costs to the national economy of meeting household energy services in South Africa is not only of intergenerational equity interest, but it may also be of interest to current fuel producers and electricity generators. In addition, if energy policy aims to provide lower cost energy services to urban households, an estimate of the true costs to the economy of the services could provide a useful indication of the better strategies to apply. Where access to energy services and the resources available to achieve the strategies are limited, an estimate of the costs of providing services of similar utility is important to making the available resources reach as wide a consumer base as possible. An example worth drawing on is that of the electrification programme, where limited resources will ultimately constrain the programme. The limitations will not only result from spending on the infrastructure for domestic supply points but the impact on demand for electricity with its associated cost implications in the ordering of power stations, transmission and local area distribution capacity. Should more infrastructure be required, the price of electricity would go up, resulting in less affordable electrical energy services.

Where the costs comparisons result in policies that may affect the transformation of institutions, the costs associated with such a transformation (for example, any appliance and/or fuel switches) should be included in the cost-benefit analysis. Institutional costs are, however, part of the national economic costs (Davis & Horvei 1995) and will be captured in a second pass of the cost analysis – once strategies to achieve lower cost energy services have been identified.

It is not the aim of this phase of the project to advocate fuel switches, but rather to contribute to arguments for fuel switching where these may result in net economic benefits.

The study considers a range of externalities which impact on the externalities of fuel and appliance use. These externalities are examined with respect to their impact on the cost of the fuels. Taxes, such as VAT and those levied on liquid fuels, are similarly examined in this section. The externality costs are estimated per unit of energy (Gigajoule) and per physical unit of fuel (kilogram, kilowatthour, litre, etc).

3.2.1 Respiratory health effects of direct domestic coal and wood burning

The impacts on human health of burning solid fuels can be divided between those experienced indoors and outdoors, both of which affect respiratory health. In the majority of studies conducted, the indicator for emissions is the concentration of total suspended particulates (TSPs), sulphur dioxide, nitrous oxides (NOx). In the early 1980s monitoring of ambient conditions began in Soweto. More recently this approach has changed to one where the Total Exposure Assessment approach has been used to examine the total exposure of individuals, by definition referring to both indoor and outdoor exposures.

In urban areas where coal is used, such as Gauteng, the recorded figures show high levels of TSPs which, in terms of frequency of sample and on average, well exceed World Health Organisation (WHO) 'lowest-observed-effects' and the United States Environmental Protection Agency (EPA) 24-hour standard. Methodologies were employed to disaggregate the quantity of the TSPs from different sources so as to apportion TSPs solely attributable to emissions from low-grade coal burning (and not road-dust, etc). Measuring diurnal fluctuations, and estimating background TSPs (contributing some 74% of the total), sufficient information is considered to exist to quantify health outcomes with respect to the TSPs emitted by domestic coal-burning. The health outcomes are then estimated at low-, mid- and high-exposure scenarios. There is insufficient data to quantify the effects of other emissions, such as carbon monoxide, sulphur dioxide, nitrogen dioxide and other unburned organics (van Horen 1996b: 129-136).

Wood-burning in inadequately ventilated rural houses can result in high levels of pollutants. However, there are few studies which have quantified the level of exposures. Van Horen (1996b: 139), while acknowledging the limitation of an existing study of 17 individuals, extrapolates the level of exposure to an estimated 17 million rural people considered to be users of fuelwood. The figures that exist are used as a mid-scenario, with 50% either side of the mid-value constituting low and high scenarios (van Horen 1996b: 138-140).

3.2.2 The effects of the ingestion of paraffin

Despite paraffin being widely available as a fuel, there are negative implications of its use, one of which is the incidence of its accidental ingestion. Based on what little data is available on the incidence of poisoning, van Horen applied an estimate of 1% to 6.5% across 2.9 million households over an assumed five-year period, implying 5 800 to 37 700 incidences nationally on an annual basis. The central estimate is taken to be 16 000, and the average hospital admission period estimated to be 2.4 days. He further assumed 1.3%, or 208 of the incidences result in death annually. The high and low estimates are, therefore, 75 and 490 annual deaths. Morbidity and mortality are costed accordingly (1996b: 141-142).

3.2.3 Fires and burns associated with the use of candles and paraffin

Extrapolating from limited data available in the Cape Metropole, it is estimated that 8 736 hospital admissions are the base estimate for the entire country in 1994. The range is extended to 33% above and below this base. Burn fatalities for 1994 are estimated to be 1 596. Using a division breakdown of 31% to 69% of victims treated as out-patients to those hospitalised, 101 338 admission days are used in the base case. These figures provide the cost bases for burns. The cost of loss of property as a result of fires is considered to be significant, particularly as those affected are the poorest, but insufficient data is available to quantify these costs (van Horen 1996b: 145-147).

3.2.4 Effects of wood gathering on the social environment

There is data on the effects of the devastation of woodlands in some areas and its effect on top-soil, but the cost of the devastation is not currently quantifiable. It is also estimated that a large proportion of households using wood purchase all of their wood requirements. An effect of the scarcity of wood on the time of the (mainly) women who gather it is, however, quantifiable as an externality. The estimation of the impact is based on an average rural woodfuel-using household shadow wages of R75/month. **A monthly allocation of 20 eight hour days. Approximations are that time spent in gathering wood is between 5.2 and 18.6 hours per household per week, and that 3.2 million people (one person per rural household) undertake the work. Using these figures, there is sufficient data to estimate the cost of this externality. Unfortunately, there is insufficient data to allow conclusions as to the effects of the scarcity of fuelwood on the natural environment (van Horen 1996b: 147-157).

3.2.5 Global effects of the burning of LPG, paraffin, coal-based electricity, coal and wood

Annual GHG emissions related to wood, coal and paraffin for direct use are estimated to be 18, 6 and 1.4 million tons respectively. Knowing the carbon content and calorific value of LPG, and assuming complete combustion, the GHG content of LPG (a mixture of propane and butane) per unit of energy can be calculated. Estimating the cost of carbon dioxide emissions as R5, R22, and R44/ton for low, mid and high scenarios, the economic costs of emissions can be estimated (van Horen 1996b: 156-157; 167).

3.2.6 Water consumption in the generation of electricity

Water accounts for approximately 1.8% of Eskom's operating budget. However, water is a limited resource in South Africa, and often the full marginal cost of its provision is not covered in the price paid for it. An example is the case of the Arnot power station where the price currently paid for water is R0.55/cubic metre, well below the R1.50 which is considered to be the long-run marginal cost of water supply. The low and high long-run costs are considered to be R1.20 and R1.80/cubic metre. The shortfall, or implicit subsidy, in this cost is included as an externality per unit of electrical energy. (van Horen 1996: 108)

3.2.7 Occupational health in the coal mining operation

Van Horen (1995a) averages fatalities and injuries sustained in opencast and underground coal mining during a recent five-year period. In 1994, 23 deaths and 131 injuries were recorded in mines supplying Eskom power stations. Using figures that reflect the cost of these incidents, and R2 000, R5 000 and R8 000, as figures reflecting the cost per injury, and knowing the amount of energy produced by the power stations, and the type of mining, a range of costs per unit of energy can be estimated. Respiratory health effects of mining while being acknowledged as significant, are not costed because of the limited available data (van Horen 1996b: 106-108).

A summary of the externality data used in the economic cost analysis are drawn and derived from van Horen (1996a&b). The figures are listed below in Table 3.1.

TABLE 3.1 Quantifiable externality costs of domestic fuels

Externality	*Rands per Gigajoule*		
	low estimate	*mid estimate*	*high estimate*
electricity externalities[1]	2.78	7.93	14.36
coal pollution	1.61	3.61	6.45
wood pollution	4.42	19.80	53.26
paraffin poisoning	3.49	14.18	51.95
fires and burns			
- candles	-	-	-
- paraffin	11.66	90.24	169.20
wood collection	2.67	6.10	9.53
greenhouse gases			
- paraffin	0.38	1.66	3.33
- coal	0.35	1.55	3.1
- LPG	0.31	1.35	2.7

(Source: van Horen 1996a, LPG figures are derived stoichiometrically)

3.3 Fuels and energy sources

The economic cost estimates of the fuels or energy sources, the steps taken in estimating the economic costs of energy services and assumptions made are discussed individually below. VAT is assumed to be paid at all levels of the distribution chains. These costs are reflected in diagrams in which the economic costs, arranged in ascending order are compared with the financial life-cycle cost estimates. The calculations are contained in Appendix B. The fuel cost data is summarised in Table 3.3 below.

Detailed calculations behind these costs are contained in Appendix C.

3.3.1 Electricity

The cost of electricity varies with demand patterns. The electricity supply industry is designed around the maximum demand for electricity. This design parameter affects generation, transmission, distribution, and the cost of service. Eskom's current short-run marginal costs are 2c/kWh (off-peak) and 7c/kWh (peak). The long-run marginal cost is 5c/kWh (off-peak) and 25c/kWh (peak) (Etzinger 1996). The reason for the low cost in the near future is that there is currently installed over-capacity. Transmission and distribution marginal costs are estimated to add 20% to the generation cost. Power stations are considered at costs per installed kW of between R2 000 to R4 000 (Surtees 1996). For the estimates, 18c/kWh (and R3 000/installed kilowatt) are utilised, as it is assumed that domestic electricity consumption will occur both on and off-peak equally.

A service cost of R25 per domestic supply point per month is included in the cost analysis (Davis & Horvei 1995), and this cost and the average cost per urban electricity connection of R2 170 are split amongst the services (National Electricity

1 Van Horen (1996a) lists Class 1 (currently quantifiable externalities) as coal mining injuries and mortalities, water consumed during generation, air pollution and health impacts, and generation greenhouse gases.

Regulator 1996). The cost of the connection is allocated to each energy service in proportion to the estimated load (see assumptions below).

Quantifiable externalities associated with the generation of electricity in South Africa include air pollution and health impacts, use of water, coalmining injuries and fatalities, and the generation of greenhouse gases. For the three scenarios 19.0, 20.9 and 23.2c/kWh are considered as the costs of electricity.

3.3.2 Solar energy

Solar energy costs nothing and has no externalities in relation to its use.

3.3.3 Coal

The cost of B grade bituminous coal, which is typically used as a domestic fuel, is considered to be the sum of mining and distribution costs. VAT is supposed to be paid at each step in the distribution chain but, as this is unlikely because most of the distribution is accomplished in the informal economy, only the VAT on the coal ex-production is removed from the financial costs. The distribution costs include transport from the mine to the point of production as well as door to door delivered by township coal merchants. R55/ton was the 1995 price ex-production and R173/ton was the distribution cost.[2] But when externalities are added, the economic cost including the costs of pollution and greenhouse gases for the three scenarios, are 29.6, 38.3 and 50.2 cents per kilogram indicating significant contributions to the economic costs of the externalities.

3.3.4 Liquefied petroleum gas

Like electricity, the cost of producing LPG fluctuates with demand and is currently priced according to a method stipulated by the Central Energy Fund which links the price to the price of 93 octane petrol. The current bulk wholesale price is 114c/litre of which 59.7c/litre is the in bond landed cost, 49.6 c/litre is the dealer margin, and the remainder of the price build-up which includes the service differential, 3.6 c/litre to the equalisation fund (being phased out), 0.3 c/litre on a safety levy.[3] When externalities associated with greenhouse gas emissions are added, the cost of LPG is increased to 200.5, 205.6 and 212.2 c/kilogram respectively for the three scenarios.

3.3.5 Paraffin (IP)

The wholesale price of paraffin as well as a maximum retail price is controlled, but this will vary according to where paraffin is purchased. Paraffin can be purchased from a range of places, including a Spaza shop, retailer, wholesaler, agent or distributor. The wholesale price build-up is as follows in Table 3.2.

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2 The 1996 cost of coal is R55/1.14*1.1+R173*1.1 = R244/ton (van Horen et al 1995).

3 For the economic cost estimate, the economic value of LPG is considered to be 59.6+49.6+0.3 =109.6 c/litre or 109.6/0.55kgs/litre=199c/kg. (SAPIA 1996)

TABLE 3.2 Price build-up of paraffin

IBLC (at March 1996 in cents per litre)		80.104
Service differential		11.100
Equalisation fund		4.000
Service differential backlog recovery		1.000
Zone differential	0.200	
Industry margin	14.262	
Under recovery		(1.036)
Wholesale price (April 1996) c/l		**109.63**
Retailers' margin		36.507
VAT		20.463
Retail price (maximum) at the coast c/l		**166.60**

For the sake this exercise, the economic cost of the paraffin is estimated at 131 cents per litre (Goy 1996). The quantifiable externalities include fires and burns, paraffin poisoning and greenhouse gases, which have substantial cost implications. When these costs are added the total economic costs become: 188, 523 and 961 cents/litre for the three scenarios.

3.3.6 Candles

Candles when purchased singly cost on average 50 cents each. The economic costs are estimated to be 50 cents less VAT, that is 43.8 cents each. While there are externalities associated with their use such as (minimal) greenhouse gas emissions and those (more substantial) related to fire hazards, these have not been estimated in this exercise.

3.3.7 Wood

Wood has a wide range of prices, from 0 up to 146c/kg. In the case of wood there are dual economies: where wood is gathered for nothing and where it is purchased. For the economic analysis the average less VAT was used as an indication of the cost – 64c/kg. The externalities associated with wood burning are airborne pollution and loss of productivity due to time spent gathering the fuel. The economic costs in cents/kilogram become: 66.1, 108 and 171c/kg respectively. These costs are summarised below in Table 3.3.

TABLE 3.3 Summary table of the full economic costs of the different fuels and energy sources

Fuels	*Price*	*Economic cost*	*Total economic costs*		
			low	*mid*	*high*
electrical energy (c/kWh)\	26.8	18	19.0	20.9	23.2
solar energy	0	0	0	0	0
coal (c/kg)	25.1	24.4	29.6	38.3	50.2
LPG (c/kg)	205.4 (bulk)	199	200.5	205.6	212.2
paraffin (c/l)	166.6 (retail)	131	188	523	961
candle wax (c/candle)	50	43.9	43.9	43.9	43.9
wood (c/kg)	0 to 146	64	66.1	108	171

3.4 Assumptions

In estimating the NPV of providing the energy services, a number of assumptions are necessary.

- *Appliance costs*

A similar step to assessing the economic cost of fuels should be used on the appliances, but in this case the cost of production is often sensitive information which local appliance manufacturers are unwilling to divulge. For the sake of this exercise, the cost is considered to be the retail price less VAT. The externalities associated with the manufacture or disposal of appliances are not included in these estimates.

- *Fuel costs*

Whereas the costs of fuels vary from city to city in the life-cycle estimates, in assessing the economic cost of the different fuels no spatial variation was considered. The additional increments for transmission of electricity and distribution of fuels are considered to be negligible.

- *Discount rate, appliance and fuel escalations*

A 10% discount rate is used, and both rates of fuel and appliance escalation are assumed to be zero.

- *Efficiencies*

The efficiency ranges were obtained from numerous sources in the literature. The efficiencies and the sources are recorded in Appendix B.

- *Level of service*

Each energy service is considered to be equivalent in its convenience or level of service. Therefore, it is not necessary to calculate any benefit sides of the economic cost estimate. Ideally, though, there are differences in convenience in the different energy services which should have costs and benefits allocated to them.

- *Connection cost and multi-utility appliances*

In considering the connection and service costs of electricity, a question arises as to how this cost should be divided amongst the different energy services. A similar question arises when considering multi-utility appliances such as solid fuel stoves. This could be addressed by using one of the following methods:

- apportioning costs to the services in a ratio accorded to the quantity of energy used;

- apportioning costs (in the case of electricity connection costs) in a ratio accorded to the power demanded by the different energy services; and
- using the 'power factor' and 'hours per day' ranges for each of the appliance/fuel combinations to calculate energy consumption proportions.

Through the reconstruction of energy use utilising end-use survey data, the consumption and demand for the different fuels can be estimated. For electricity connection costs, the demand estimates were utilised, and for the solid fuel stoves the energy consumption for the different services were used to disaggregate the costs between end-uses.

The disaggregation of these costs has been estimated in accordance with delivered energy consumption ranges and is as follows:

TABLE 3.4 The division of multiple utilities to different energy services

Energy service	*Electrification*	*Coal/wood stoves*
cooking	25 to 30	20 to 40
space heating	15 to 20	20 to 40
water heating (for solar/elec. heaters)	35 to 45 (0.15 to 0.25)	30 to 50
lighting	5 to 10	-
refrigeration	5 to 10	-

(Source: estimates drawn from Simmonds & Mammon 1996)

The replacement costs of electrical reticulation are estimated over a 30-year lifespan. The cost of electrical connection is apportioned to two (high) and four (low) light bulbs in the case of lighting, the connection costs are assumed to be part of the initial costs of providing the service, and are not reduced or increased where the appliance life is shorter than, or extends beyond, 30 years.

- *Externality costs*

Costs based on figures other than 1996 figures are escalated at a rate of 10% per annum.

- *Space-heating season*

The space-heating season used for the economic analysis assumed 4, 5 and 6 month heating seasons for the three scenarios. This makes the Durban figures incomparable, because of the shorter heating season and they are excluded in the national average estimate.

- *Comparable benefits*

When the figures which are generated in this paper are compared with one another in the development of the least-cost options, the relative benefits do not estimate costs and benefits for the entire fuel switch.

3.5 Energy services

The economic costs of cooking, space- and water-heating, lighting and refrigeration are estimated in Appendix B. These costs are compared with the financial costs of the energy services averaged across urban areas: Cape Town, Port Elizabeth, Durban and Johannesburg. The economic costs for all cities are arranged in ascending cost order. The least-cost options for each of the services are those furthest to the left.

3.5.1 Cooking

The economic and financial costs of cooking are shown in Figure 3.1.

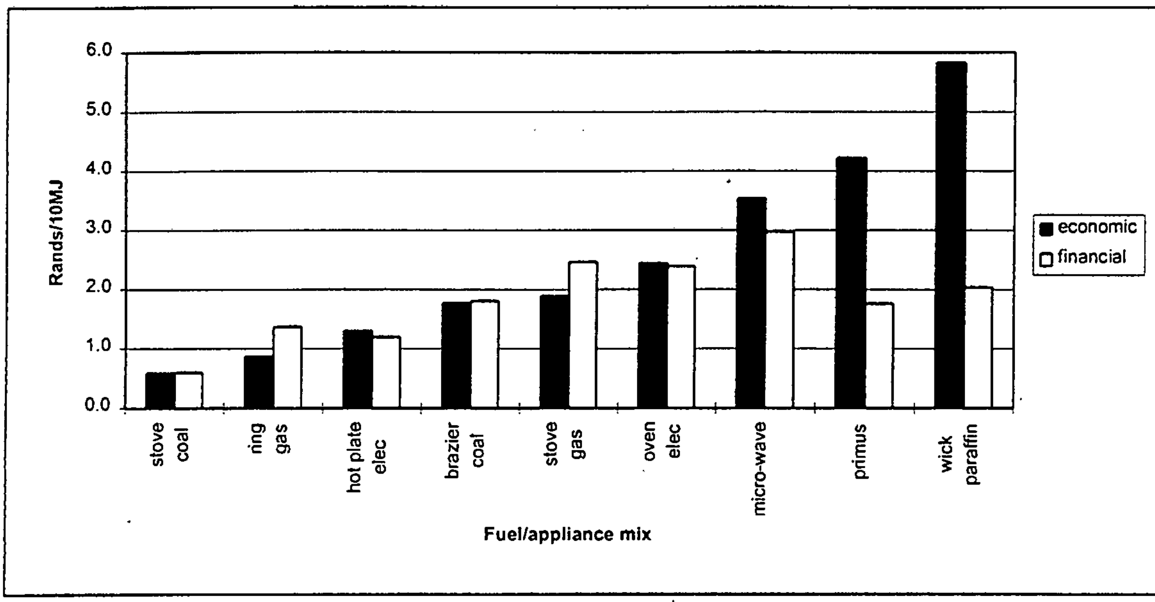

FIGURE 3.1 The economic cost estimates of cooking

The coal stove is the least-cost option for cooking in both cases. The gas ring, which is ranked third-lowest in the financial LCC is ranked second in terms of economic costs. The electric hotplate retains its ranking as the third-best electrical option. Paraffin using appliances are the most costly in the economic terms. The micro-wave oven, broadly considered to be efficient, has the third-highest economic cost. In understanding this result it must be remembered that the microwave is a comparatively costly item, with a magnatron efficiency of converting electricity to heat lower than that on simple conduction heated cookers (see Appendix B). Perhaps the convenience and time efficiency of the micro-wave has been conflated with the delivered to useful energy efficiency.

3.5.2 Water heating

The economic costs of water heating are shown in Figure 3.2.

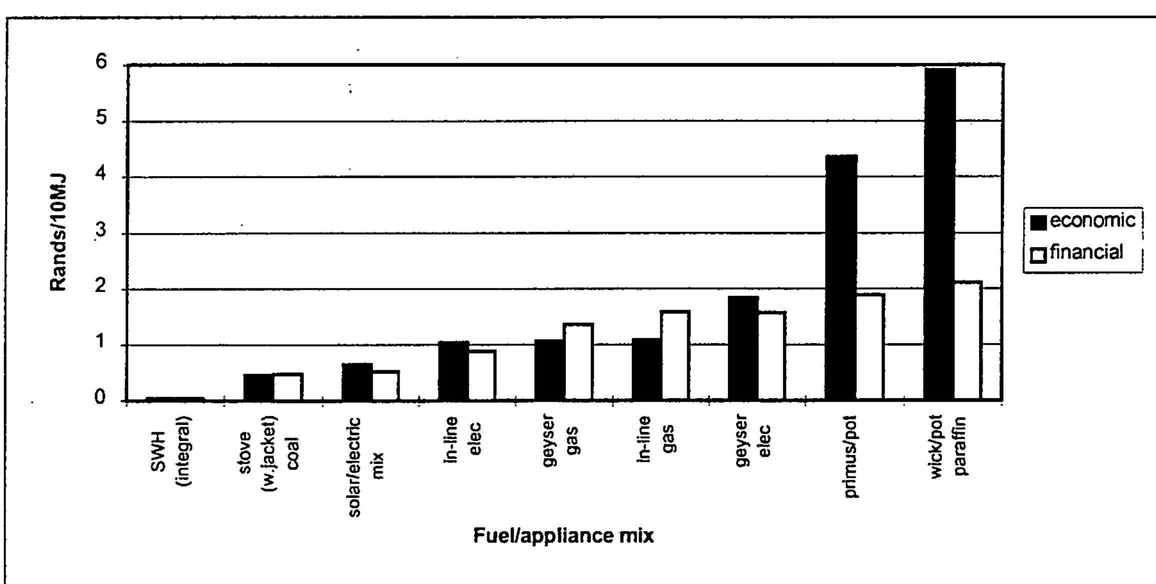

FIGURE 3.2 The economic cost estimate of water heating options

The first five least-cost options for the financial LCC analysis of water heating options are mirrored in the economic analysis. The electric geyser, which is the sixth-best option in terms of the financial analysis, becomes the eighth-best after gas in-line water-heaters and the coal stove with water jacket and high pressure boiler. Paraffin water-heating remains the most expensive in both analyses.

The integral solar water heater provides the cheapest useful energy, but the level of service is not comparable to the hot water on demand of the other water-heating options. A comparison in this case is therefore not justified.

3.5.3 Space heating

The economic cost of space heating options are shown in Figure 3.3.

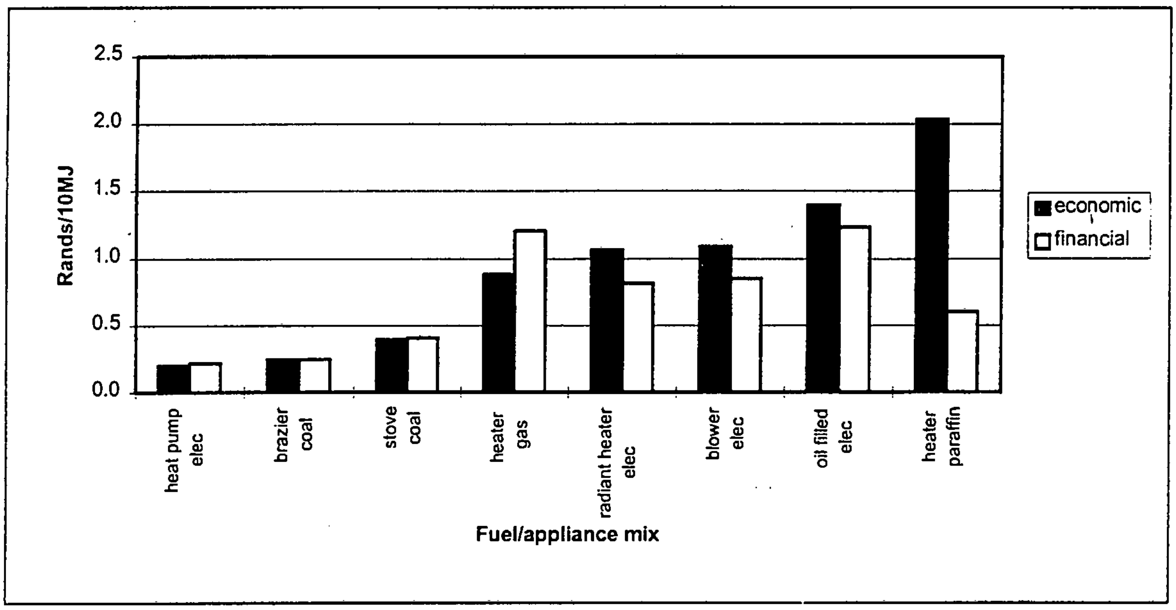

FIGURE 3.3 The economic cost estimates of space heating

The heat pump is the least cost option, replacing the coal brazier which was the least financial cost option. The coal stove becomes the second-lowest cost option followed by the electric heaters. The paraffin heater, which is the fourth-lowest cost option in financial analysis, becomes the highest economic cost option.

The heat pump option is an exception to the use of electricity for thermal loads. Strictly speaking, the service in this instance, like refrigeration is a shaft power service that 'pumps' energy from a low temperature to a higher temperature heat source. This process provides three to four units of heat energy for each unit of electrical energy – and this is where the advantage of heat pumps lies. While the delivered service from a heat pump is the cheapest for space-heating, the technology is expensive in first cost terms and therefore more applicable to larger than domestic space-heating requirements. However, heat pumps could find applications in multi-family dwellings, such as hostels.

The coal brazier appears to be the second-best option for space-heating but, as is the case with the integral solar water heaters, the level of service is incomparable. The brazier, by definition has no chimney and will result in significant emissions within the dwelling, posing a significant inconvenience and health hazard.

3.5.4 Lighting

The economic costs of lighting options are shown in Figure 3.4.

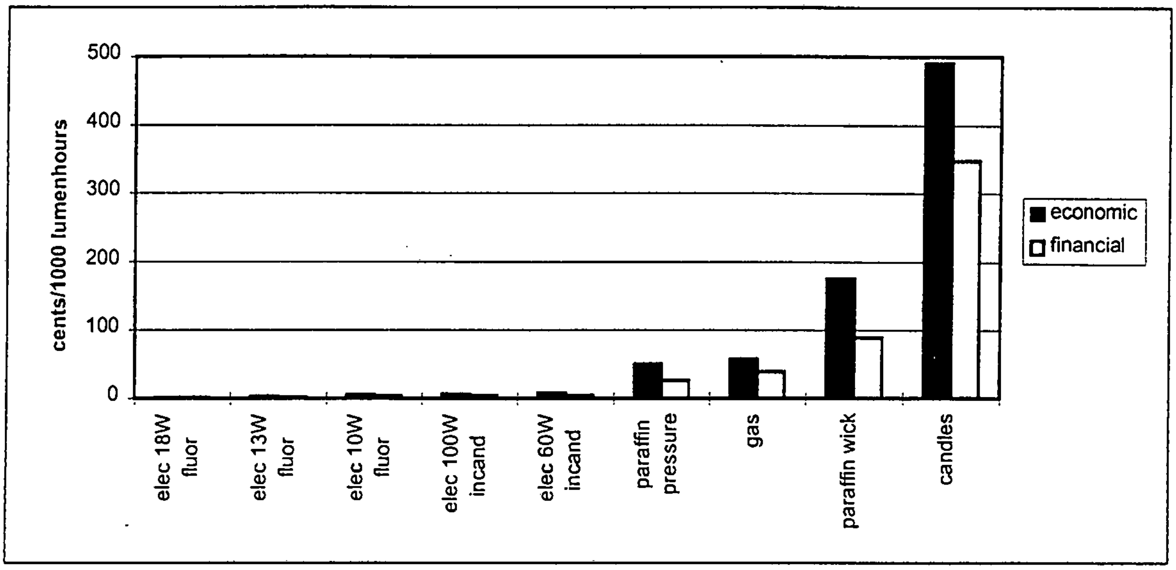

FIGURE 3.4 The economic cost estimates for lighting

The least-cost order of the lighting options is the same for the economic as the financial cost analysis, the compact fluorescent 18W bulb providing the cheapest option followed by electric incandescent lamps. The calculations are based on two electric bulbs used for four hours per night.

After electrical lighting the paraffin pressure lamp provides 1000 lumen hours at a lower cost than the gas lamp.

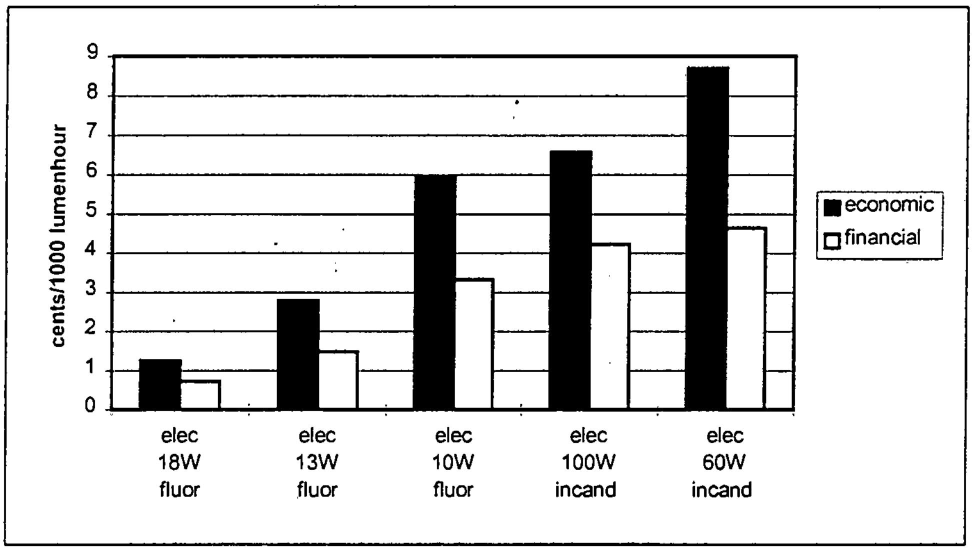

FIGURE 3.5 The economic cost estimates for electric lighting

The electric fluorescent lighting options are closer to the incandescent in the economic cost analysis. The failure to include the costs associated with power demand in the financial analysis and its link to the infrastructural requirements is partially attributable to the proximity of the economic costs of fluorescent to the incandescent technologies.

This surprising increase in the economic costs of the electrical lighting options is explained by the excessive burden which the electric lighting service faces with 7.5% of the R2 170 average connection cost being passed on to two electrical lighting sources (National Electricity Regulator 1996). It may be better considered in both analyses to assume that there are, say, three or four electric lights per household. Such an assumption may provide a more realistic economic cost estimate.

3.5.5 Refrigeration

The economic cost estimates for the refrigeration options are shown in Figure 3.6.

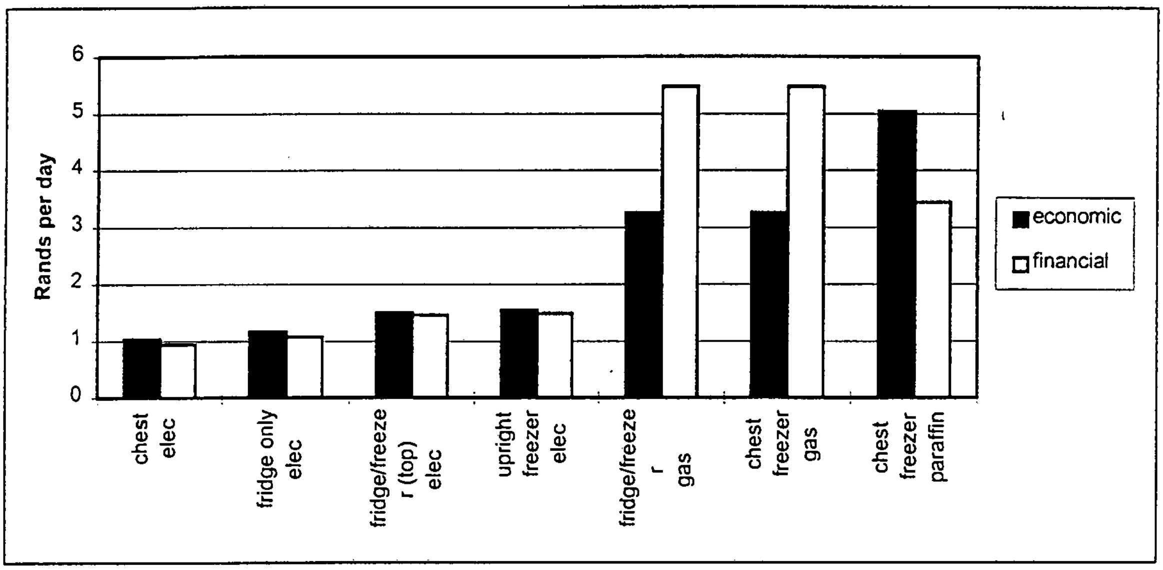

FIGURE 3.6 The economic cost estimates for refrigeration

The electric fridge/freezer options are the least-cost options in both the financial and economic analyses. The paraffin fridge/freezer replaces the gas fridge/freezer and freezer as the next-lowest cost option. This is surprising and may have something to do with the absorption fridge assumptions which were used to estimate the amount of both gas and paraffin absorption units would use. Unfortunately no better information is currently available.

3.5.6 Conclusions

The main conclusions which can be drawn from the economic analysis, is that it has resulted in lower gas and to a lesser extent, electricity costs, (despite higher connection costs). Higher costs for paraffin (though this is not the case in refrigeration and lighting), wood and coal fueled energy services.

The least-cost economic and financial options for the energy services are:

- coal stoves for cooking;
- heat-pump (economic) and by coal stoves (financial) for space heating;
- integral solar water heaters remain the least-cost water heaters;
- 18W compact fluorescents for lighting; and
- electric chest freezers for refrigeration.

The assumptions need refining, particularly the appliance cost figures.

4. Sensitivity analysis

The financial LCC estimate is subject to a number of assumptions and parameters that can have a range of values. This chapter sets out to assess how sensitive the LCC estimate is to some of these assumptions and parameters. In undertaking the sensitivity analysis, the LCC is estimated by changing one variable across a range while all other variables and assumptions remain constant.

The variables and parameters against which the amortised LCCs are tested in this sensitivity analysis exercise are:

- the cost of the fuel;
- the cost of the appliance;
- the appliance efficiency;
- the durability of the appliance; and
- the discount rate.

For energy efficiency, fuel and appliance costs, a range is defined in the LCC calculations. The mid-point of this range is used for demonstrating the average life-cycle, but for the sensitivity analysis three equidistant increments are set between the maxima and minima at which to test the sensitivity. This method provides five points at which LCC is estimated. The results of the test are presented as the percentage change in LCCs using the LCCs at the bottom of the range as a baseline. The LCC trends over the range provide an indication of the comparative sensitivity of the LCC to the variable.

A second presentation of sensitivity shows the effect on the LCC of five appliance combinations: (coal stove, paraffin wick and primus, gas ring and electric hot-plate) at minimum, mid and maximum points on the variable's range.

In the case of the last two variables, an estimate of the reasonable fluctuation in the parameter is also divided into five increments. For example: 8, 12, 16, 20, and 24% increments are used for the real discount rate analysis.

Figure 4.1 describes the connection cost (see section 3.4), maintenance cost, operation cost and appliance price contributions to the LCC for cooking appliance/fuel mixes.

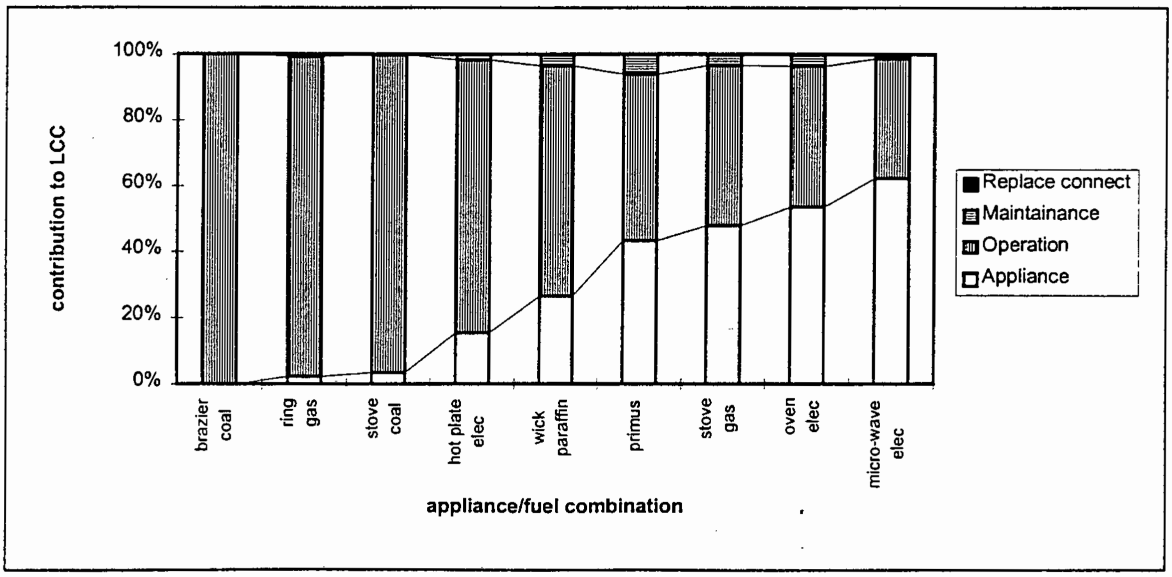

FIGURE 4.1 Contributions to the life-cycle cost

Table 4.1 summarises the variables and the ranges and increments at which the financial LCCs were tested.

Variable	*Top of the range*	*Bottom of the range*	*Increments*
cost of the fuel	lowest price less tax, plus externalities	lowest price less tax, plus externalities	25%
cost of the appliance	lowest price less tax, plus externalities	lowest price less tax, plus externalities	25%
efficiency	most efficient	least efficient	25%
durability	40% above listed estimate	40% below listed estimate	20%
discount rate.	24%	8%	4%

TABLE 4.1 Sensitivity variables, ranges and increments

The senitivity to the economic LCCs of these variables will be tested and discussed below.

4.1 Sensitivity of life-cycle cost estimates with respect to variable fuel prices

The sensitivity of the life-cycle cost is tested with respect to increasing fuel prices within the empirical ranges recorded for each of the fuels. The result of the exercise is illustrated in Figure 4.2.

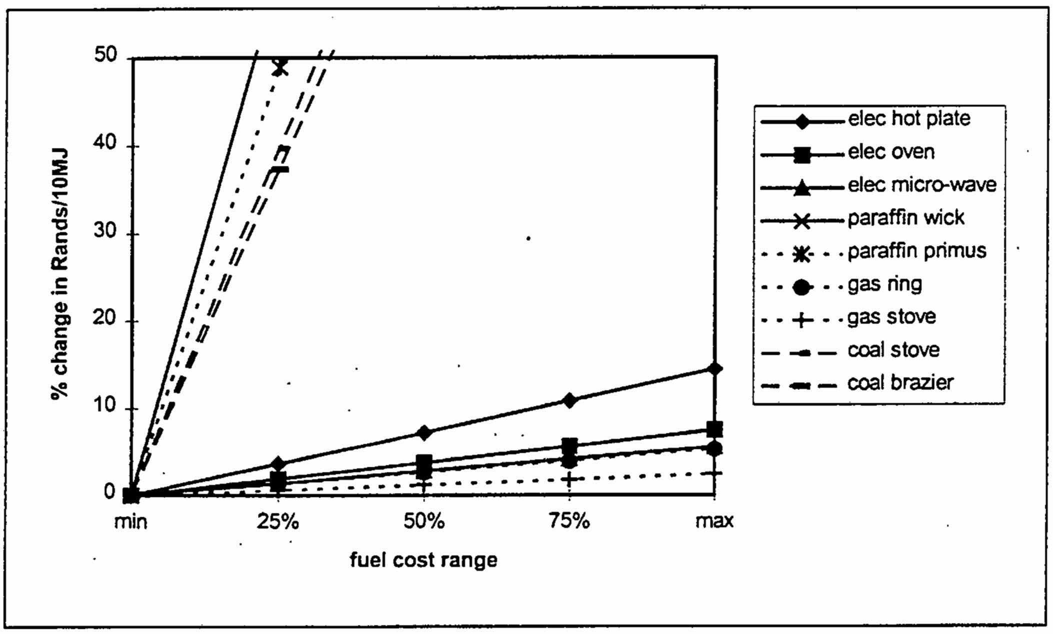

FIGURE 4.2 Life-cycle cost sensitivity to fuel cost variations

The figure shows two distinct families of sensitivity curves. As expected, all LCCs increase with increasing fuel cost. The electricity and gas fueled appliances show a lower sensitivity than those fueled by coal and paraffin. The reason for the acute sensitivities of the latter two relates to the wide range of costs of these two fuels. In contrast the narrow cost ranges of electricity and gas are likely to account for the modest percentage change in the LCC over the fuel cost range.

Translating the percentage changes in LCCs into the costs of five popular cooking fuel/appliance combinations provides the economic LCCs shown in Figure 4.3

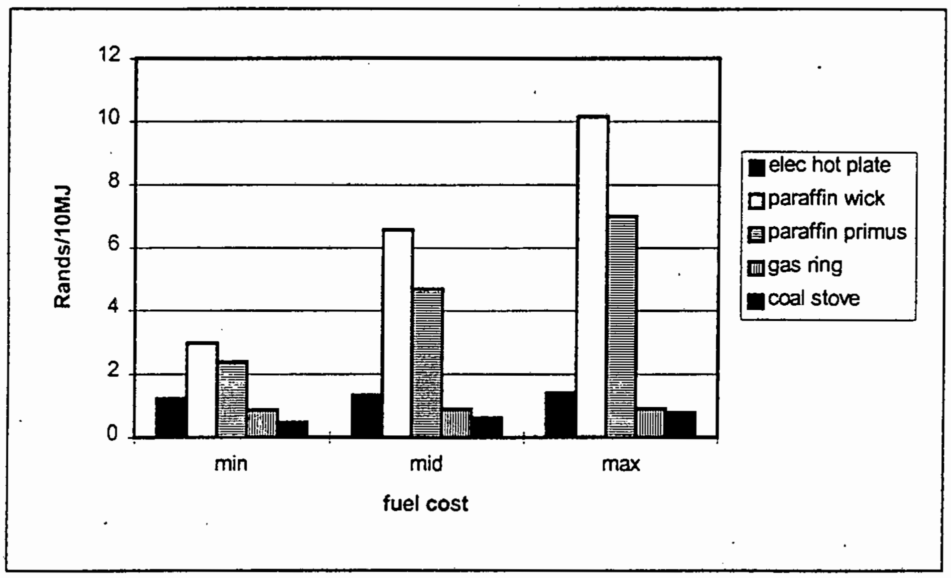

FIGURE 4.3 Effects on LCC of varied fuel costs

Figure 4.3 shows that at the bottom of the fuel cost range all five fuel/appliance combinations are within a narrow LCC range, with the coal stove the lowest at R0.5/10MJ and at the top of the range the paraffin wick at R3/10MJ. The range, as expected, is exacerbated from a factor of 6 between the highest and lowest to a factor of 12. Throughout the range, the electric hotplate, the coal stove and the gas ring remain within a narrow range, with the coal and gas appliance/fuel mixes approaching each other at the top of the fuel cost range.

4.2 Sensitivity of life-cycle cost estimates with respect to variable appliance prices

The sensitivity of the life-cycle cost is tested with respect to increasing appliance prices. The result of the exercise is illustrated in Figure 4.4.

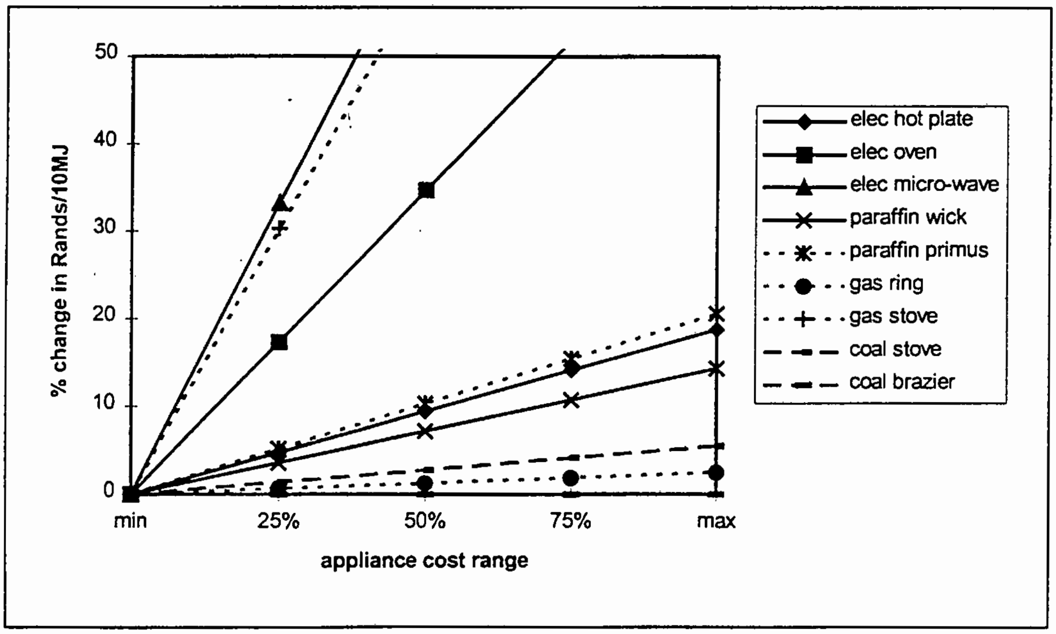

FIGURE 4.4 Life-cycle cost sensitivity to appliance price variations

In all cases, the increase in the appliance costs across the range result in increases in the LCC. The sensitivity of the LCC to appliance cost ranges shows that microwave ovens, primus stoves and electric ovens are the most sensitive to variations in the appliance cost changes. The sensitivity of these fuel/appliance combinations is due to the wide ranges in the cost of the appliances (see Appendix B). All three of these appliances exhibit a wide range between the cheapest and most expensive retail price in the appliance class range from which the economic costs were derived.

Figure 4.5 reveals the actual economic LCCs of the five common fuel and appliance combinations.

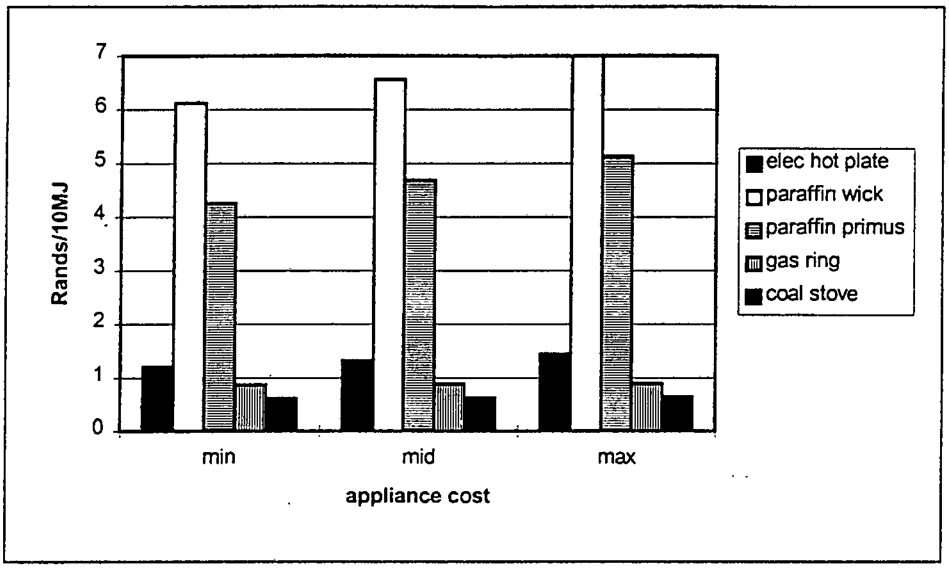

FIGURE 4.5 Effects on LCC of varied appliance costs

The coal stove, in all points across the appliance cost range is the cheapest fuel/appliance combination. The gas ring shows limited changes across the range. The electric hot plate shows a more rapid increase across the appliance range than the coal stove and the gas ring. To cook using the electric hot-plate costs approximately twice that of the coal stove, but only 15-20% of the paraffin appliances.

4.2.1 Sensitivity of economic cost estimates with respect to variable efficiency

The effect of increasing efficiency on the LCC of the cooking appliance and fuel mixes is shown in Figure 4.6.

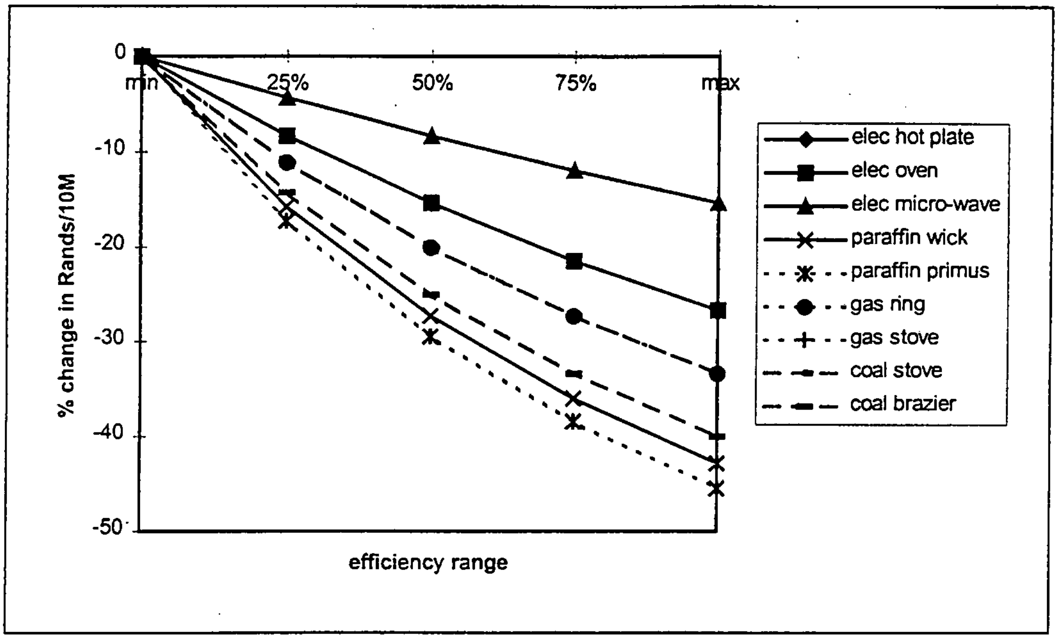

FIGURE 4.6 Life-cycle cost sensitivity to efficiency variations

In all cases the increasing efficiency across the range results in decreasing LCC. The most sensitive to the increase in efficiency are primus stoves, and the least effect on LCC is on the microwave ovens. Figure 4.7 describes the effect on the individual cooking appliance/fuel mixes.

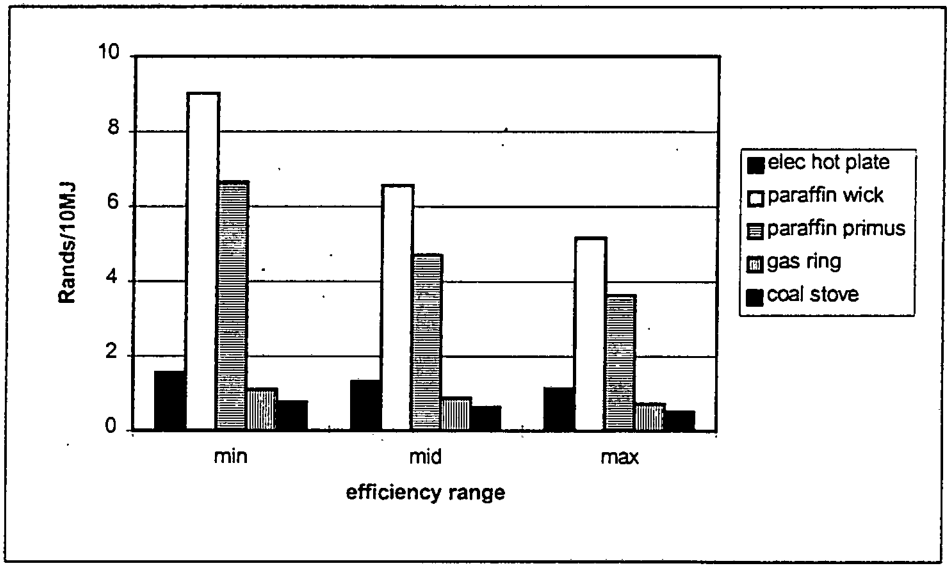

FIGURE 4.7 Effects on LCC of efficiency variations

The paraffin appliances show a considerable decrease across the range with the primus stove from R6.8 to R3.4/megajoule. The gas ring and coal stove approach similar LCCs at the high efficiency end of the range.

4.2.2 Sensitivity of economic cost estimates with respect to durability assumptions

As there is little data describing the durability of domestic appliances, throughout the LCC analysis, durability is assumed. The sensitivity analysis tested the effects on the LCC on the cooking appliances and fuels of altering the assumed life span of the appliances. Figure 4.8 shows the effect of durability changes on the LCC.

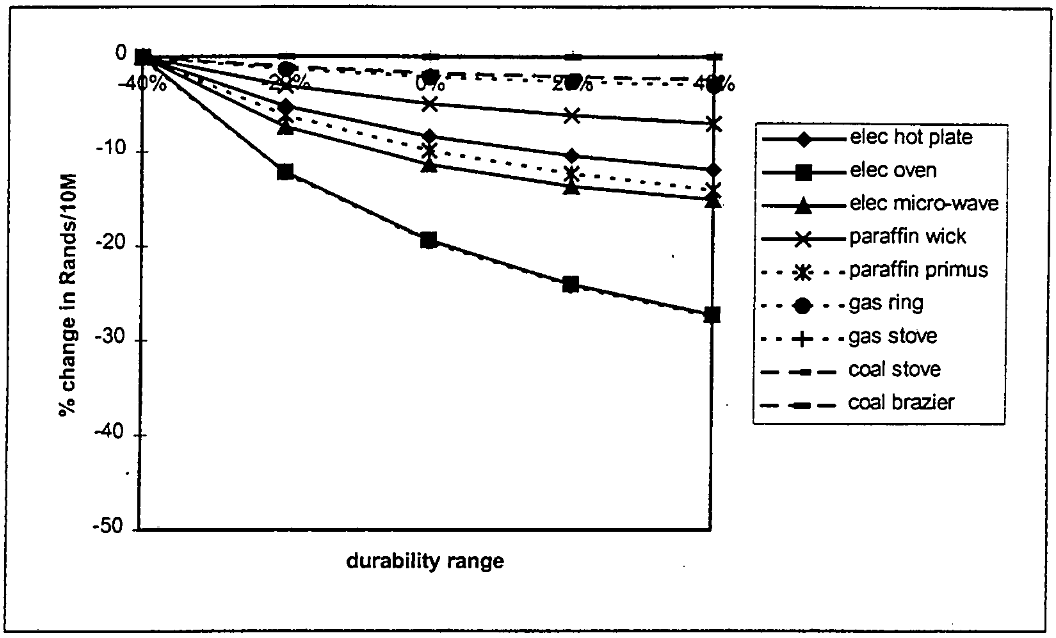

FIGURE 4.8 Life-cycle cost sensitivity to durability variations

As expected, in all cases the LCC has decreased with increasing durability. However, it is apparent that the LCC is not very sensitive to durability. Most sensitive to increasing durability are the most costly items, like electric stoves. Figure 4.9 shows the actual changes in LCC for the appliance/fuel combinations across the range.

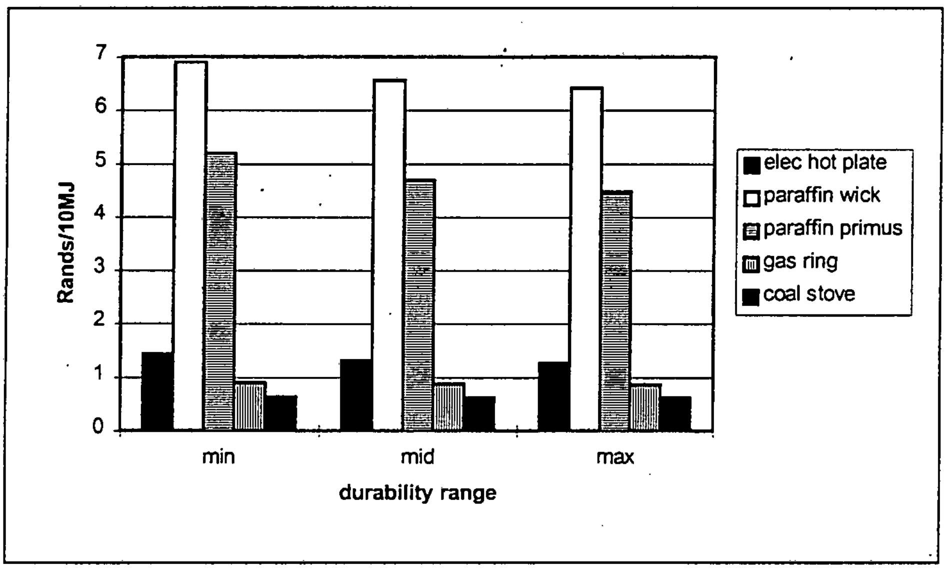

FIGURE 4.9 Effects on LCC of varied durability

The LCC of the different appliances are mapped out in Figure 4.9. The decrease in LCC is not large across the range.

4.2.3 Sensitivity of economic cost estimates with respect to variable discount rates

Figure 4.10 shows the effect of increasing discount rates on the appliance fuel mixes. In all cases the increase in discount rates are increased across the range from 8% to 24% per annum and amortised at 10% to a useful energy base of 10 Megajoules.

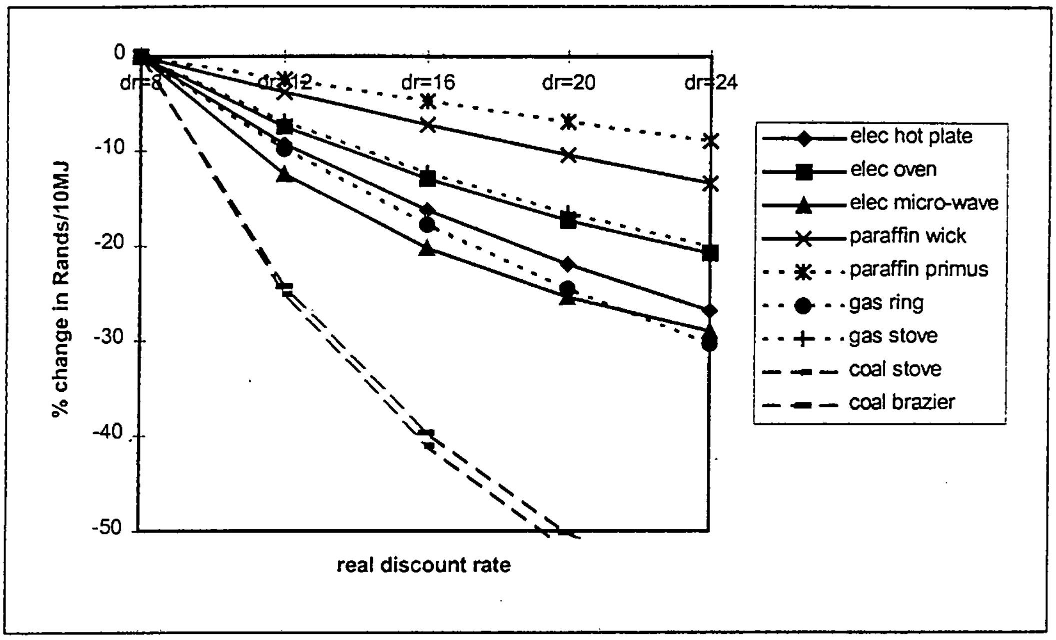

FIGURE 4.10 Life-cycle cost sensitivity to discount rate variations

In all cases the increase in the discount rate between 8% and 24% across the range result in decreases in the LCC. The sensitivity of the LCC to discount rate ranges shows that coal using appliances are the most sensitive to variations in the discount rate. The sensitivity of these fuel/appliance combinations is at the high end of the fuel-to-appliance cost ratio over the life of the appliance. The paraffin fueled appliances show the least sensitivity to the changes in discount range.

Figure 4.11 reveals the actual LCC of the five common fuel and appliance combinations at three different real discount rates. While these discount rates straddle a wide range, it is apparent that social discount rates can be far higher than the 24% which tops this range. Gadgil (1996) suggests that rates of up to 80% amongst the poorest of the poor are not unreasonable.

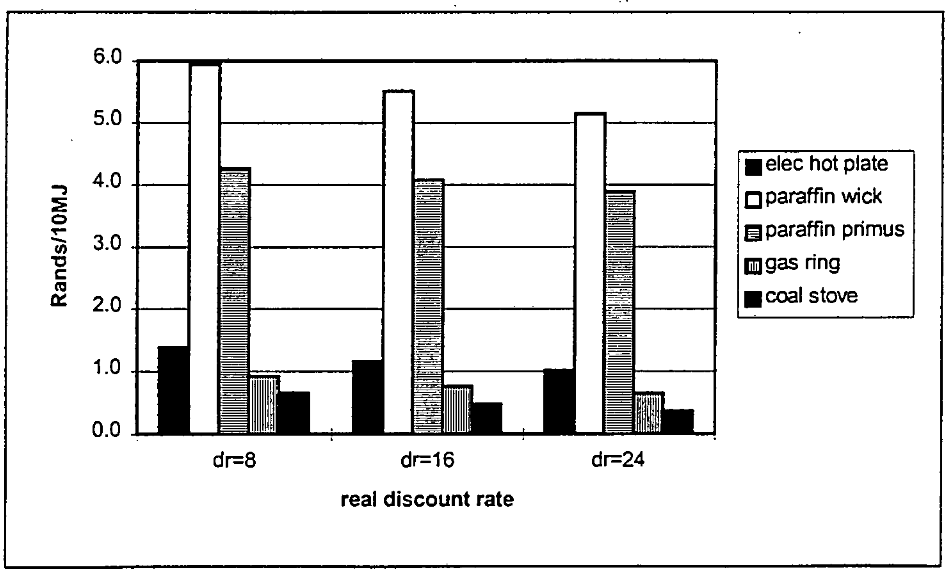

FIGURE 4.11 Effects on LCC of varied discount rates

Throughout the range the coal-fueled appliances reveal the least-cost options. Second best is the gas ring followed by the electric hot-plate. The paraffin-fueled appliances are by far the most expensive in economic terms. The paraffin wick cooker is more than ten times as costly as the coal stove option at the low end of the discount range, and nearly fifteen times more expensive at the high discount rate end of the range.

4.3 Conclusions

The sensitivity analysis has been conducted on assumptions made during the life-cycle estimate rather than showing a range of the cost estimates. The average of ranges in price (appliance and fuel), appliance durability, discount rates, and energy efficiency was used to provide an average estimate and it was on this average that the sensitivity was tested.

The analysis concludes that estimates of cost that the amortised life-cycle costs are most sensitive to variations in price of fuel and appliances. Exceptions to this were in the price of electricity, which has a comparatively narrow range. The other variables have a lesser effect on the cost. Variables include; discount rate, energy efficiency and appliance durability.

5. Conclusions

The paper described a process of estimating the economic costs of fuels and appliances currently used to fulfill energy service needs in low-income urban households in South Africa. Energy services examined included cooking, water and space heating, refrigeration and lighting. Initial steps involved the estimation of the economic cost of fuels in which the taxes and subsidies on the fuels were removed from the price and environmental, health, social and other externalities added. In the case of the appliances, the economic costs were approximated by removing the value added tax from empirical retail prices. The life-cycle costs were estimated using a 10% discount rate and an average of the cost range of the fuels and appliances. The average costs were compared with the financial life-cycle costs on the basis of an amortised 10 Megajoules of useful energy (for the thermal services), per 1000 lumenhours and per day (for refrigeration).

The paper concludes that the cost of paraffin makes it the least efficient of the fuel options, without exception. Electricity is the preferable least-cost option for lighting and refrigeration (with the exception of and heat-pumping of thermal energy, though this is clearly not a low-income solution unless multiple family housing is included), solar for water-heating and coal for cooking and space-heating. Gas (LPG) emerges as a competitive fuel for cooking. Wood was not considered as the dual economies of collected and bought wood make an average LCC estimate meaningless.

The life-cycle estimates were tested for sensitivity to a number of variables, including fuel and appliance cost and energy efficiency, (which were tested across the real cost range), durability of the appliance and the discount rate (which were tested at 20% and 4% increments respectively. The cost estimates were most sensitive to fuel and appliance cost changes and the energy efficiency of the appliances.

APPENDIX A

The life-cycle cost estimate

The life-cycle cost provides an estimate of the cost in current financial terms of all the costs involved in the use of an appliance, from purchase to the disposal. The life-cycle cost (LCC) composes the sum of the initial costs, the present value of any replacements or maintenance, and the present value of operational costs. The life-cycle cost is the present value cost of the entire system over the appliance's lifetime (Davis 1991). In the calculations below, the LCC is presented in 1996 Rands per 10 Megajoules of useful energy. The useful energy is the delivered energy multiplied by the efficiency of energy transformation of the appliance.

The LCC includes the actual amount paid for the asset (appliance), C, the present value of replacing all or part of that asset R_{pva}, the present value of replacing the connection to the energy infrastructure (electrical or gas) R_{pvc}, the present value of operating the appliance O_{pv}, and the present value of the maintenance M_{pv}, that would be required by the appliance over the life-cycle.

$$LCC = C+R_{pva}+R_{pvc}+O_{pv}+M_{pv} \qquad (1)$$

The cost of the appliance (C) and its replacement cost (R_{pva})

The cost of the appliance can be obtained from retailers and manufacturers. The replacement cost of the appliance is calculated using the following equation:

$$R_{pva} = C * ((1+esc_p)/(1+dr))^n \qquad (2)$$

n is the life of appliance in years. The terms esc_p and dr refer to the escalation in the cost of the purchase price of appliances and the discount rate gives an indication of the future value of money.

The replacement cost of the appliance is estimated using the operational lifetime and dividing this by the time the appliance is in use during an average year. In the life-cycle cost estimates in this paper, the operational or useful life of the project coincides with the life-cycle of the project, therefore there is assumed to be no residual value accorded the appliance. Similarly, replacement of parts of the appliance is covered in the maintenance cost estimate.

For the minimum replacement costs, the minimum cost of the appliance is used and the maximum life in years is used. For the maximum replacement costs, the maximum cost of the appliance and the minimum life in years is used.

The operating costs of the appliance (O_{pv})

This quantity is calculated from the annual operating costs over the life of the appliance. The annual operating costs is the product of the annual operational hours, the average power estimate (fuel use per unit of operational time) and the cost of the fuel.

$$O \text{ annual} = \text{hours used per year} * \text{units per hour} * \text{cost per unit} \qquad (3)$$

The present value of operation is:

$$O_{pv} = O \text{ annual} * ((1+esc_o)/(dr-esc_o))*(1-((1+esc_o)/(1+dr))^n) \qquad (4)$$

The terms esc_o and dr refer to the escalation in the cost of operating the appliance (fuel price increases) and the discount rate gives an indication of the future value of money.

The minimum operating cost is calculated using the lowest annual operational time and the lowest price for the fuel. The highest operational costs are calculated using the highest number of hours per year and the highest fuel costs per unit.

The maintenance cost of the appliance (M_{pv})

This quantity is calculated in a similar way to the operating costs. In most cases information on the maintenance costs of appliances is not readily available, and has to be estimated.

The amortised LCC per day

At this point the LCC can be calculated using equation 1, above. However, to amortise this down to a daily amount is the next step:

$$LCC\ (amortised) = LCC * ((1+dr)^n * dr)/((1+dr)^n - 1) \quad (5)$$

The annualised LCC can be divided by 365 to provide a daily LCC[4].

The amortised LCC for ten Megajoules of utilised (useful) energy

The final step in the calculation is to give cost of providing a utilised arbitrary quantity of energy service. For most thermal energy services 10 Megajoules of utilised (or useful) energy is considered as the amount of heating energy for services of cooking, water heating and space heating, while for lighting 1 000 lumenhours is used. For refrigeration the volumes are normalised linearly to 200 litres and the life-cycle cost estimated in R/day.

$$LCC\ (10MJ) = 10\ MJ * LCC\ (R\ per\ day)/MJ\ per\ day\ (utilise \quad (6)$$

The minimum LCC per ten Megajoules of useful energy is calculated using the minimum daily LCC divided by the minimum daily Megajoules and multiplying this by ten. The maximum LCC per ten Megajoules of useful energy is calculated using the maximum daily LCC divided by the maximum daily Megajoules, dividing by the conversion efficiency and multiplying this by ten.

4 The daily amortised figures can be calculated using the *Microsoft Excel* function @PMT(LCC, dr, n)/365.

APPENDIX B

Economic costs in all cities

(see table on following pages)

APPENDIX C

Sample calculations - the economic costs of fuels

(These calculations are provided in a tabulated form in Appendix B.)

C1. Electricity
The price of electricity is between 23 and 27 cents per kilowatthour. An average of 25 cents or R0.25 is used.

The cost of electricity is based on estimates of the long run marginal costs on and off peak, which are estimated to be 25 and 5 cents per kilowatthour respectively. An additional 20% to the marginal costs was described as the contribution attributable to transmission. Taking an average of the peak and off-peak LRMC the costs is considered to be 15 plus 3 cents or 18 cents per unit.

This cost is considered to have no explicit subsidies or taxes associated with it. However, the externalities which have been estimated listed in Table 3.1 should be added. Van Horen estimated their contribution to be 2.78, 7.93 and 14.36 Rands per Gigajoule.

Each kilowatthour is 3.6 Megajoules or 0.0036GJ implying an additional externality cost of 1.001, 2.85, and 5.170 cents per unit. The externality costs for the three scenarios are therefore 19.00, 20.85 and 23.17 cents per unit.

An additional cost is for the electricity infrastructure which is costed at a national average of R2 170 per domestic supply point. Using Table 3.4, between 25 and 30% of those costs are attributable to cooking. This accounts for the R542.5, 596.8 and 651 additions to the cost of using electricity.

C2. Coal
The cost of coal ex-production in 1995 was R55/ton on which VAT was paid, the costs of distribution in the same year were estimated to be R173/ton. Bringing the cost to 1996 Rands provides a cost of R244 per ton (using a 10% annual inflation rate). Assuming VAT is only paid at the pit head (ex-works) and no further along the distribution chain. The R55 per ton is reduced by 14% to account for the VAT applied at that point.

The externality costs of using the coal are attributable to coal pollution and the emissions of greenhouse gases is assumed to be 1.96, 5.16, and 9.55 Rands per Gigajoule. Using a calorific value of 27 Megajoules per kilogram, the externality cost additions are estimated at 5.29, 13.93, and 25.79 cents per kilogram. The full cost is therefore 29.6, 38.3, and 50.2 cents per kilogram.

C3. LPG
The cost of LPG for the sake of this exercise is made up of the IBLC (59.7 cents per litre), the dealer margin (49.6 cents per litre), and a safety levy (0.3 cents per litre). The total is 109.6 cents per litre or 199 cents per kilogram.

To this amount is added the externality, which in this case is limited to the GHG contribution of 0.31, 1.35, and 2.7 Rands per Gigajoule. LPG has a calorific value of 49MJ per kilogram. The cost of the externality per kilogram is therefore 1.52, 6.6, and 13.23 cents per kilogram. This amounts to 200.5, 205.6, and 212.2 cents per kilogram.

The additional costs involved are those associated with the cost of LPG infrastructure, which includes LPG bottles.

C4. Paraffin
The cost is made up of the IBLC (80.104), and the industry (14.26) and retailers' (36.507) margins. These three components add up to 130.87 cents per litre. The externalities are obtained from Table 3.1 and include paraffin poisoning, fires and

burns, and greenhouse gases. For the three scenarios these add up to 15.53, 106.08, and 224.48 Rands per Gigajoule.

The calorific value of paraffin is estimated to be 37MJ per litre. The additional cost of paraffin is therefore 57.5, 392.5, and 830.5 cents per litre for the low, mid and high scenarios. The full costs are therefore 188.4, 523.4, and 961.4 cents per litre.

C5. Candles

Candles cost on average 50 cents each. The VAT is removed from this price to provide the economic costs of 43.9 cents each.

C6. Solar energy

There is assumed to be cost or externalities linked to the use of solar energy in a passive application. Solar photo voltaics would have externalities associated with the disposal of batteries, but PV systems are not included in this exercise.

C7. Wood

As wood is not considered in the costing, it has been excluded from this exercise.

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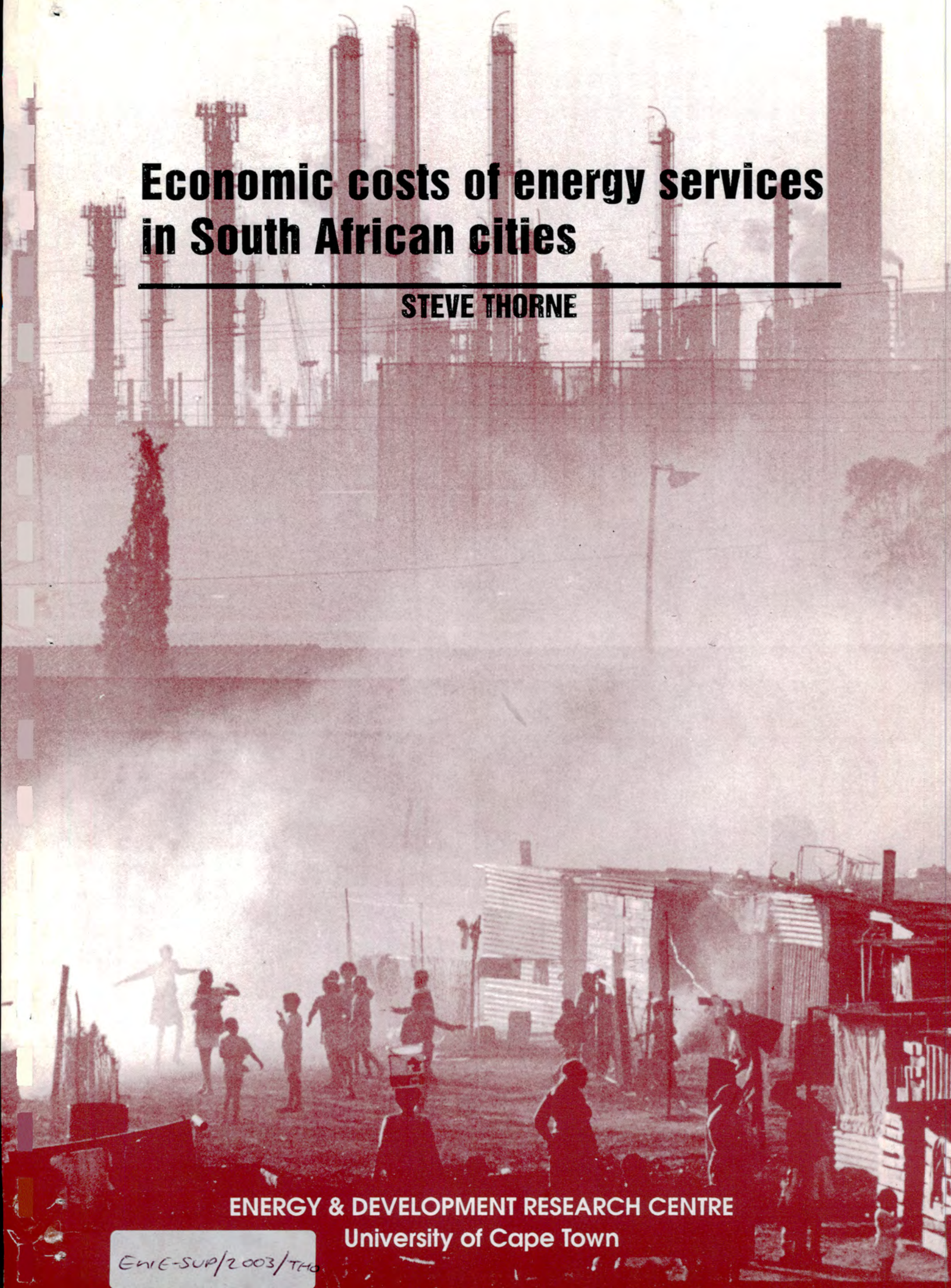

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